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# DEN NORSKE NORDHAVS-EXPEDITION

1876—1878.

## C H E M I.

- I. OM LUFTEN I SOVANDET.
- II. OM KULSYREN I SOVANDET.
- III. OM SALTHOLDIGHEDEN AF VANDET  
I DET NORSKE NORDHAV.

AF

**HERCULES TORNØE.**

MED 3 TRESNIT OG 3 KARTER.



**CHRISTIANIA.**

GRONDAHL & SØNS BOGTRYKKERI.

1880.

THE NORWEGIAN NORTH-ATLANTIC EXPEDITION

1876—1878.

C H E M I S T R Y.

- I. ON THE AIR IN SEA-WATER.
- II. ON THE CARBONIC ACID IN SEA-WATER.
- III. ON THE AMOUNT OF SALT IN THE WATER OF THE NORWEGIAN SEA.

BY

HERCULES TORNØE.

WITH 3 WOODCUTS AND 3 MAPS.



CHRISTIANIA.

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1880





## I. Om Luften i Søvandet.

Allerede i lange Aarrækker har der fra Tid til anden af forskellige Chemikere været foretaget Experimenter i den Hensigt at studere Forholdene ved den atmosfæriske Lufts Absorption af de Vædsker, hvormed den i Naturen kommer i Berøring, men det er dog først i de seneste Aar, at dette Spørgsmaal har været gjort til Gjenstand for mere omfattende Undersøgelser, hvad angaar Søvandet i de aabne Have. Rigtig nok foreligger der ogsaa fra ældre Tider enkelte Opgaver over Sammensætning og Mængden af den i Søvandet opløste Luft, men disse ere for det Meste bundne til nogle ganske få Puncter af Kysterne, og der, hvor Forsøgene ogsaa omfatte Vandprover fra det aabne Hav, er der ofte saameget at indvende mod Materialets Indsamling og Opbevaring, at man, selv om Indet maatte være at udsætte paa Methoderne til dets Undersøgelse, ikke kunde sætte disse i Klasse med de med vore Tiders fuldkomnere Hjælpemidler udførte Observationer.

Naar saaledes vort Kjendskab til Fordelingen af Luften i Verdenshavene specielt for de store Dybs Vedkommende lige til de seneste Aar man siges at have været meget mangelfuldt, da man Grunden hertil søges i de mange Vanskeligheder, som man alleevne møder, naar man vil undersøge disse Spørgsmaal. Hvor det gjælder at bestemme Sammensætningen af den atmosfæriske Luft, giver Luftens Letbevægelighed Ret til af Undersøgelser udførte paa få Puncter at slutte til den hele Atmosfære, hvad der imidlertid ikke er Anledning til for Søvandets Vedkommende. Der fordrer Havenes langt ringere Bevægelighed et større Antal Observationer, idet der her man stilles meget strengere Fordringer til den geografiske Udbredning. Enten maatte altsaa Vandprover hjemføres fra fjerne Farvande, saaledes at de ved en længere Tids Henstand udsatte for allehaande fremmed Indvirkning kunde blive aldeles ubrugbare, eller Analytikeren maatte, udsat for alle de Ulemper, som et Skibs Bevægelser medfører for videnskabelige Undersøgelser, forsøge bedst muligt at udføre sine Observationer ombord. Men selv naar der hos mange Chemikere fra ældre Tider kan have været Interesse for ved Undersøgel-

## I. On the Air in Sea-Water.

Experiments have long since been instituted, from time to time, by divers chemists, with the object of investigating the absorption of atmospheric air by the fluids with which in the course of nature it comes in contact. But not till of late years has this phenomenon been made the subject of extensive treatment in its relation to ocean-water. True, there do exist comparatively early statements respecting the amount and composition of the air present in sea-water, but the great majority of such are confined to a very few coastal localities; and when, as was sometimes the case, the samples of sea-water examined had been drawn from the open sea, the mode of collecting and preserving them was frequently so open to objection that, even assuming the methods adopted for their examination to have been in every respect trustworthy, these early experiments will not bear comparison with those of modern date, performed with the far superior apparatus since devised.

Our knowledge therefore, till but a few years since, of the distribution of air in ocean-water, must be said to have remained very imperfect; and the reason is found in the numerous difficulties everywhere encountered when proceeding to investigate so intricate a subject. From the great mobility of the atmosphere, experiments in a few localities only will suffice to determine the general composition of air, but with sea-water the case is different. Water being far less fluid than air, many observations are obviously needed, since the greatest importance must be attached to geographical position. Hence, samples of sea-water had to be brought home from distant regions, and in that case, by being allowed to stand over for a comparatively long period, left exposed to all manner of disturbing influences; or the observations were taken on board, and experiments performed to the best of the analyst's ability, in spite of the numerous drawbacks entailed by the motion of the vessel. But, though many of the earlier chemists would, when at sea, no doubt have felt an interest in contributing to solve the problem of the distribution of air in the water of the ocean, they almost invari-

ser paa Reiser at give Bidrag til Løsningen af Spørgsmaalet om Fordelingen af Luftten i Havet, da har Anledningen dertil næsten bestandig manglet. Først ved de i de senere Tider hyppigt udsendte Expeditioner, hvormed der har været givet Chemikere Anledning til at medfølge, har det været muligt mere detaljeret at studere disse Ting. Ved disse Expeditioner har Formaalet udelukkende været videnskabelig Undersøgelse af Havet, og der har derfor med Hensyn paa Udrustningen altid været lagt megen Vind paa ved hensigtsmæssige Foranstaltninger og omhyggelige Forberedelser at fremme dette Formaal saa meget som muligt, og det er derfor klart, at disse Expeditioner maa have den største Betydning for den chemiske Undersøgelse af Havene specielt, hvor Tiden er om sandanne Observationer, der ligesom Bestemmelser af Gasarterne ikke taale Opsættelse, men nødvendigvis maa udføres oiedblikkelig efter at Vandprøven er øst. Saaledes maa endelrigt de under disse Omstændigheder udførte Observationer faa størst Vægt, hvor det drejer sig om at skaffe Oplysninger om Gasarterne i Søvandet, udenat det dog derfor vil findes paa næste Plads her at give en kort Oversigt ogsaa over de herover udførte ældre Undersøgelser.

De tidligste Undersøgelser, der mig bekendt ere gjorte over Luftten i Søvandet, udførtes i 1838 af Frémy<sup>1</sup> paa nogle Vandprøver, der over et Aar forud vare bleven optagne paa den franske Expedition med 'La Bonite' i 1836 og 37. Vandprøverne bestode dels af Overfladevand dels af Vand fra forskjellige Dyb indtil 450 franske Favne og vare optagne med et af Biot opfundet Apparat.<sup>2</sup>

Ved Analysen af den indkøgte Gas absorberede Frémy Kulsyren med Kalilud og Surstoffet med Phosphor. Resultaterne ansaes allerede af Frémy selv for upaarlidelige og de staa saa bestemt i Strid med alle nyere Angivelser, at man med temmelig stor Sikkerhed kan antage, at det lange Tidsrum mellem Vandprøvenes Osning og deres Undersøgelse har gjort dem fuldstændig ubrugbare.

I 1843 udførte Morren<sup>3</sup> nogle Undersøgelser af Overfladevandet ved Saint-Malo nærmest i den Hensigt at paavise Sollysets Indflydelse paa den relative Sammensætning af den af Vandet absorberede Luft. Han kom i den Henseende til det Resultat, at Surstoffmængden fandtes størst og Kulsyremængden mindst ved klart Sollys, hvorimod omvendt Surstoffmængden fandtes mindst og Kulsyremængden størst ved mørkt overskyet Veir. Vandprøverne undersøgte ikke paa Stedet, men sendtes til Rennes, hvor de af Morren indkøgte i Kølber paa 4.5 Litre. Den indkøgte Gas lededes gennem Kautschukledning over i en Flaske, hvori Gasarterne opsamledes over Vand. Ved Analysen af Gasen anvendte han til Absorption af Kulsyren Kalilud og for-

riably lacked the means. Not till chemists had been sent out on the numerous Expeditions dispatched of late years to all quarters of the globe, was it possible to study this subject in detail. The sole object of such Expeditions having been the scientific investigation of the ocean, they were naturally fitted out with the greatest possible care, being furnished with the latest and most improved apparatus, and every necessary aid and appliance. It is obvious, therefore, that these Expeditions must largely contribute to our chemical knowledge of the ocean, more particularly with regard to observations which, like the determination of gaseous bodies, will not brook delay, but must be taken immediately the sample of water has been drawn. Hence, very great weight should be attached to observations instituted under such circumstances, viz. those that relate to the determination of gaseous bodies in sea-water. It will not, however, be out of place, briefly to notice some of the earlier observations undertaken with that object in view.

The earliest experiments, so far as I am aware, relating to the air in sea-water, were instituted in 1838, by Frémy,<sup>1</sup> with samples of water drawn more than a year before on the French Expedition with the 'Bonite,' in 1836 and 1837. These samples of water consisted partly of surface-water, partly of water from various depths, the greatest being 450 French fathoms; and were collected with an apparatus devised by Biot.<sup>2</sup>

When analysing the gas driven off, the carbonic acid was absorbed in a lye of potash, the oxygen being consumed with phosphorus. But Frémy himself did not regard as trustworthy the results of this process; and they have proved so decidedly at variance with those of all later observations, that his samples of water, owing to the length of time for which they had been preserved previous to examination, had no doubt become utterly worthless for experimental purposes.<sup>3</sup>

In 1843, Morren<sup>3</sup> instituted a series of experiments with surface-water, near St. Malo, chiefly with the object of determining the influence of solar light on the composition of the air absorbed by sea-water. He found the proportion of oxygen to be greatest, and that of carbonic acid least, in bright weather; whereas the proportion of oxygen was least, and that of carbonic acid greatest, with a dark, cloudy sky. The samples of water were not examined on the spot, but taken to Rennes, and there boiled by Morren, in matrasses containing 4.5 litre. The gas driven off during the process was conducted through a caoutchouc tube into a phial, and there collected over water. When analysing the gas, Morren used a lye of

<sup>1</sup> Compt. rend. 6, p. 616.

<sup>2</sup> Pogg. Ann. 37, p. 416.

<sup>3</sup> Ann. Chim. Phys. [3], 12, p. 5.

<sup>1</sup> Compt. rend. 6, p. 616.

<sup>2</sup> Pogg. Ann. 37, p. 416.

<sup>3</sup> Ann. Chim. Phys. [3], 12, p. 5.

bændte Surstofgassen med overskydende Vandstof. Han brugte ogsaa her som Sæerrevædske Vand, som paa Førelaad var mættet med Luft, og det kan saaledes ikke formidre, at de Resultater, han erholdt, vise temmelig betydelige Afvigelser. Surstofmængden varierer saaledes fra 30,5 til 31,0 og ndgør i Middel 34,7 % af den samlede Surstof-Kvælstofmængde, medens denne varierer mellem 20,0 og 30,5 og i Middel ndgør 24,5 CC. pr. Litre af det ndkogte Vand. Som man heraf ser, svarer den midlere Surstofprocent meget noie med det af Bunsen senere for destilleret Vand opstillede Tal, hvorimod de Tal, Morren opfører som Udtryk for den samlede Surstof-Kvælstofmængde, ingen noieagtig fixeret Betydning have, da han intetsteds angiver den Barometerstand og Temperatur, hvortil han har reduceret sine Gasvolumina.

Nogle Aar senere i 1846 gjenoptog Lewy<sup>1</sup> Morrens Undersøgelser paa nogle Vandprover, som han øste ved Langrune i Nordøst for Saint-Malo, og anvendte for at kunne sammenligne sine Resultater med Morrens noieagtig den af ham beskrevne Arbeidsmethode. Hans Resultater vise ogsaa, naar man tager Hensyn til, at Vandproverne alle skrive sig fra samme Sted, ikke ubetydelige og end meget mindre Afvigelser, som han ligesom Morren tilskriver Sollysets Indflydelse. Surstofmængden varierer hos ham fra 35,4 til 32,4 og ndgør i Middel 33,6 % af den samlede Surstof-Kvælstofmængde, som gjennemsnitlig beløber sig til 17,3 CC. pr. Litre og ikke overskrider Grændserne 18,9 og 16,3. Heller ikke Lewy har nermere fixeret Betydningen af de opførte Gasvolumina. Der har forresten i hans Tabel indsnæget sig meningsforvirrende Regnefejl, som har givet Anledning til, at han er bleven misforstaaet.

I 1851 har endvidere A. Hayes<sup>2</sup> offentliggjort nogle Fædtalelser om Fordelingen af Luften i Søvandet dog uden at vedføie sine Originalobservationer. Ifølge ham findes i Vand fra større Dyb altid en betragtelig mindre Mængde Surstof end i Overfladevandet, en Regel, som overalt holdt stik saavel i den hede som tempererede Zone, naar undtages i Golfstrømmen, hvor den sterke Bevægelse i Vandet kunde antages at forstyrre den almindelige Ligevegt. Han fandt ogsaa efter Storme en betydelig større Surstofmængde i Overfladevandet.

I 1855 udførte M. F. Pisani<sup>3</sup> nogle Undersøgelser af Saltene i Overfladevandet ved Bujuk-Déré og bestemte samtidig de i Vandet indeholdte Gasarter. Resultaterne findes sammenstillede i nedenstaaende Tabel, hvor Volumet er reduceret til 0° og 760<sup>mm</sup> Tryk og ndtrykt som CC. pr. Litre Vand.

potash for absorbing the carbonic acid, and consumed the oxygen with a surplus of hydrogen. Here, too, the confining fluid was water, previously saturated with air, and hence it is not surprising, that the results obtained should have been found to vary considerably. Thus, for instance, the amount of oxygen varies between 30,5 and 31,0 per cent, the mean proportion being 34,7 of the total amount of oxygen and nitrogen; while the latter ranges from 20,0 to 30,5, giving a mean proportion of 24,5° per litre. The mean percentage of oxygen agrees, therefore, very closely with the proportion afterwards found by Bunsen for distilled water; whereas no definite importance can be attached to Morren's figures representing the total amount of oxygen and nitrogen, since that observer does not anywhere state to what temperature and atmospheric pressure he had reduced the volume of the gas.

Some years after, in 1846, Lewy<sup>1</sup> repeated Morren's experiments, with samples of water drawn at Langrune, north-east of Saint-Malo, adopting the latter to compare his results with those of Morren, precisely the same mode of operation. The results obtained by this chemist, seeing that the samples of water were all of them from the same locality, vary, too, considerably, though by no means to the same extent, which he, in common with Morren, ascribes to the influence of solar light. The amount of oxygen ranges from 35,4 to 32,4 33,6 per cent, being the mean proportion of the total amount of oxygen and nitrogen, which averages 17,3° per litre, having in no case passed the limits 18,9 and 16,3. Lewy, too, omits to give the factors determining the volume of the gas. Moreover, divers perplexing errors have slipped into his Table; and hence he has been misunderstood by some.

In 1851, A. Hayes<sup>2</sup> published a paper on the distribution of air in sea-water, without however embodying his original observations. According to the observations of that chemist, the amount of oxygen in water drawn from great depths is always appreciably less than that in surface-water, a rule which holds good for all seas both of the torrid and the temperate zones, with the exception of the Gulf Stream, where the strong current may be supposed to exert a disturbing influence. After a heavy gale of wind, too, the proportion of oxygen in the surface-water was found to be much greater.

In 1855, M. F. Pisani<sup>3</sup> instituted a series of observations near Bujuk-Déré on the salts in surface-water, and also determined the gaseous bodies it contained. His results are given in the following Table, the volume being reduced to a temperature of 0° and a pressure of 760<sup>mm</sup>, expressed in cubic centimetres per litre.

<sup>1</sup> Ann. Chem. Phys. [3] 17. Ann. Chem. Pharm. 58 — 326.

<sup>2</sup> Sillim. Amer. Jour. [2] 11 — 241.

<sup>3</sup> Compt. rend. 41 — 532.

<sup>1</sup> Ann. Chem. Phys. [3] 17. Ann. Chem. Pharm. 58 p. 326.

<sup>2</sup> Sillim. Amer. Jour. [2] 11, p. 241.

Compt. rend. 41, p. 532.

$O + N$ pr. Litre	16.0	16.2
$O + N = 100$	$O$ %	$N$ %
	31.4	33.2
	68.5	66.8

I Aaret 1869 udgik fra England Porcupineexpeditionen, hvor der for første Gang foruden de øvrige videnskabelige Arbejder ogsaa foreslages udført mere omfattende chemiske Undersøgelser. Man besluttede her at benytte den udmærkede Anledning til ved talrige Forsøg saavel med Overfladevand som Vand fra større Dyb at skaffe sig Oplysning om de Fluctuationer, som optræde saavel i de absolute som relative Mængder af de i Søvandet opløste Gasser. Først udgik de Feil, som nødvendigvis maatte indsnige sig, naar de til Gasanalyser bestemte Vandprover opbevaredes i længere Tid før Undersøgelsen, bestemte man sig her for den Edder at foretage Gasanalyserne ombord. Til Optagelse af de fra større Dyb stammende Vandprover benyttedes en meget simpel Vandhenter bestaaende af en hul Metalcylinder med betvevæglige opadslaaende Kegelventiler, et Apparat, hvis Paalidelighed senere Undersøgelser giver Anledning til at betvivle. Udkøgningen og Opsamlingen af Gasarterne foretoges i alt Væsenligt som ved de tidligere beskrevne Forsøg, og anvendtes under Analysen til Absorption af Kulsyre og Surstof Kalihydrat og pyrogallussur Kali. Det siger sig selv, at de paa denne Maade erholdte Resultater maatte være behæftede med meget betydelige Observationsfeil, hvad der ogsaa tydeligst vises af de store Afvigelser mellem de tal forskellige Observationer efter denne Fremgangsmaade udførte Bestemmelser. Som Udtryk for Sammensætningen af den af Overfladevandet udtagne Luft fandt nemlig de tre Chemikere, som paa de tre Togter, hvori denne Expedition deltes, efter hinanden udførte de chemiske Arbejder, følgende Tid:<sup>1</sup>

W. L. Carpenter . . . . .	31.6 % $O$ med 68.4 % $N$
Hunter . . . . .	36.4 - $O$ - 63.6 - $N$
P. Herbert Carpenter . . . . .	30.5 - $O$ - 69.5 - $N$

Dette er kun de af de enkelte Observationer udledede Middelværdier, men, som man ser, er allerede Afvigelserne mellem disse overmaade store, medens de enkelte Bestemmelser, som ikke findes opførte, varierer mellem langt videre Grændser. Saaledes opføres som Ydergrændser for Variationerne af Surstofmængden i Overfladevandet Maximum 45.3 og Minimum 14.0 % at den samlede Gas-mængde, Kulsyren iberegnet.

Porcupineexpeditionens Chemikere ansaa selv sine Resultater upaalidelige, dog mindre paa Grund af Mangler ved Arbejdsmethoderne, end fordi den af dem benyttede Vandhenter tillod Udvigelsen af den Luft, som de mente kunde udvikle sig, naar Vandet fra de større Dyb naaede op til det ved Overfladen herskende mindre Tryk. De tog forresten sin Tilflugt, ogsaa til andre Midler for at forklare

$O + N$ pr. Litre	16.0	16.2
$O + N = 100$	$O$ p.ct.	$N$ p.ct.
	31.4	33.2
	68.5	66.8

In the year 1869, the 'Porcupine' Expedition was dispatched by the British Government, and it was now proposed, for the first time, to institute a series of chemical experiments on a more comprehensive scale than any hitherto performed. By taking advantage of this excellent opportunity to examine numerous samples of sea-water, both from the surface and from great depths, the fluctuations that occur alike in the absolute and the relative amounts of gaseous bodies in ocean-water might be effectively investigated. In order to guard against the error that must necessarily arise when the samples of water are preserved for any length of time previous to examination, it was resolved to undertake all analyses of gas on board. For obtaining samples of water from great depths, a very simple instrument was used, consisting of a hollow metal cylinder, furnished with conical-shaped valves, opening above, an apparatus the trustworthiness of which subsequent experiments have shown reason to doubt. The gas was boiled out and collected by a process essentially similar to that adopted for the experiments previously described, the carbonic acid and the oxygen having been absorbed by hydrate of potash and pyrogallic acid. As a matter of course, very considerable errors of observation would attach to results obtained by this method, the best proof of which lies in the extent to which the determinations of different observers performed by this mode of operation are found to vary. For instance, the three chemists who successively accompanied the Expedition on the three voyages into which it was divided, express the composition of the air boiled out of surface-water by the following figures:<sup>1</sup> —

W. L. Carpenter . . . . .	31.6 p.ct. $O$ and 68.4 p.ct. $N$
Hunter . . . . .	36.4 - $O$ - 63.6 - $N$
P. Herbert Carpenter . . . . .	30.5 - $O$ - 69.5 - $N$

These amounts, however, are the mean values deduced from the several observations, and yet they vary exceedingly; the individual determinations, which are not given, must obviously have ranged between far wider limits. Thus, the extreme limits between which the amount of oxygen was found to vary in surface-water, is stated to have been 45.3 (maximum) and 14.0 (minimum) per cent of the total amount of gas, including the carbonic acid.

The chemists who accompanied the 'Porcupine' Expedition did not even themselves regard the results obtained as trustworthy, less however on the ground of possible defects in the modes of operation, than because the the apparatus used for collecting the water admits of the escape of air which, in their opinion, may be liberated on water drawn from great depths reaching the surface, where the atmos-

<sup>1</sup> Proc. Roy. Soc. 18, p. 397.

<sup>1</sup> Proc. Roy. Soc. 18, p. 397.

de observerede store Afvigelser, saaledes tilskreves stærke Bevægelser af Havoverfladen enten ved Størme eller paa anden Maade den Evne at forøge Surstofmængden og forringe Kulstvemængden, ligesom rigt Dyreliv ogsaa tilskreves en meget stor Indflydelse paa Sæmmensætningen af den i Søvandet opløste Luft.

I 1871 udgik atter igjen denne Gang fra Tyskland en Expedition til Undersøgelse af Østersøen, hvormed som Chemiker fulgte Dr. O. Jacobsen. Med Resultaterne af de fra de tidligere Expeditioner hidrørende Gasbestemmelser for Øie besluttede han sig hverken for den ene eller den anden af de ved Bonite eller Porepineexpeditionen anvendte Fremgangsmaader men slog ind paa en Middelvei, den eneste, som i dette Tilfælde kunde føre til paalidelige Resultater.

Han delte Undersøgelserne i to Dele og indførte den uopsatte Del af dem nemlig Gasarternes Udkogning strax, medens han, indseende Umuligheden af at udføre tilfredsstillende Gasanalyser ombord paa et Fartoi i aaben Sø, opsatte deres nærmere Undersøgelse til Hjemkomsten. Desværre gav Mangelen af en til Optagelse af Dybyandsprover egnet paalidelig Vandhenter Anledning til, at det 1ste Aars Udbytte af denne Expedition for Gasanalysernes Vedkommende reducerede sig til blot og bart Indsamling af den Erfaring, som senere skulde komme til Anvendelse ved det Aaret efter foretagne Toget i Nordsoen. Manglerne ved den paa Porepineexpeditionen benyttede Vandhenter havde nemlig bevæget Jacobsen til ogsaa til Osning af de for Gasanalyser bestemte Vandprover at benytte en Vandhenter, der nedsenkedes fyldt med Luft. Naar nu Apparatet i Dybet anbrædes, absorberedes under det der herskende store Tryk momentant en Del af den nedbragte atmosfæriske Luft, hvorved de paa disse Vandprover udførte Gasanalyser bleve saa upaalidelige, at der ikke engang værdigedes dem en Offentliggjørelse.

De paa Østersøtoget i 1871 indhøstede Erfaringer, umuliggjorde det imidlertid for Jacobsen ved en omhyggelig Forberedelse til den i 1872 foretagne Expedition i Nordsoen at overvinde eller omgaa de Vanskeligheder, som havde levirket Manglerne ved de paa Porepineexpeditionen foretagne Undersøgelser, og det lykkedes ham denne Gang som Resultat af sine Arbejder at offentliggjøre en Afhandling,<sup>1</sup> som giver en Række af vore Tidens Fordringer strengt tilfredsstillende Oplysninger om Luftens i Søvandet. Til Optagelse af de til Gasanalyser bestemte Vandprover fra Dybet tjente paa Nordøtoget et af Dr. H. A. Meyer angivet Apparat<sup>2</sup> bestaaende af en tung Metalcylinder, som ved Udlosning i det bestemte Dyb faldt ned over to vel islebne koniske Ventiler, og derved afspærrede det mellem disse

pheric pressure is less. But they had recourse to other means whereby to explain the great differences observed, ascribing to the state of violent agitation into which the surface of the ocean is thrown by heavy storms, or to some other adequate cause, the ability of increasing the proportion of oxygen and diminishing that of carbonic acid: an abundance of animal life, too, was believed to exert very great influence on the composition of the air absorbed in sea-water.

In 1871, an Expedition was despatched from Germany for the investigation of the Baltic. Dr. O. Jacobsen accompanied it as chemist. Warned by the unsatisfactory results of former gas-analyses, he resolved to adopt neither of the methods resorted to on the 'Bonite' and 'Porepine' Expeditions, but rather to take a middle course, which indeed held out the only prospect of success.

Accordingly, he divided his observations. Experiments admitting of no delay, such as boiling off the gas, were performed at once, whereas all analyses of gas, impossible as it is found to operate satisfactorily on board a vessel in the open sea, were deferred till his return home. Unfortunately, the want of a trustworthy apparatus for collecting samples of water from great depths, confined the results obtained on the first voyage of the Expedition, as regards analyses of gas, to the mere acquisition of experience, which, however, there was ample opportunity of applying on the cruise undertaken the following year in the North Sea. The defective construction of the instrument employed for collecting water on the 'Porepine' Expedition had induced Jacobsen to make use of an apparatus which, even when drawing water for gas-analysis, was sunk full of air. Now, on opening this apparatus at the required depth, some portion of the air it contains will, by reason of the great pressure, be momentarily absorbed; and hence all analyses of gas with such samples of water proved to that extent defective as to be not even deemed worthy of publication.

Meanwhile, taking advantage of the experience acquired in 1871 on the cruise in the Baltic, Dr. Jacobsen succeeded, after careful preparation to meet the requirements of the Expedition undertaken in 1872 to the North Sea, in surmounting or evading the difficulties experienced on the 'Porepine' Expedition, and was enabled, as the result of his labours, to publish a treatise<sup>1</sup> on the air present in sea-water recording a series of eminently satisfactory results. For collecting samples of water when with to undertake analyses of gas in water from the bottom, or from great depths, an apparatus, described by Dr. H. A. Meyer, was made use of on the cruise in the North Sea.<sup>2</sup> It consists of a heavy metal cylinder, which, at the required depth, will drop down on two accurately fitted conical valves, cutting off all com-

<sup>1</sup> Ann. Chem. Pharm. 167. 1. Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel, 1872 — 73, p. 13.

<sup>2</sup> Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel 1872 — 73, p. 5.

<sup>1</sup> Ann. Chem. Pharm. 167, p. 1. Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel, 1872 — 73, p. 13.

<sup>2</sup> Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel, 1872 — 73, p. 5.

beliggende Vandlag. Føløsningen foregik enten ved Apparatets Anslag mod Bunden eller i intermediate Dyb ved et langs Linnen nedsenket Lød.

Ved Udtrivelsen af de i Vandet indeholdte Gasarter anvendte Jacobsen Bunsens Princip, idet Vandet kogtes i

momentation with the outside water. The detachment was effected either by the instrument striking the bottom, or, at intermediate depths, by running a weight down the line.

For expelling the gas contained in the water, Jacobsen made choice of Bunsen's method, boiling the water in

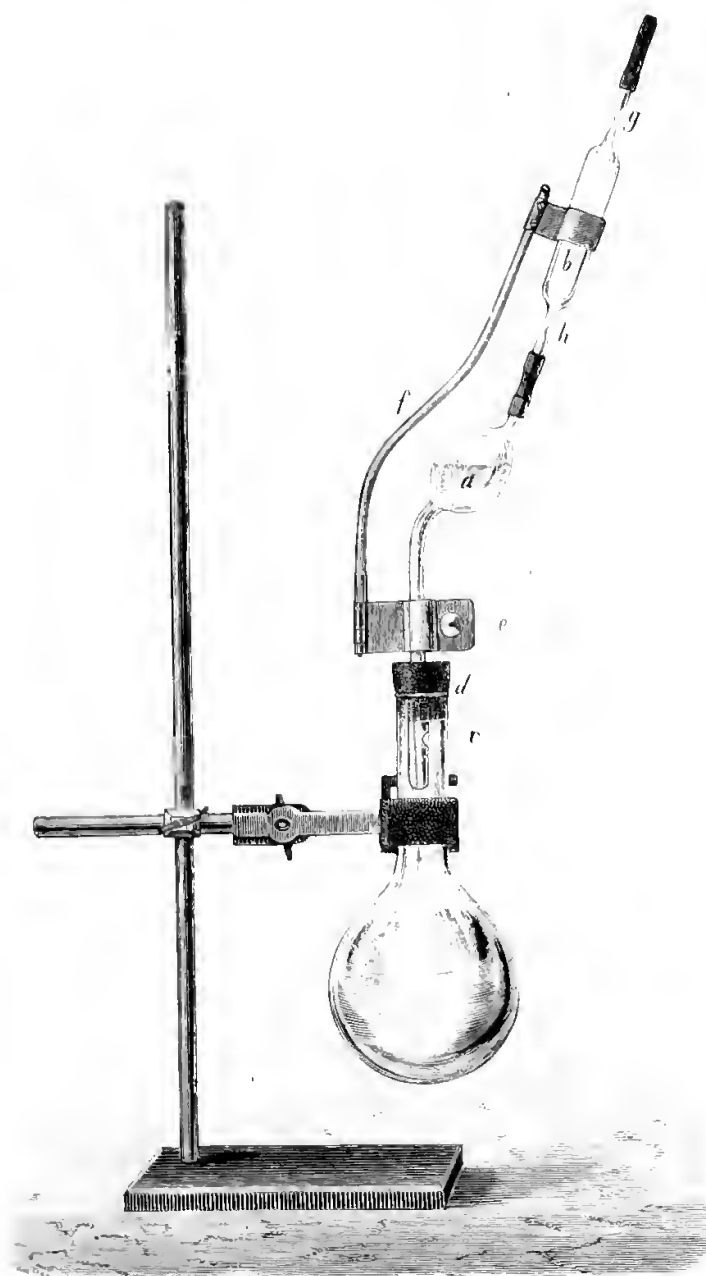


Fig. 1.

et ved Vanddamp frembragt Vacuum, og konstruerede i Førløbet med Dr. H. Behrens i dette Ojemed et Apparat, som i Simpelt og Paalidelighed Intet lader tilbage at ønske. Apparatet, som findes afbildet i Fig. 1, har af Jacobsen faaet folgende Beskrivelse:

a vacuum created by steam; and to meet the requirements of this process, he devised, with the assistance of Dr. H. Behrens, an apparatus which in trustworthiness and simplicity of construction leaves nothing to be desired. This apparatus, of which a drawing is given in Fig. 1, Dr. Jacobsen has described as follows: —

Die Siedekugel *a* läuft in ihrem unteren Theil in ein starkwandiges, genau cylindrisches Glasrohr aus, welches unten zugeschmolzen, aber bei *e* mit einer seitlichen Oeffnung versehen ist. Je nachdem diese Oeffnung bis unter den Kautschukpfropfen *d* hinabgedrückt oder bis in seine Durchbohrung heraufgezogen wird, ist die Siedekugel mit dem Innern des Wasserkollens in Verbindung oder gegen dasselbe abgeschlossen. Das Glasrohr muss sich in der glatten Durchbohrung des Kautschukpfropfens mit Reibung auf- und niederbewegen, diese Reibung darf aber nicht so stark sein, wie die zwischen dem Pfropfen und dem cylindrischen Kolbenhals. Ist einmal ein fehlerfreier Pfropfen aus vulkanisirtem Kautschuk den Glasteilen des Apparates auf das Sorgfältigste angepasst, so kann diese Ventilvorrichtung unbegrenzt lange benutzt werden, ohne von ihrer völligen Zuverlässigkeit einzubüßen.

Das Gassammelrohr *b* ist durch ein kurzes Kautschukröhrchen mit der Siedekugel verbunden und zwischen die federnden Arme des messingenen Halters *f* eingeklemmt. Das untere Ende dieses Halters trägt eine weit stärkere Klammer, deren Korkfütterung durch die starke Schraube *c* sehr fest um das Rohr der Siedekugel gepresst wird, so dass man, am unteren Theil des Halters anfassend, Siedekugel und Sammelrohr in dem Kautschukpfropfen auf- und niederschieben und damit die Oeffnung *e* beliebig verlegen kann.

Der Rauminhalt der Siedekugel beträgt etwas mehr als das Doppelte von dem Volumen, um welches sich die auszukochende Wassermenge beim Erwärmen auf 100° ausdehnt.

Bei der Benutzung des Apparates füllt man zunächst die schon im Pfropfen steckende und in den Halter eingeklemmte Siedekugel zur Hälfte mit Wasser und schiebt den Pfropfen über die seitliche Oeffnung. Man füllt nun die Kochflasche durch ein bis auf ihren Boden reichendes Gummirohr direct aus dem Schöpfapparat bis zum Ueberlaufen mit dem auszukochenden Wasser und setzt, nachdem die Oeffnung *e* bis eben unter den Kautschukpfropfen verschoben ist, diesen sehr fest in den Hals der Kochflasche ein. Zieht man nun die Siedekugel bis zur Herstellung des Verschlusses in die Höhe, so entsteht dadurch in der Kochflasche ein kleines Vacuum, in welches sofort Gasbläschen aus dem Wasser aufsteigen. Es wird dadurch Raum geschafft für die Ausdehnung, welche das oft sehr kalte Wasser schon in den ersten Augenblicken durch die höhere Temperatur der umgebenden Luft erfährt. Man fügt nun das Sammelrohr an, über dessen beide Enden vorher kurze Gummiröhren gezogen sind, stellt die Kochflasche in ein Wasserbad, erhitzt das Wasser in der Siedekugel durch eine darunter angebrachte Weingeistflamme und erhält es im Sieden, bis man der vollständigen Austreibung der Luft aus dem Sammelrohr gewiss sein kann. In dem Augenblick, in welchem man mit der rechten Hand die Flamme entfernt, kneift man mit der linken das Ende des oberen Gummirohrs zu, verschliesst es darauf durch Hineinstecken der abgerundeten Spitze eines passenden Glasstäbchens und schneidet sofort bei *g* ab.

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Nachdem nun die Oefnung *c* los oben unter den Pfropfen hinaufgeschoben ist, wird das Wasserbad erwärmt und der Inhalt des Kolbens in heftigem Sieden erhalten. Nach einiger Zeit hat sich im oberen Theil des Kolbenhalses ein freier Raum gebildet, in welchen die Dampfblasen mit Geräusch hineinschlagen. Man bringt durch Entfernen der Wärmequelle oder durch kurzes Herausheben des Apparates aus dem Wasserbade das Wasser aus der Siedekugel in den Kolben zurück und wiederholt dieses Erwärmen und theilweise Abkühlen des Kolbenhalses noch zweimal, wodurch können verhältnissmässig kurzer Zeit eine sehr vollständige Anstreibung der Luft bewirkt wird.

Es ist sehr leicht, schliesslich das Wasser bis zur vollständigen Anfüllung der Siedekugel steigen zu lassen, worauf man durch Anziehen derselben den Verschluss herstellt und das Sammelrohr nun auch bei *h* abschmilzt.

Das Sammeln der Gase mittelst dieses Apparates machte auch bei ziemlich stark bewegter See keine Schwierigkeit.

Gewöhnlich wurden 900 CC. Wasser zur Auskochung verwendet.

Ved Hjælp af dette Apparat udsmedede Jacobsen paa Nordstøtget 73 Luftprover, som efter Hjemkomsten analyseredes efter Bunsens Methode, idet Kulsyren fjernes med Kali og Surstoffet bestemt ved Forbrænding med overskydende Vandstof. Han sammenstiller sine Resultater i en Tabel, hvor han i Modsetning til de tidligere Forfattere betragter den kulsyretræ Luft og Kulsyren hver for sig,<sup>1</sup> saaledes beregnes Surstof og Kvælstofmængderne som Procenter af den kulsyretræ Luft, der opgives som CC. pr. Litre udkogt Vand reduceret til 0° og 760<sup>mm</sup> Tryk. Ifølge denne Tabel hersker der en ganske mærkelig gjennemført Ensartethed i Sammensætningen af den Luft, der er uddrevet af de Vandprover, som have befundet sig under samme fysikalske Forhold, saaledes ligger Surstofprocenten i alle de 24 Luftprover, som stamme fra Overfladevandet, tilfjæds for at de skrive sig fra meget forskellige Localiteter, mellem de meget snævre Grændser af 34.14 og 33.64, og naar denne Overensstemmelse ikke i samme Udstrækning er fundet at gaa igjen i de dybere Lag, da har dette sin Forklaring i en ujevn Circulation. Naar Surstofmængden overalt i Dybet er funden lig eller noget mindre end i Overfladen, da kan det vel ikke være tvivlsomt, at dette skriver sig fra Surstoffets Forbrug til Oxydation af de i Søvandet forekommende organiske Plante- og Dyrerester samt til Sodyrenes Aandedraætes, saaledes som det af Jacobsen udtales med følgende Ord: "Der Zusammenhang dieses Unterschiedes ist leicht zu deuten. In dem schwereren Wasser, welches ohne erhebliche Beimischung aus tieferen

Nachdem nun die Oefnung *c* los oben unter den Pfropfen hinaufgeschoben ist, wird das Wasserbad erwärmt und der Inhalt des Kolbens in heftigem Sieden erhalten. Nach einiger Zeit hat sich im oberen Theil des Kolbenhalses ein freier Raum gebildet, in welchen die Dampfblasen mit Geräusch hineinschlagen. Man bringt durch Entfernen der Wärmequelle oder durch kurzes Herausheben des Apparates aus dem Wasserbade das Wasser aus der Siedekugel in den Kolben zurück und wiederholt dieses Erwärmen und theilweise Abkühlen des Kolbenhalses noch zweimal, wodurch können verhältnissmässig kurzer Zeit eine sehr vollständige Anstreibung der Luft bewirkt wird.

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Gewöhnlich wurden 900 CC. Wasser zur Auskochung verwendet."

With this apparatus Jacobsen collected on the cruise in the North Sea 73 samples of air, which, after the return of the Expedition, were analysed by Bunsen's method, potash being used for absorbing the carbonic acid, and the oxygen consumed with a surplus of hydrogen. His results are set forth in a Table, where, reversing the custom of earlier authors, he refers separately to the carbonic acid and the air free from that body;<sup>1</sup> thus, for instance, the respective amounts of oxygen and nitrogen will be found computed as percentages of the air free from carbonic acid, which is given in cc. per litre of the water examined, reduced to a temperature of 0° and a pressure of 760<sup>mm</sup>. According to this Table, a truly remarkable uniformity prevails in the composition of the air expelled from samples of sea-water which have been exposed to the same physical influences; thus, for instance, the percentage of oxygen in the 24 samples of air derived from surface-water, was found, notwithstanding the collection of the latter in widely different localities, to range between the exceedingly narrow limits of 34.14 and 33.64; and though equal agreement does not extend to the deeper-lying strata, this may be accounted for by irregularity of circulation. That the amount of oxygen at the bottom, or in great depths, should invariably prove equal to, or somewhat less than, that at the surface, is a phenomenon the cause of which must unquestionably be ascribed to the consumption of that gas in the oxidation of organic remains, and for the support of the res-

<sup>1</sup> Naar jeg her overalt har anvendt denne Jacobsens Foranstillingsmaade og ifølge denne anregnet de pldre Forfatterses Opgaver, hvor Gasemængderne overalt ere fremstillede som Procenter af den samlede Surstof-Kvælstof-Kulsyremængde, da vil Grunden hertil fremgaa af min senere Afhandling Om Kulsyren i Søvandet.

<sup>1</sup> The reason that induced me to adopt exclusively Jacobsen's mode of representation, and by the standard of that process to recompute the results of earlier observers, who invariably give the proportions of the gases determined as percentages of the total amount of oxygen, nitrogen, and carbonic acid, will appear in my next Memoir on the carbonic acid present in sea-water.



ren Schichten sehr lange in der Tiefe verweilt, wird ohne genügenden Ersatz fortwährend Sauerstoff verbrannt zur Oxydation der im Wasser und besonders am Meeresgrunde vorhandenen oxydirbaren Stoffe, — in wahrscheinlich weit untergeordnetem Grade auch durch die Athmung der Thiere.”

Men de herved foranledigede Afvigelser ere ikke meget store, idet Surstofprocenten, hørtset fra nogle fra Undtagelser, ligger indesluttet mellem 30 og 34, saaledes at den som Regel aftager med Dybet.

Jacobsens Observationer, der vare udførte under de mest forskjelligartede Omstændigheder, vise ogsaa paa det Bestemteste, at de tidligere gjorte Antagelser, om at Sollyset og Stormene eller i det Hele taget de meteorologiske Forhold skulde spille nogen fremtrædende Rolle ligeoverfor den relative Sammensætning af Overfladevandsluften, vare fuldstændig ubegrundede, i ethvert Fald vise de store Overensstemmelser, at disse Factors Indflydelse maatte være meget ringe.

Med Hensyn paa den absolute Mængde af den Luft, der indeholdes i de fra forskjellige Dylh optagne Vandprover, da viser den sig at tiltage med Dybet, noget der imidlertid let lader sig forklare ved Temperaturens Aftagen med Dybet, uden at det er formodent at tage sin Tilflugt til de store Tryk. Der blev ogsaa paa Pomeraniaexpeditionen for at bevise Urigtigheden af den tidligere paa flere Steder udtalte Formodning, om at Luftgehalten i de store Dylh skulde staa i Forhold til det der herskende større Tryk, foretaget specielle Experimenter med en af Dr. Behrens og Jacobsen construeret Vandhenter af Kautschuk. Denne sammenklemtes først mest muligt, hvorefter den sidste Rest Luft uddreves af den ved Hjælp af Kviksølv, og nedsænkedes derefter fuldstændig lufttom og lufttæt igenlukket. Først i Dybet ved Apparatets Anslag mod Bund aabnedes det, ndspændtes og fyldtes med Vand, hvorefter det atter lufttæt igenlukket og fyldt med Vand ankom til Overfladen. Det viste sig altid, at de med dette Apparat optagne Vandprover ikke indeholdt mere Luft, end de ved Vandprovens Temperatur kunde holde opløst under almindeligt Atmosfæretryk. At dette maatte være saa, kunde man allerede være berettiget til at slutte af nogle Forsøg, som Aimé<sup>1</sup> i 1843 udførte. Han anvendte et i den ene Ende aabent Glasrør, som nedsænkedes fyldt med Kviksølv og i det bestemte Dyb vendtes omkring, hvorved Kviksølvet i Glasrøret delvis erstattedes af Vand paa en saadan Maade, at dette afspærredes af Kviksølvet, der optoges af en nedenunder anbragt passende Beholder. Som Resultat af de med dette Apparat udførte Forsøg udtalte Aimé den Sats, at den Mængde Luft, som indeholdtes i en bestemt Mængde Søvand, i alle Dylh var meget nær den samme.

puratory process in marine animals, as stated by Dr. Jacobsen in the following words: “Der Zusammenhang dieses Unterschiedes ist leicht zu denken. In dem schwereren Wasser, welches ohne erhebliche Beimischung aus tieferen Schichten sehr lange in der Tiefe verweilt, wird ohne genügenden Ersatz fortwährend Sauerstoff verbrannt zur Oxydation der im Wasser und besonders am Meeresgrunde vorhandenen oxydirbaren Stoffe, — in wahrscheinlich weit untergeordnetem Grade auch durch die Athmung der Thiere.”

But the differences thus occasioned are not very great, since the percentage of oxygen, with but few exceptions, ranges from 30 to 34, as a rule diminishing with the depth.

Moreover, Jacobsen's observations, instituted under circumstances the most diverse, furnish incontestable proof, that the views of earlier authors, according to which the effect of solar light and storms, or indeed meteorological influence generally, was assumed to play an important part in modifying the composition of the air in surface-water, were wholly unfounded; nay, the extent to which the results based on that hypothesis are found to vary, will of itself show the comparative insignificance of such factors.

As regards the absolute amount of air contained in samples of water collected from different strata, this is found to increase with the depth, — a fact sufficiently obvious from the temperature diminishing as the depth increases, without needing to seek an explanation in the greater pressure. And with the object of showing that the proportion of air present in sea-water at great depths, is not, as assumed by some, to any appreciable extent dependent on the greater pressure prevailing there, a special series of experiments was instituted on the ‘Pomerania’ Expedition, with an apparatus for collecting water constructed of caoutchouc by Drs. Behrens and Jacobsen. This instrument was first pressed flat, and then sunk, after the air still remaining in it had been expelled by means of mercury, perfectly air-tight. On its striking the bottom, it opened and filled with water, after which it again closed, and was then brought up to the surface, air-tight as before. The samples of water collected in this apparatus were never found to contain more air than would be absorbed, with the same temperature, at the surface. That such must be the case, there was indeed reason to infer from the experiments instituted by Aimé<sup>1</sup> in 1843. Aimé made use of a glass tube, which, open at the upper extremity, was sunk full of mercury, and at the required depth inverted, causing part of the mercury in the tube to be replaced by water, in such manner that the mercury, flowing into a receiver of proper size and shape, prevented its escape. As the result of the experiments performed with this instrument, Aimé ventured to assume, that the proportion of air contained in a given quantity of sea-water, is at all depths very nearly the same.

<sup>1</sup> Ann. Chim. Phys. [3] — 7 — 497. Pogg. Ann. 30 — 412.  
Den norske Nordhavsexpedition. Tromsø: Chemé.

<sup>1</sup> Ann. Chim. Phys. [3] 7, p. 497. Pogg. Ann. 30, p. 412.

I Aaret 1873 udgik efter fra England en Expedition, Challengerexpeditionen, som i et Tidrum af 3 Aar skulde undersoge lande de equatoriale og antarktiske Farvande. Med denne Expedition fulgte som Chemiker J. Y. Buchanan, som besluttede sig til at anvende de paa Pomerania-expeditionen benyttede Metoder og Apparater saa godt som uden Modifikationer. Resultaterne af hans Undersogelser ere, saavidt jeg ved, endnu ikke offentliggjorte i sine Enkeltheder, medens der dog er gjort nogle foreløbige Meddelelser, hvorefter man vil kunne danne sig et Begreb om de Slutninger, hvortil hans Observationer ville føre.

Han finder<sup>1</sup>, at Surstofmængden i Overfladevandet varierer mellem 33 og 35 % af den samlede Surstof-Kvælstofmængde, saaledes at den største Mængde er fundet (daude relativt og absolut) i Vandprover tise i Nærheden af den sydlige Polarcirkel og den mindste i Pasatvind-egnene. Hvad angaar de under Overfladen liggende Lag, da har han observeret det mærkelige Factum, at Surstofprocenten aftager nedover indtil et Dyb af 300 Favne, hvor den opnaar et Minimum før atter igjen at stige, saaledes som det fremgaa af følgende Tabel.

Dybde i engelske Favne	0	25	50	100	200	300	400	800	Der- over.
$\frac{O + N \cdot 100}{O_{\text{per.}}}$	33.7	33.4	32.2	30.2	33.4	11.4	15.5	22.0	23.5

Om den absolute Mængde af de af hans Vandprover udtagne Gasarter findes paa dette Sted Intet, hvorimod der senere er bleven offentliggjort følgende Tabel<sup>2</sup>:

Dybde i Fod	CC. O per Litre.	Midlere Temperatur i °C.	CC. N per Litre $N_1$	CC. N per Litre destill. Vand ved Temperatur, $t$ , Rausen $N_2$	$N_2 - N_1$
000	4.24	14.6	11.26	11.75	0.49
1200	3.59	13.0	11.74	11.92	0.21
1800	1.07	6.0	13.00	13.45	0.45
2400	2.41	5.1	13.10	14.00	0.90
4800	4.00	2.5	13.82	15.00	1.14
derover	-	1.5	14.37	15.40	1.03

Hermed er i Korthed gengivet det Vigtigste af de til Dato fremkomne Bidrag til Løsningen af Spørgsmaalet om Luften i Søvandet.

I Vaaren 1876, da man i Norge var beskæftiget med Edrustningen af den Expedition, som var besluttet udsendt for i Sommermaanederne af Aarene 1876—77 og 78 at

In the year 1873, another Expedition was dispatched, from England, with H. M. S. 'Challenger,' its object being the investigation, during a period of 3 years, both of the Equatorial and the Antarctic Seas. As chemist to this Expedition, had been secured the services of J. Y. Buchanan, who resolved to adopt the methods and apparatus employed on the 'Pomerania' Expedition, almost without modification. The results of his labours are not yet, I believe, published in detail; preliminary papers have, however, appeared, from which we can form some general idea of his results.

Buchanan found<sup>1</sup> the proportion of oxygen in surface-water to vary between 33 and 35 per cent of the total amount of oxygen and nitrogen; it was greatest (both relatively and absolutely) in the samples of water drawn near the Antarctic Circle, and smallest in those collected within the region of the trade winds. As regards the proportion of oxygen in water below the surface, he observed the very remarkable fact, that it generally diminishes down to a depth of 300 fathoms, where a minimum is reached, and then begins to increase, as shown by the following Table.

Depth in English Fathoms.	0	25	50	100	200	300	400	800	Great- er Depths.
$\frac{O + N \cdot 100}{O_{\text{per.}}}$	33.7	33.4	32.2	30.2	33.4	11.4	15.5	22.0	23.5

With respect to the absolute amounts of the gases boiled out of the different samples of water, nothing is stated in the work alluded to, but the following Table<sup>2</sup> has since appeared.

Depth in Feet.	CC. O per Litre.	Mean Temperature in °C.	CC. N per Litre $N_1$	CC. N per Litre distilled Water, at Temp. $t$ , Rausen $N_2$	$N_2 - N_1$
000	4.24	14.6	11.26	11.75	0.49
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2400	2.41	5.1	13.10	14.00	0.90
4800	4.00	2.5	13.82	15.00	1.14
Greater Depths.	-	1.5	14.37	15.40	1.03

A brief account has now been given of what had previously been accomplished as regards the solution of the problem presented by the air in sea-water.

In the spring of 1876, when fitting out the Norwegian Expedition, which had for its object the investigation, during the summer months of 1876, 1877, and 1878, of

<sup>1</sup>The Voyage of the 'Challenger,' The 'Atlantic,' 2, p. 306.

<sup>2</sup>Ber. Berl. chem. Ges., 11, p. 410.

<sup>1</sup>The Voyage of the 'Challenger,' The 'Atlantic,' 2, p. 306.

<sup>2</sup>Ber. Berl. chem. Ges., 11, p. 410.

undersøge det mellem Norge, Færøerne, Island, Jan Mayen og Spitzbergen liggende Hav, vare heller ikke de paa den engelske Challengerexpedition indborte Observationer offentliggjorte, saant de Data, der den Gang forelaa, i Rigdhedighed paa ingen Maade kunde sammenlignes med dem, som nu staa til Raadighed. Især var det med Hensyn paa den geografiske Udledning, at Observationerne ikke kunde give synderlig omfattende Oplysninger, idet det eneste Hav, som endnu var grundigt undersøgt, nemlig Nordøen, haade med Hensyn paa Dybde og øvrige fysikalske Forholde afveg i høi Grad fra det store Verdenshav, forsaavidt man kjendte det. Da der først var fattet Beslutning, om at der ogsaa paa den norske Nordhavsexpedition skulde indføres chemiske Undersøgelser af samme Art som paa de tidligere Expeditioner, maatte det derfor for Hr. S. Svendsen, hvem disse Arbejder oprindelig vare overbragne, fremstille sig som en meget vigtig, ja man kan sige, som den vigtigste Opgave at tilvejebringe de fornødne Oplysninger om Gasarterne i Søvandet, hvad angaar den Del af Verdenshavet, som Norge havde paataget sig at gjøre til Gjenstand for videnskabelig Undersøgelse. Med Hensyn paa de Midler, der skulde benyttes til Løsningen af denne Opgave, da kunde Valget af disse ikke fulde vanskeligt, da de af Dr. Jacobsen benyttede Metoder og Apparater strax maatte tilpaa sig som de hensigtsmæssigste fremfor Alt, hvad der for Resten stod til Raadighed, selv om ikke Hensynet til Resultaternes Sammenlignelighed havde gjort deres Anvendelse ønskelig. Svendsen besluttede derfor uden Modificationer at optage de paa Pomoranienexpeditionen benyttede Arbeidsmetoder, og var det i Henseende til Expeditionens Udrustning et stort Held, at Professor Dr. Jacobsen velvilligen tilbød sig at anskaffe de til de chemiske Undersøgelser fornødne Apparater.

Det var dog ikke alle de ved Pomoranienexpeditionen benyttede Apparater, som ogsaa kom til Anvendelse paa den norske Nordhavsexpedition, idet man der besluttede at anvende en af Captain Wille konstrueret Vandhenter, som især i en Henseende maatte være at fortrække for den af Dr. H. A. Meyer angivne. Paa denne maatte nemlig, naar den skulde optage Vandprover fra intermediate Dyb, Cylindren udløses ved et laags Lumen nedsænket Lool, som aldeles udelukkede Muligheden af paa Lumen saantidz at have anbragt Thermometre eller detslge, saaledes som det uden mindste Ulempe kan forenes med Brugen af Willes Vandhenter.

Willes Vandhenter, som findes afbildet i Fig. 2, er af Opfinderen bleven beskrevet paa følgende Maade:

“Vandproven indsluttes i dette Instrument i et for Pladsens Skyld spiralformigt bøiet Rør, der under Nedfiringen i Vandet holdes aabent i begge Ender, saaledes at Vandet frit kan strømme igjennem; men naar Instrumentet ophales et kort Stykke, lukkes Enderne af Røret med to Ventiler, hvorved det da i Røret staaende Vand afstenges og kan bringes op.

the sea lying between Norway, the Féroé Islands, Ireland, Jan Mayen, and Spitzbergen, the results of the observations instituted on the ‘Challenger’ Expedition had not yet been made public; and hence the data then obtained were few compared to those of which we are now in possession. It was more particularly with respect to geographical distribution, that the information former observations could supply had proved but meagre, inasmuch as the only sea thoroughly investigated, viz the German Ocean, was found to differ widely in regard to depth and other physical conditions from the Atlantic and Pacific, so far at least as our knowledge of both may be said to extend. The resolution once formed, of instituting on the Norwegian North-Atlantic Expedition a series of chemical experiments similar to those performed on former Expeditions, Mr. S. Svendsen, the gentleman on whom the execution of this task was to have devolved, could not but regard as an important, nay the most important, part of his labours, accurate determinations of the gases present in that tract of the Atlantic Ocean which the Norwegian Expedition was to make the subject of scientific investigation. Respecting the means whereby to solve this problem, no difficulty could be experienced in making a choice, since Dr. Jacobsen’s methods and apparatus must at once suggest themselves as by far the best, even apart from the consideration, that, for the better comparing of his results with those obtained, their adoption was desirable. Svendsen, therefore, decided in favour of the process without modification, resorted to on the ‘Pomoranien’ Expedition, and it was a fortunate concurrence, that Professor Jacobsen should kindly volunteer his assistance in procuring the various apparatus necessary for the chemical experiments.

All the apparatus made use of on the ‘Pomoranien’ Expedition, were not, however, adopted on the Norwegian North-Atlantic Expedition, the instrument, for instance, employed to collect water, which, particularly in one respect, must be held preferable to that described by Dr. H. A. Meyer, had been constructed by Captain C. Wille. R. N. When drawing water from intermediate depths, the cylinder in the latter is detached by running a weight down the line, which precludes the possibility of having a thermometer, or any other instrument, attached to it, an advantage which may, without the slightest drawback, be combined with Wille’s apparatus.

Wille’s instrument for collecting water, of which Fig. 2 is a representation, has been described by the inventor as follows:—

“The samples of water drawn with this instrument are, to save space, brought up in a spiral tube, which, when sunk through the water, is kept open at both ends, to admit of the free passage of the fluid; but, on the instrument, at the required depth, being hauled in a few fathoms, the ends of the tube are closed by means of two valves, and the water it contains, thus prevented from escaping, may be brought to the surface.

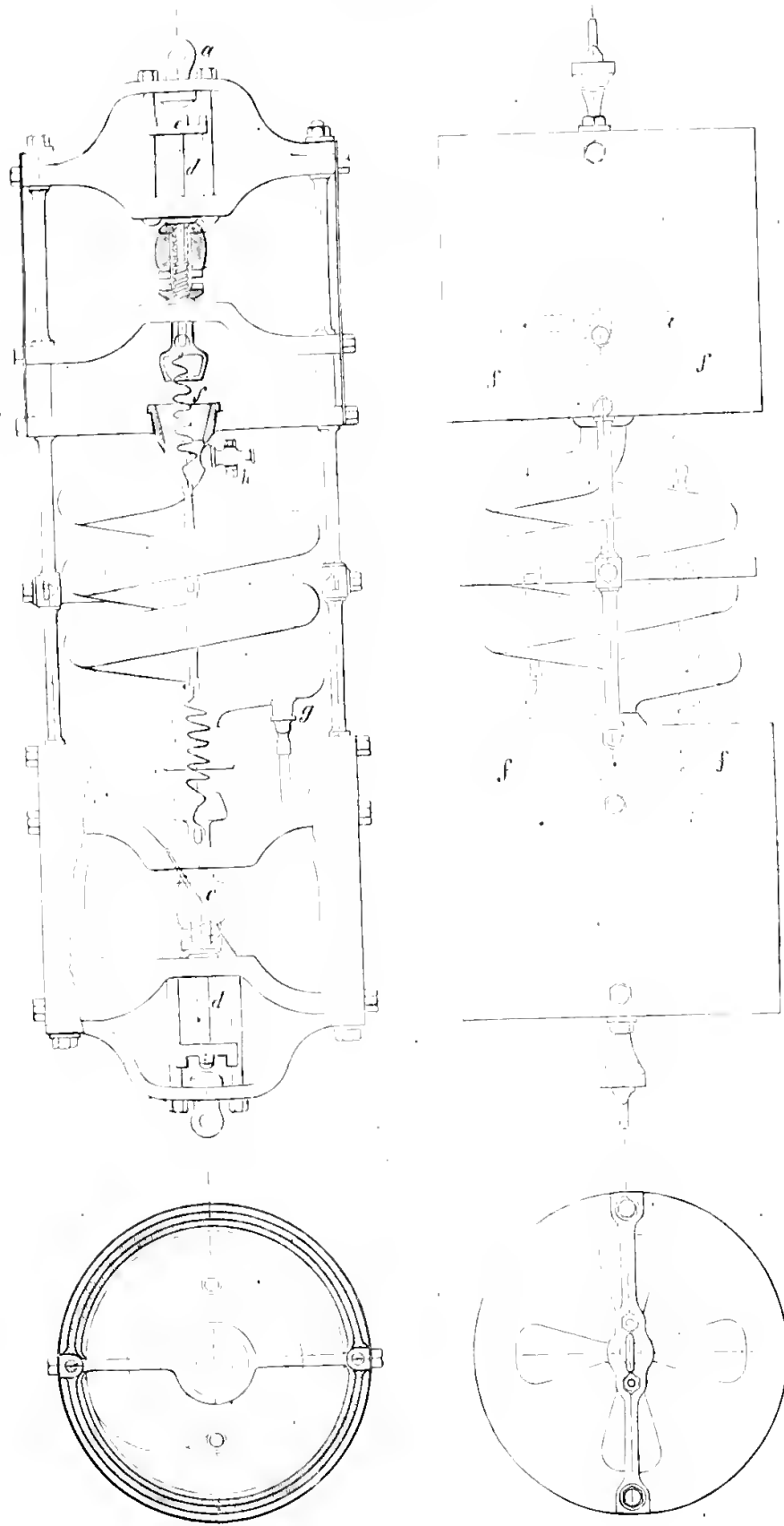


Fig. 2.  
at naturlig Storrelse.  
(The eighth of the Actual Size.)

Tegningen fremstiller Instrumentet klar til Nedfiring; Tappen af Lødløsen hexes i øverste Ophæng (a) og Lødløsen i den nedre (b). Under Nedfiringen løfter Vandtrykket Propellerne op, saa at Taggerne i Underkant af Propelbøsset (c) kommer klar af Taggerne i Muffen, gennem hvilken Ventilstangen (d) gaar, og om de ikke kommer ganske klare, sker Propellens Ombreming med Skraaplanerne, saa at Muffen og Ventilstangen bliver staaende stille. Naar Instrumentet dermed under Ophængen hejves opad, driver Vandtrykket Propellerne ned, de dreies rundt den anden Vej og tager Mufferne med sig. Ventilstængerne, der ikke kan dreie sig rundt, men styres af Tværstykkerne (e), skrues da, tilligemed de med Kautschuk overtrukne Ventiler, med Ventilsælerne i Enderne af Røret, og naar de ere næsten lukkede, glipper den sidste Skruetjænge paa Ventilstangen ud af Skruetjængerne i Muffen, og Spiralfjædere (f) klapper da Ventilerne i, medens Propellerne og Mufferne gaa løse rundt om den glatte Del af Ventilstængerne, og frembyder saaledes meget liden Modstand under Resten af Indhævningen. Instrumentet lukker sig efter omtrent 7 Fathoms (13 Meters) Indhævning. Ringen om Midten og Skjermene rundt Propellerne beskytte Instrumentet, saaledes at det uden Skade kan ligge paa Bunden.

For at konstatere, om der var Overskud af Luft i de nedre Vandlag, blev der over Sykkelløst paaskrevet et gennemløbet Læng (g), der ved Hjælp af et Stykke Gummislange forenedes til et i den ene Ende lukket Glasrør. Naar Vandet under Nedfiringen strømmede ind i Vandrøret, løb det ogsaa ned i Glasrøret, af hvilket Luften saaledes blev udjaget. Naar Instrumentet kom ombord, endevendtes det, saa at Kramen kom ned og Glasrøret op. Man bemærkede nu Vandhøiteten lidt frem og tilbage med den øvre Ende, og hvis der havde været Overskud af Luft, maatte denne have arbejdet sig op og vist sig i Toppen af Glasrøret, men dette viste sig stadig midt lige til Tops, og blev derfor i den sidste Tid ikke paasat.

Instrumentet kan tømmes gennem Tappekranen (h) og leverer en Vandprøve paa circa 5 Litre.

Udførelsen af de chemiske Arbejder ombord paa den norske Nordhavsexpedition overtoges altsaa først i Følge den oprindelige Plan af Hr. Svendsen, som gjorde Tøgtet i 1876 med, men blev senere, da denne af Høllandskensisn bad sig fritaget, overdraget Forfatteren, der saaledes har udført de paa de to sidste Tøgter gjorte Observationer delvis med Assistance af Hr. L. Schmelek, som sidste Sommer medfulgte Expeditionen, og som for Tiden er beskæftiget med Bearbejdelsen af en anden Del af det paa Expeditionens Tøgter til chemisk Undersøgelse indsamlede Materiale.

The figure shows the instrument ready for sinking. The end of the sounding-line is made fast to the upper eye-bolt (a), and the lead to the lower (b). On the downward passage, the pressure of the water lifts up the propellers, enabling the tags in the under surface of the base of the latter (c) to get clear of the tags in the bush, through which passes the rod of the valve (d); and if not quite clear, the propeller revolves with the inclined planes, the bush and the rod of the valve remaining stationary as before. On the other hand, when the instrument, on being hauled in, is given an upward motion, the pressure of the water forces down the propellers, which then revolve in the opposite direction, carrying along with them the bushes. The rods of the valves, which cannot revolve, being kept in position by transverse pieces (e), are, together with the valves covered with caoutchouc, screwed against the ends of the tube. Now, when the latter are almost closed, the last twist of the screw on the rod of the valve slips out of the corresponding twist of the screw on the bush, and the spiral springs (f) instantly press down the valves, the propellers and the bushes revolving independently round the smooth portion of the rods, thus presenting but little resistance to the water during the remainder of the upward passage. The instrument closes on being hauled in about 7 fathoms (13 metres). The ring round the middle, and the shields protecting the propellers, prevent the instrument from sustaining injury on its striking the bottom.

With a view to ascertain whether the proportion of air were really greater in the lower strata, a perforated cover (g) was screwed over the spout-hole, and connected by means of a piece of caoutchouc hose with a glass tube, open at one end. Now, when the water on the downward passage flowed into the spiral tube, it also descended into the glass tube, expelling the air. So soon as the instrument came on board, it was inverted, the stopcock therefore pointing down, and the glass tube up. The upper end of the apparatus being now moved a little backwards and forwards, the surplus of air, if any had been present, must obviously have forced its way upwards, and have appeared, in the form of bubbles, at the top of the tube, which, however, was invariably found to be quite full, and therefore not attached to the apparatus when the fact would no longer admit of doubt.

The stopcock (h) serves to empty the instrument, which will hold about 5 litres of water.

The chemical work to be done on board was, as stated above, originally undertaken by Mr. S. Svendsen, who went out on the first cruise, in 1876, but, his health failing, Mr. Svendsen was succeeded by the author, who had therefore to take the observations instituted in 1877 and 1878, partly with the assistance of Mr. L. Schmelek, that gentleman having accompanied the Expedition on the last cruise. (Mr. Schmelek is now engaged in working up other materials collected on the Expedition for chemical investigation.)

Da jeg Vaaren 1877 blev opfordret til at overtage disse Arbejder, var der kun givet mig fra Dages Varsel, saet jeg havde de største Vanskeligheder med at faa udført selv de aller nødvendige Forberedelser, og naar det alligevel lykkedes at faa Alt tilfredsstillende ordnet for Afreisen, da skyldes dette udelukkende den Beredvilighed, hvormed Hr. Professor Waage lod sig blandt Andet ogsaa med Indretningen af det kemiske Laboratorium ombord.

Det paa Expeditionens første Tojt i 1876 frembræskende ualmindeligt stormfulde Veir gjorde det i høj Grad vanskeligt ja næsten umuligt at udføre de kemiske Observationer ombord, og det Udlytte, som af Svendsen hjembragtes fra første Tojt, indskrænkede sig derfor i denne Branche til 17 Luftprover, hvoraf desuden 3 ved Uheld senere gik tabt. Det rolige Veir, som de to sidste Aar lægnstagede Expeditionens Arbejder, tillod mig derimod paa de Tojter, hvormed der var givet mig Anledning til at medfølge, at indsmelte et større Antal, end der før disse Aars Vedkommende erholdtes 80 Luftbestemmelser af de hjembragte Luftprover, hvoraf 9 vare indsmeltede af Hr. Schmeleck, Naar Udlyttet ikke er blevet større, da har dette sin Grund i, at tidlige Observationer gik tabt, nogle fra ved Uheld under Analysen men de fleste ved Uheld under Indsmeltningen. Saaledes var der til Brug paa sidste Tojt fra Kuehler & Solme i Himmeln sendt mig nogle Luftopsamlingsrør, hvorefter over 75% tilrook for den omhyggeligste Behandling sprang enten under Indsmeltningen eller efter samme. Luftproverne ere alle analyserede ved det af Franckland og Ward<sup>1</sup> angivne Gasanalyseapparat, saaledes at Kulsyren er tjernet med Kalkhyd og Surstoffet bestemt ved Forbrænding med Vandstøv. De 14 førstnævnte Prover ere analyserede af Hr. Svendsen de øvrige 80 af Forfatteren. De erholdte Resultater findes sammenstillede i Tabel I, hvortil kan bemærkes følgende: De i Tabellen opførte Temperaturangivelser ere mig meddelte af Professor Mohr. Ved Angivelse af de Dybder, hvorfra Vandproverne ere hentede, er ikke taget Hensyn til, at Vandbenteren først lukker sig efter circa 7 Fathoms Indbivning. Ved de med \* betegnede 10 Nummere var der, i de til Luftprovernes Opbevarelse benyttede Glasrør smaa Feil, uden at jeg dog har fundet mig foranlediget til at tillægge disse mindre Vægt end de Øvrige, da man vel ikke kan tænke sig Muligheden af en Lækage, uden at den, naar Glasrørene i flere Maanedes opbevares under en Trykdifferens mellem det ydre og indre Gastryk af circa 300 til 400<sup>mm</sup>, maatte have øvet en merkbar Virkning paa den indesluttede Lufts Sammensætning. Jeg kan saa meget trostgere tage dem med i Beregningerne, hvor det gjælder at opstille de almindelige Slutninger, som de ikke i synderlig Grad ville bidrage til at forrykke Udsæendet af de endelige Resultater. Alle Gasvolumina findes i Tabellen indtrykte i CC. per Litre indkogt Søvand reduceret til 0° og 760<sup>mm</sup> Barometerstand.

When, in the spring of 1877, I was requested to undertake these labours, I had but a few days' notice, and experienced, therefore, very great difficulty in making even the most necessary preparations; nor would it indeed have been possible to get everything satisfactorily arranged in so short a time but for the readiness with which Professor Waage came forward to assist me; for instance, in fitting up the chemical laboratory on board.

The exceptionally heavy weather on the first cruise in 1876, rendered it in the highest degree difficult, nay well nigh impracticable, to perform the necessary experiments on board, and hence the chemical work done by Svendsen on the first voyage was, with regard to gas-determinations, confined to collecting 17 samples of air, 3 of which however were subsequently lost. On the two last cruises of the Expedition the weather proved much more favourable, and I succeeded in obtaining a larger number of samples (9 of them collected by Mr. Schmeleck), with which, when brought home, 80 air-determinations were performed. A more satisfactory result would, however, have been obtained but for the loss of numerous samples, some few from accident when analysing the gass, but the great majority by reason of the difficulty experienced in sealing. Thus, for instance, on the last voyage 75 per cent of the glass tubes for collecting air, procured from Kuehler & Solme in Himmeln, notwithstanding the greatest care cracked either during the sealing-process or after its completion. The samples of air were all of them analysed in the apparatus described by Franckland and Ward,<sup>2</sup> the carbonic acid having been absorbed in a lie of potash and the oxygen determined by consuming it with hydrogen. The first 14 samples were analysed by Mr. Svendsen, the remaining 80 by myself. The results obtained will be found in Table I. The temperatures in the Table were given by Professor Mohr. When stating the depths from which the samples of water were drawn, regard has not been had to the fact, that the instrument used for collecting them does not close till it has been hauled in about 7 fathoms. The asterisk marking 10 of the determinations signifies that the glass tubes used for preserving these samples of air had small defects. To these determinations, however, I have not attached less weight than to the others; for it is impossible to conceive that a leakage, after the glass tubes had been exposed for months together to a difference of pressure amounting to 300<sup>mm</sup>—400<sup>mm</sup>, viz. that existing between the air inside and the atmosphere without, should not have had an appreciable effect on the composition of the air they contained. Moreover, I hesitate the less to include them as factors when seeking to arrive at general conclusions, since they cannot to any considerable extent disturb the character of the final results. The volumes are given in cubic centimetres per litre of the sea-water examined, reduced to a temperature of 0° and a pressure of 760<sup>mm</sup>.

<sup>1</sup> Chem. Soc. Journ., 22, p. 413; 1869.

<sup>2</sup> Chem. Soc. Journ., 22, p. 413; 1869.

Tabel I.

No.	Stat. No.	Nordlig Brokke. (North Latham.)		Længde fra Greenwich (Longitude from Greenwich)		Dybde hvortil Proben hentet. (Depth from which the Samples were collected.)		O <sub>2</sub> A. CC. per Litre.	N. CC. per Litre.	CO <sub>2</sub> A. $\frac{A}{100}$ CC. per cent.	Temperatur. Celsius.	Anmærkninger (Remarks)
		Long. East.	Lat. North.	Færdige Fathom.	Metre.							
1				Husø		0	0	17.4	11.3	35.1	10.5	
2	14	62° 4'	2° 44' 5" E.	220	413	20.1	13.8	31.1		0.1		
3	32	63 10	4 51.3	430	780	10.0	13.0	31.7		0.0		
4	33	63 5	3 0	0	0	18.0	12.4	34.4		11.8		
5	33	63 5	3 0	525	900	17.3	11.7	32.0		1.1		
6	35	63 7	1 20 W.	0	0	17.0	11.1	35.0		10.1		
7	35	63 7	1 20	724	1310	18.4	12.4	32.0		0.0		
8	37	62 28.3	2 20	300	505	18.5	12.4	32.8		0.0		
9	37	62 28.3	2 20	600	1202	18.3	12.3	32.7		1.1		
10	40	63 22.5	5 20	0	0	17.1	11.1	35.2		0.7		
11	40	63 22.5	5 20	515	942	20.5	13.0	32.1		-0.4		
12	51	65 53	7 18	515	942	20.0	13.0	32.3		0.0		
13	51	65 53	7 18	1103	2127	20.0	14.1	32.7		1.1		
14	52	65 17.5	3 7	1861	3493	-	-	32.2		1.2		
15	65	66 42	4 13.7 E.	175	320	-	-	32.1		5.8		
16	66	66 8.5	3 0	805	1472	-	-	32.3		1.1		
17	125	67 52.5	5 12	700	1280	20.5	13.7	33.0		1.1		
18	125	67 52.5	5 12	700	1280	20.0	13.3	33.0		-1.1		
19	152	67 18	12 40	125	220	-	-	34.0		4.1		
20	162	68 23	10 20	705	1454	20.0	13.0	32.0		-1.2		
21	162	68 23	10 20	705	1454	10.4	12.0	33.7		1.2		Collected from the bottom of the vessel.
22	171	69 18	14 20	642	1174	10.0	13.0	33.5		-1.0		Collected from the bottom of the vessel.
23	170	69 12	11 10	1007	2030	-	-	32.1		1.2		
24	183	69 50.5	6 15	0	0	20.2	12.0	30.1		8.0		
25	183	69 50.5	6 15	0	0	-	-	30.1		8.0		
26	184	70 4	9 50	1547	2820	21.5	14.0	32.0		4.3		
27	184	70 4	9 50	600	1007	20.7	14.1	32.1		0.0		
28	180	69 41	15 42	0	0	18.4	12.0	35.0		0.0		
29	180	69 41	15 42	800	1573	21.5	14.0	32.0		1.1		
30	200	71 25	15 40.5	620	1134	10.0	12.8	35.8		-1.0		Collected from the bottom of the vessel.
31		Inlet of Malungstrand (Inlet to the Malungstrand Fjord)		0	0	-	-	35.5		8.5?		
32	213	70° 23'	2° 30'	0	0	18.0	12.1	34.0		8.2		
33	213	70 23	2 30	1700	3210	10.0	12.0	34.0		1.2		
34	213	70 23	2 30	1700	3210	-	-	33.8		1.2		
35	215	70 53	2 0 W.	0	0	-	-	34.8		8.0		
36	215	70 53	2 0	700	1280	20.1	13.0	22.4		0.0		
37	215	70 53	2 0	1005	3045	10.2	12.0	32.8		1.2		
38	220	70 50	7 51	0	0	-	-	33.7		3.0		
39	220	70 50	7 51	340	622	-	-	32.7		0.0		
40	-	69 20	11 18	0	0	20.7	13.3	35.8		4.3		
41	-	69 20	11 18	0	0	-	-	35.1		4.3		
42	243	68 32.5	0 20	0	0	20.0	13.1	34.7		7.8		
43	243	68 32.5	0 20	0	0	22.1	15.0	32.2		0.8		
44	243	68 32.5	0 20	1385	2533	22.0	15.3	32.5		1.3		
45	247	68 5.5	2 24 E.	0	0	19.3	-	-		0.4		
46	247	68 5.5	2 24	500	914	-	-	32.3		0.4		
47	240	68 12	0 35	1003	1944	21.4	14.5	32.3		-1.3		
48	252	Inlet of Skarvstrand (South of Skarvstrand Fjord)		0	0	18.2	14.0	34.7		14.0?		
49	253	Inlet of Skarvstrand (The Skarvstrand Fjord)		203	481	20.0	13.8	34.2		3.2		
50	254	67° 27'	13° 25'	0	0	18.2	11.0	34.8		10.0		
51	254	67 27	13 25	70	128	21.3	14.2	33.2		4.8		
52	254	67 27	13 25	140	250	10.5	13.2	32.4		5.8		
53	204	70 50	35 37	0	0	20.0	13.3	35.5		5.2		
54	204	70 50	35 37	80	157	20.7	13.8	33.1		1.0		
55	275	74 8	31 12	0	0	20.5	13.3	34.0		2.0		
56	275	74 8	31 12	147	200	21.0	14.0	33.4		0.4		
57	278	74 1.5	22 27	0	0	20.4	13.3	35.0		3.2		
58	278	74 1.5	22 27	230	421	20.7	13.8	33.3		0.0		

No.	Stat. No.	Nørdlig Bredde. (North Latitude)	Længde fra Greenwich. (Longitude from Greenwich)	Dybde-Hydrogen-Pro- venderet. (Depth from which the Hydrogen was collected)		O <sub>2</sub> N per Liter. per Liter.	N per Liter. per Liter.	O <sub>2</sub> N = 100 O <sub>2</sub> N (per cent)	Temperatur. Celsius.	Anmærkning. (Remarks)
				Engelske Fæmte. (English Fathoms)	Metere. (Meters)					
59	283	73° 47' 5"	14° 21'	0	0	10.8	12.8	35.4	7.2	
60	283	73 47.5	14 21	0	0	10.5	12.0	35.3	7.2	
61	280	72 57	14 32	0	0	20.0	13.2	35.8	7.2	
62	280	72 57	14 32	147	817	21.8	14.8	31.0	-0.8	
63	203	74 7	21 11	95	474	10.0	13.0	33.5	5.1	
64	205	74 59	11 40	0	0	20.2	12.8	36.7	7.0	
65	205	74 55	11 30	600	1007	21.4	14.0	31.7	-0.8	
66	205	74 50	11 40	1110	2030	21.5	14.0	32.4	-1.3	
67	200	72 15.5	8 0	100	183	20.4	13.4	34.2	3.1	
68	207	72 30.5	5 12	1280	2341	21.3	13.8	35.1	-1.4	
69	301	74 1	4 20	W.	0	21.0	14.4	35.0	2.2	
70	303	75 12	3 2	E.	150	274	22.0	14.7	33.4	-1.1
71	304	75 3	1 54	0	300	549	21.7	14.7	32.2	-0.8
72	301	75 3	1 51	0	1735	3173	21.0	14.0	32.2	-1.5
73	321	74 50.5	10 30	0	0	23.8	15.4	35.2	0.5	
74	321	74 50.5	10 30	25	40	23.7	15.3	35.4	0.2	
75	333	72 53.5	21 51	0	0	10.3	12.3	36.5	7.8	
76	323	72 53.5	21 51	0	0	—	—	35.8	7.8	
77	332	75 50	11 30	1149	2101	21.0	14.8	32.2	1.5	
78	332	75 50	11 30	1149	2101	22.0	15.0	34.8	-1.5	
79	335	70 10.5	14 30	0	0	20.8	13.3	30.2	5.4	
80	335	70 10.5	14 30	470	327	21.0	14.0	33.4	1.0	
81	330	70 30	15 30	37	68	21.0	14.2	34.1	0.0	
82	342	70 33	13 18	0	0	21.8	14.1	35.3	0.2	
83	342	70 33	13 18	523	050	20.8	13.8	33.8	1.0	
84	345	70 12.5	10 0	300	549	20.0	13.7	34.4	1.0	
85	345	70 12.5	10 0	300	549	21.5	14.2	33.0	1.0	
86	347	70 10.5	7 47	0	0	20.0	13.4	35.7	4.4	
87	347	70 10.5	7 47	1420	2613	21.4	13.0	35.1	-1.3	
88	349	70 30	2 57	1487	2714	21.7	14.0	32.5	-1.5	
89	350	70 20	0 20	W.	300	549	21.0	14.7	32.7	-1.1
90	350	70 20	0 20	1086	3083	22.0	15.3	33.3	1.5	
91	352	77 50	3 20	E.	300	549	21.0	14.8	32.5	-0.8
92	352	77 50	3 20	1086	3083	22.4	15.1	32.8	-1.5	
93	350	78 2	0 25	0	0	—	—	35.7	1.3	
94	302	70 50	5 40	0	0	20.3	13.0	35.8	5.2	

Vandproverne ere overalt, hvor det Mudsatte ikke utrykkelig er antort, ndkøgte strax efter deres Optagelse.

Som man ser, ligner denne Tabel overmaade meget den af Dr. Jacobsen opstillede, hvad man ogsaa paa Forhaand kunde vente, da de undersøgte Districter fuldstændig gaa over i hinanden, og naar Differentserne mellem de af Hr. Svendsen og mig opførte Tal ere noget større, da kommer dette ligefrem af det af os lemlændede Følts større Udstrækning og deraf følgende større L'ensartethed i de fysikalske Forholde.

Hvad der er mest iøjnefaldende, er det paaafaldende Phenomen, at der med Hensyn paa den relative Sammensætning af den i Overfladevandet indeholdte Luft paa den norske Nordhavsexpedition er fundet betydeligt større Surstofhalt end af Dr. Jacobsen for Nordsoen opstillet, saaledes er Surstoffprocenten i Overfladen i Nordsoen bestemt til i Middel 33.93 % af den samlede Luftmængde, medens den for det af den norske Expedition i 1876 og 77 undersøgte Strog sønderfor den 70de Breddegrad, løber sig

The samples of water were all, except when the reverse is stated, boiled immediately on being drawn.

As will be seen, this Table agrees very closely with that prepared by Dr. Jacobsen, which was indeed to be expected, since the tracts investigated coincide; and the somewhat greater differences exhibited by Mr. Svendsen's and my own figures arise simply from the region explored by the Expedition having been more extensive, involving greater dissimilarity in the physical conditions.

With regard to the relative composition of the air in surface-water, the proportion of oxygen was, strange to say, on the Norwegian North-Atlantic Expedition found to be considerably greater than that given by Dr. Jacobsen for the North Sea. The mean proportion of oxygen in the surface-water of the North Sea he determined to be 33.93 per cent of the total amount of air, whereas the mean proportion for the tract of the North-Atlantic stretching south of the 70th parallel of latitude, that investigated by the



til i Middelt 34,96 og for det i 1878 undersøgte mellem 70de og 80de Breddegrad beliggende Strøg til 35,64  $\%$ .<sup>1</sup> Fuldstændigt tilsvarende er det af Buchanan fundet at være paa den sydlige Halvkugle, idet Surstofprocenten i Overfladen der varierer fra omkring 33 i Æquatorregionen til ca. 35 omkring den sydlige Polarcirkel.

Dette lod med temmelig stor Bestæthed formode, at de for destilleret Vand gjældende, af Bunsen opstillede, Absorptionscoefficienter ikke skulde være gyldige for Søvand, idet det, naar Overfladevandsluftens Sammensætning fandtes at variere med Bredden, maatte være det Naturligste at skrive disse Variationer paa Temperaturforandringerne. Det vil imidlertid ikke fore til noget rimeligt Resultat, om man vil betragte Temperaturen som den Variable og at de her foreliggende Observationer forsøge at indlede en Lov for Absorptionscoefficienternes Variationer med Temperaturen. Man vil da finde, at de enkelte Observationer staa ikke ubetydeligt i Strid med hinanden, idet der for Surstofmængdernes Vedkommende overalt optræder meget større Afvigelser, end man kan antage begrundede i Observationsfejl. Det kunde dog ikke synes tilnærdeligt at lade det høre hermed og forsøge at discutere de foreliggende Observationer uden niere Kjendskab til Absorptionscoefficienternes Afhængighed af Temperaturen, og jeg besluttede derfor at bestemme saavel Sammensætning som Mængde af den i Søvandet ved forskjellige Temperaturer opløste Luft.

Først gjordes en Del Forsøg, hvorved Søvandet i et Bad af constant Temperatur søgtes mættet ved flere Timers Gjennembløding af Luft, (saaledes som Bunsen har gaaet frem ved sine Besøgmøder<sup>2</sup>), hvorefter den opløste Luft udledes og analyseredes paa den for beskrevne Maade. De paa denne Maade mættede Vandprover afgave bestandig Luftmængder, som uden Hensyn til den Temperatur, hvorved Vandet var mættet, viste nogenlunde nær den samme Sammensætning (med 34,9  $\%$  Surstof med 65,1  $\%$  Kvælstof), medens de ofte temmelig stærkt afvigende Tal, som udtrykte de absolute Mængder af opløste Gasser, tydeligt viste, at der paa denne Maade ikke var opnaaet fuldstændig Mætning.

Professor Waage foreslug mig derfor at gjentagelige Forsøg med nogen Variation i den Maade, hvorpaa Mætningen iværksattes, og har jeg som Følge deraf ved de senere Forsøg benyttet følgende Fremgangsmaade. En passende Partium Søvand af nogenlunde høj Egenvægt rystedes med Luft i en rummelig Kålbe i et Tidsrum fra 1 til 2 Timer under stadig Vexlen af den i Kålben værende Luft og hensattes derpaa i nogle Timer ganske rolig, idet Temperaturen saavel under Rystningen som senere holdtes fuldstændig constant. Forat overbevise mig om, at jeg har opnaaet fuldstændig Mætning, har jeg nærmest mig Mæt-

Norwegian Expedition in 1876 and 1877, amounts to 34,96, and for that lying between the 70th and 80th parallels of Latitude, to 35,64 per cent. Buchanan observed precisely the same phenomenon in the southern hemisphere, the proportion of oxygen varying from about 33 per cent in the Equatorial Seas to about 35 per cent in the vicinity of the Antarctic Circle.

Reasoning on these data, there were strong grounds to assume, that the coefficients of absorption given by Bunsen for distilled water could not apply to sea-water; for, the composition of the air in surface-water having been found to vary with the latitude, the most probable cause of this phenomenon would seem to be temperature. Meanwhile, we shall not arrive at a satisfactory result by regarding temperature as the variable factor, and by seeking from the observations here set forth to discover a law according to which the coefficients of absorption vary with the temperature. The individual observations would in that case be found to clash, inasmuch as the variation with regard to oxygen is invariably greater than can be assumed to arise from errors of observation. However, it did not seem advisable to leave the question as it stood, and proceed to the discussion of the results without having further investigated the relation of the coefficients of absorption to the temperature; and I resolved, therefore, on determining alike the composition and the amount of the air absorbed by sea-water at different temperatures.

A series of experiments were first instituted with a view to saturate sea-water with air, viz. by placing it in a bath of constant temperature, and for the space of several hours uninterruptedly conducting through it a current of air. The mode of operation adopted by Bunsen for his determinations,<sup>1</sup> after which the air absorbed by the water was driven off, and analysed by the process previously described. The samples of water saturated in this manner invariably yielded quantities of air which, irrespective of the temperature at which the water had been saturated, were found to be very nearly uniform in composition, viz. 34,9 per cent oxygen and 65,1 per cent nitrogen, whereas the figures, often widely divergent, expressing the absolute quantities of the gaseous bodies absorbed, gave sufficient proof that by this method complete saturation had not been attained.

At Professor Waage's suggestion, I repeated these experiments, varying slightly the means by which saturation was sought to be effected, and have since adopted the following mode of operation. A quantity of sea-water, of considerable specific gravity, is shaken, along with air, in a roomy matrass for one or two hours, the air in the matrass being frequently renewed, and then left perfectly still for a few hours, at the precise temperature preserved during its continual agitation. To be quite sure that I have really succeeded in saturating the water, I approach the point of saturation as it were from opposite directions.

<sup>1</sup> Bunsen, Gasom. Methoden, p. 165.

<sup>2</sup> Bunsen, Gasom. Methoden, p. 165.

manøspometet fra begge Sider, idet jeg paa den ene Side har behandlet Vand, som paa Forhaand var uilstrækkeligt mættet med Luft ved vedkommende Temperatur, og paa den anden Side først har mættet Vandet ved en betydelig lavere Temperatur før derefter, som ovenfor beskrevet, at ryste det med Luft ved den Temperatur, hvorved det omskedes mættet. Den Barometerstand, hvorved Vandproverne ere mættede, er altid ildeyen observeret, og ere de addroevne Gasmengder reducerede til Mætning ved 760<sup>mm</sup>, idet de absorberede Volumina ere satte proportionale med Trykket. Resultaterne ere sammenstillede i nedenstående Tabel, hvor Gasmengderne ere udtrykte som CC. pr. Litre udkøbt Vand reduceret til 0° og 760<sup>mm</sup> Tryk. De med fede Typer trykkede Tal hidrøre fra de Vandprover, der i Forvein have været mættede med Luft ved en lavere Temperatur. Ved de med Klammer sammenføjede Tal ere lægge Luftprover udkøbt af samme Vandprove.

10° C.		5° C.		10° C.		15° C.	
O	N	O	N	O	N	O	N
7.76	14.30	6.83	13.20	6.31	12.14	5.60	10.70
7.85	14.50	6.90	13.30	<b>6.30</b>	<b>12.06</b>	5.79	11.20
7.71	14.31	<b>6.97</b>	<b>13.16</b>	<b>6.25</b>	<b>12.04</b>	<b>5.70</b>	<b>11.04</b>
—	—	<b>7.01</b>	<b>13.20</b>	—	—	—	—

Som Middelværdier erholder man heraf:

C.	0°	5°	10°	15°
O	7.77	6.93	6.29	5.70
N	14.41	13.22	12.08	11.01
O + N = 100 O pct.	35.93	34.39	34.24	34.11

Til yderligere Control paa Rigtigheden af denne Tabel henstilles en Vandprove i uopropet Kælle ved 0° i 7 Dage, hvorpaa den deri opløste Luft udkøbt og analyseredes, og viste den addroevne Gas sig at være omtrentlig af samme Sammensætning som ovenfor angivet nemlig 35.18% O med 64.82% N. Af den samlede Luftmængde erholdtes her ingen Måling, da desværre en liden Blære under Overfyldningen i Eydometret gik tabt, den resterende Del maatte 21.71° C. Som man af denne Tabel vil kunne se, er den Kvælstofmængde, som i Litre Sevand absorberer af den atmosfæriske Luft, ligetil proportional med Temperaturen og lader sig udtrykt i CC. meget nice fremstille ved Formelen

$$N = 14.4 - 0.23 t,$$

hvoraf man istedetfor de

observerede Værdier	14.41	13.22	12.08	11.01
kan beregne	14.40	13.25	12.10	10.95

Hvad angaar den absorberede Surstofmængde, da er Forholdet ikke længere saa simpelt, idet den Curve, der betegner Variationen med Temperaturen, ikke længere er en ret men en svagt krummet Linie, som paa Stroget fra 0 til 10°, hvorefter der her nærmest er Tale, lader sig udtrykke ved Formelen

on the one hand, operating with water that has been imperfectly saturated at a given temperature, and on the other, saturating that water at a much lower temperature; and not till then proceeding to shake it along with air at the temperature for which saturation is sought to be attained. The atmospheric pressure at which the samples of water were saturated, was always noted down, and the quantity of gas driven off reduced to the point of saturation at 760<sup>mm</sup>, the volumes absorbed being put proportional with the pressure. The results are set forth in the following Table, the amounts of gas being expressed in cubic centimetres per litre of the water examined, reduced to a temperature of 0° and a pressure of 760<sup>mm</sup>. The figures printed in thick type refer to samples of water previously saturated with air at a lower temperature, those in brackets are determinations performed with the same sample of water.

10° C.		5° C.		10° C.		15° C.	
O	N	O	N	O	N	O	N
7.76	14.30	6.83	13.20	6.31	12.14	5.60	10.70
7.85	14.50	6.90	13.30	<b>6.30</b>	<b>12.06</b>	5.79	11.20
7.71	14.31	<b>6.97</b>	<b>13.16</b>	<b>6.25</b>	<b>12.04</b>	<b>5.70</b>	<b>11.04</b>
—	—	<b>7.01</b>	<b>13.20</b>	—	—	—	—

The mean proportions are accordingly:—

C.	0°	5°	10°	15°
O	7.77	6.93	6.29	5.70
N	14.41	13.22	12.08	11.01
O + N = 100 O pct.	35.93	34.39	34.24	34.11

With the object of testing still further the accuracy of this Table, a sample of water was allowed to stand over in an open matrass at a temperature of 0° for the space of 7 days, when the air absorbed by it was boiled out and analysed; but the composition of the gas driven off proved to be almost the same as that specified above, viz. 35.18 per cent oxygen and 64.82 per cent nitrogen. Of the total amount of air no measurement was obtained, a small bubble of gas having unfortunately escaped when transferring the air into the eudiometer; the remaining portion measured 21.71°. As appears from this Table, the quantity of nitrogen absorbed from the atmosphere by 1 litre of sea-water is strictly proportional to the temperature, and may be very accurately expressed in cubic centimetres by the formula—

$$N = 14.4 - 0.23 t,$$

which, in place of

the values observed,	14.41	13.22	12.08	11.01
gives	14.40	13.25	12.10	10.95

With regard to the amount of oxygen absorbed, the proportion is less easily expressed, since the curve indicating the variation with the temperature will no longer be a straight, but a slightly curved line, which, from 0° to 10°, the interval most important here, may be expressed by the formula—

$$O = 7.79 - 0.2t + 0.005t^2,$$

som istedetfor de observerede Værdier 7.77 6.93 6.29  
giver . . . . . 7.79 6.92 6.29

Men Hensyn paa den relative Sammensætning af den absorberede Luft da er den ikke, saaledes som at Bunsen for destilleret Vand fundet, uafhængig af Temperaturen men varierer med denne, saaledes at Surstofprocenten paa Strøget fra 0° til 15° forandrer sig med en hel Procent.

Betragter man Resultaterne af disse Forsøg som Norm, viser det sig, at den relativt til den samlede Luftmængde meget høje Surstofgehalt, som er observeret i Overfladen i den nordlige Halvkugle af det undersøgte Hav, i Virkeligheden skriver sig fra en Overmætning med Surstof og ikke, som man ogsaa kunde tænkt, fra en mangelfuld Mætning med Kvalstof, idet der mærkeligt nok her findes en Surstofgehalt, der meget hyppigt overskrider den af disse Forsøg beregnede med 0.5 C.C. og dogover. Det vil sige, der optræder saa store Afvigelser, at de paa ingen Maade kunne tilskrives Observationsfejl, og det viser sig saaledes, at Surstofgehalten i Overfladen ikke alene afhænger af Tryk og Temperatur, men rimeligvis ogsaa paa yndvirkning af en eller flere andre ukendte Aarsager.

Naar det gjælder nærmere at studere Surstofmængdens Variation med Dybden, falder det betydningsfuld at udtrykke den som Procenter af den samlede Luftmængde, da den absolute Luftmængde varierer i meget stærkere Grad med Temperaturen end Luftens relative Sammensætning, og man vil saaledes ved at benytte denne Udtryksmaade opnaa at gjøre sig i betydeligt større Udstrækning uafhængig af Temperaturens Indflydelse.

Ordner man de paa denne Maade adtrykte Tal efter Dybden, viser det sig, at der med Hensyn paa Surstofprocentens Størrelse i de forskjellige Dyle existerer en temmelig udpræget Løvmæssighed, som nærmere kan karakteriseres af nedenstaaende Tabel, der er udtaget af sautlige Observationer, naar indtages de to, hvor Udkogningen ikke foretoges strax men først efter nogen Tids Henstand.

Dybdeintervaller.		Antal Observa- tioner.	Middlere Dybde		Middlere Surstof- procent.
Engelske Fathoms.	Meter.		Engelske Fathoms.	Meter.	
0	0	28	0	0	35.31
0—100	0—183	6	60	120	33.93
100—300	183—549	14	210	384	32.84
300—600	549—1097	16	420	768	32.59
600—1000	1097—1820	11	684	1251	32.58
1000—1400	1820—2560	6	1102	2180	32.78
1400—1700	2560—3210	10	1640	3010	32.80

De enkelte Observationers Afvigelser fra den ved denne Tabel bestemte Regel ere i Betragtning af det undersøgte Felts store Udstrækning hverken mange eller syn-  
derlig store, idet kun 10, No. 2, 19, 38, 49, 64, 68, 83,

$$O = 7.79 - 0.2t + 0.005t^2,$$

giving . . . . . 7.79 6.92 6.29  
in place of the values observed, 7.77 6.93 6.29

Hence, the relative composition of the air absorbed is not, as Bunsen found to be the case with distilled water, independent of temperature, but varies with that factor, the percentage of oxygen, for instance, differing as much as 1 per cent between 0 and 15.

Now, assuming the results of these experiments to furnish a normal standard, the relatively large proportion of oxygen as compared with the total amount of air present in the surface-water of the northern tracts of the sea investigated, will be found to arise from supersaturation with oxygen, and not, as might be supposed, from imperfect saturation with nitrogen, seeing that the proportion of oxygen exceeded that computed from these experiments by as much as, or even more than, 0.5 : for a difference so considerable does not admit of being ascribed to errors of observation. On the basis of these facts, the proportion of oxygen in surface-water is shown to depend not only on pressure and temperature, but, probably, also on the effect of one or more causes as yet unknown.

When investigating the degree in which the proportion of oxygen varies with the depth, it will be most convenient to express the difference as a percentage of the total amount of air, the absolute amount of air varying to a much greater extent with the temperature than does its relative composition, besides, with this mode of expression considerably less regard need be had to the influence of temperature.

If the figures representing the results thus expressed are arranged according to depth, the proportion of oxygen present in the different strata will be found to exhibit very considerable uniformity, as appears from the following Table, based as it is on the whole series of determinations, with the exception of two, the water with which the latter were performed not having been boiled at once, but allowed to stand over for some time previous to examination.

Intervals of Depth.		Number of Obser- vations.	Mean Depth		Mean Per- centage of Oxygen
English Fathoms	Meters.		English Fathoms	Meters.	
0	0	28	0	0	35.31
0—100	0—183	6	60	120	33.93
100—300	183—549	14	210	384	32.84
300—600	549—1097	16	420	768	32.59
600—1000	1097—1820	11	684	1251	32.58
1000—1400	1820—2560	6	1102	2180	32.78
1400—1700	2560—3210	10	1640	3010	32.80

Considering the great extent of the region investi-  
gated, the deviation of the individual observations from the standard given in this Table is neither frequent nor con-  
siderable, 10 only, viz. Nos. 2, 19, 38, 49, 64, 68, 83, 84,

84, 85 og 87. Ijerne sig om mere end 1 Procent fra det almindelige Resultat, medens man at samtlige Observationer kan bestemme en enkelt Observations sandsynlige Afvigelse fra den eller deene Tabel optrukne Curve til  $\pm 0.52$  „ en Afvigelse saa liden, at en ikke ringe Del af den kan skrives paa Observationsfeil.

De største Overensstemmelser optraede tabrigst i et Dyb fra 300—600 Favne (549—1097 Meter) men findes ogsaa enkeltvis i større Dyb.

Fire Bunden indtræder i de større Dyb kun to Luftprøver med væsentlig for høj Surstofprocent nemlig No. 68 og 87, optraede fra to Puncter, som mærkeligt nok begge ligge paa en Linie parallel med og tæt ved Grænsen mellem den nordover strygende varme Strøm og den sydover fra den Mayen gaaende Polarstrøm. Bortser man midlertid fra disse de væsentligste Overensstemmelser, som indtræde til at give Curven et om end meget svagt Minimum i 300—400 Favnes (549—732 Meters) Dyb, vil man i Korthed kunne udtale Regelen for Surstofprocentens Afgangen med Dybet saaledes: Surstofprocenten er i Overfladen gennemsnitlig 35.3 og aftager derpaa først hurtigt senere langsommere til henmod 32.5 i 300 Favnes (549 Meters) Dyb, hvortil den med stigende Dyb holder sig paa det Nærmeste constant. Det kan bemærkes, at af de her undersøgte Vandprøver 40 ere øste lige ved Havbunden. Man vil midlertid foregives bestrebe sig for at oplyse nogen Forskjellighed i Egenskaber mellem disse og de fra ligestore intermediate Dyb optraaede.

Hvor det gælder at studere Variationerne af den absolute Luftmængde, man det synes naturligt som Mål for denne at benytte den opløste Kvælstof, idet den observerede Luftmængde paa Grund af det vedvarende Forbrug af Surstof i de dybere liggende Lag bestandig kan forudsættes at være mere eller mindre forskjellig fra den Mængde, som vilde absorberes i Overfladen under direct Paavirkning af Atmosfæren. Kvælstofmængden kan derimod paa Grund af dens stærkt udprægede Indifferentisme ligeoverfor andre Legemer uden synderlig Feil antages uafhængig af locale Tilfældigheder.

Anvendt saaledes Kvælstofmængden som Mål for den i Søvandet opløste Luft, viser der sig i Fordeelingen ogsaa her en ulpræget Lovmessighed, naar indtages, at der i de af Svendsen paa det første Tøgt indtagne Observationer overalt er fundet en mindre Kvælstofmængde, end man efter alle øvrige foreliggende Observationer skulde vente. Bortser man midlertid fra disse paa første Tøgt indførte 14 Observationer, vil man se, at alle de øvrige paa sin Indtagelser naar meget vel stemme overens med de Tal, man kan lægge efter den ved de ovennævnte Forsøg bestemte Formel

$$N = 14.4 - 0.23 t.$$

85, and 87 exhibiting a difference of more than 1 per cent as compared with the general result, whereas the probable deviation of a single observation from the curve drawn according to this Table may be computed at  $\pm 0.52$  per cent, a deviation so small as to arise, probably, in no slight degree from errors of observation.

The greatest discrepancies refer chiefly to a depth of 300—600 fathoms (549—1097 metres); now and again, however, they were met with in water obtained from greater depths.

In only two of the samples of air expelled from bottom-water drawn where the depth was great, did the percentage of oxygen prove much too high, viz. in Nos. 68 and 87, the samples of water yielding them having been obtained from two spots which, strange to say, are in a line running parallel and, in close proximity to the boundary between the warm current flowing north and the cold Arctic current flowing south past the Island of Jan Mayen. Now, if we exclude from these differences the effect of those that contribute towards giving the curve a very slight but appreciable minimum at a depth of from 300 to 400 fathoms (549—732 metres), the rule according to which the proportion of oxygen is found to diminish with the depth may be expressed as follows:—The proportion of oxygen, which at the surface is 35.3 per cent, begins at once and continues to diminish, at first rapidly and afterwards at a slower rate, till it has reached 32.5 per cent, at the depth of 300 fathoms (549 metres), from whence it keeps almost constant. I will not omit to observe, that of the samples of water examined 40 had been drawn from the bottom; it was, however, impossible to detect any difference in composition between these and the samples obtained from equal intermediate depths.

When investigating the variation in the absolute amount of air, it will obviously be advisable to make use of the nitrogen absorbed, since the quantity of air observed in the deeper strata may, by reason of the steady consumption of oxygen, be assumed to differ more or less from that which would be absorbed at the surface under the direct influence of the atmosphere, whereas nitrogen, from the very slight affinity evinced by that gas for other bodies, may, without involving appreciable error, be regarded as proof against the accidents of locality.

If, therefore, the amount of nitrogen be adopted as the standard of measurement for the air absorbed in sea-water, a marked uniformity will here, too, be found to characterise the distribution, as determined by the observations described, with the exception however of Svendsen's, on the first voyage, by which the amount of nitrogen was found to be less than all subsequently instituted observations gave reason to expect. Excluding, then, the 14 observations from the first voyage, all of the others, with but few exceptions, agree closely with the figures which may be found by the formula stated above—

$$N = 14.4 - 0.23 t.$$

Man får nemlig af Observationerne følgende Midelværdier:

Dybdeintervallet.		Middeltemp. °C.	Middelværdi af Kvælstofmængde observeret	Kvælstofmængde beregnet.	Differens.
Engelske Fathoms.	Meter.				
0	0	6.4	13.07	12.03	-0.14
0—100	0—183	2.7	13.68	13.78	-0.20
100—300	183—540	1.0	14.15	14.37	-0.02
300—600	540—1097	-0.6	14.54	14.54	0.00
600—1000	1097—1820	-0.8	14.01	14.58	-0.54
1000—1700	1820—3210	-1.4	14.38	14.72	-0.34

Naar den midlere Kvælstofmængde her i de dybere Lag er funden noget lavere end man skulde vente, da har dette sin Grund i, at der ved de 5 Observationer No. 17, 22, 33, 36 og 37, alle hidrørende fra Vandprøver fra det i 1877 undersøgte Streg, er fundet en ca. 1.5°C. lavere Gehalt, end de ved sin Temperatur vilde kunne optage ved almindeligt Atmosfærtryk. Forresten vil efter alle de øvrige Observationer af domme ogsaa i de større Dyb Kvælstofmængden findes at stemme overens med den af Formelen beregnede.

En lignende Sammenligning<sup>1</sup> er af Buchanan gjort mellem de af ham for de sydlige Have fundne Tal og de af Bunsen for destilleret Vand opstillede. Der optræder ved denne Sammenligning især ved de lavere Temperaturer ikke ubetydelige Differentser paa lige op til over 1 CC. pr. Litre, men disse vil ved Sammenligning med de efter Forfatterens Formel beregnede Tal saa godt som bortfalde, idet man får:

Dybde i Fod.	Middelværdi af Temperatur, °C.	Kvælstofmængde efter Buchanan.	Kvælstofmængde efter Formelen.	Differens.
600	14.0	11.26	11.04	-0.22
1200	13.0	11.71	11.41	-0.30
1800	9.9	13.00	12.81	-0.19
2400	5.1	13.10	13.23	0.13
4800	2.5	13.82	13.82	0.00
Greater Depths.	1.5	14.37	14.05	-0.32

Det fremgaar heraf, at Kvælstofmængden, saaledes som det allerede af Dr. Jacobsen og Andre er antaget, ikke i mindste Maade retter sig efter de i de store Dyb herskende Tryk men kun afhænger af Temperaturen. Den eneste rimelige Fortolkning udelukker Muligheden for, at Tryk- og Temperaturdifferentser i de under Overfladen

as will be seen from the following Table showing the mean values.

Intervals of Depth.		Mean Temp. °F.	Mean Amount of Nitrogen observed.	Amount of Nitrogen computed.	Difference.
English Fathoms.	Meters.				
0	0	6.4	13.07	12.03	-0.14
0—100	0—183	2.7	13.68	13.78	-0.20
100—300	183—540	1.0	14.15	14.37	-0.02
300—600	540—1097	-0.6	14.54	14.54	0.00
600—1000	1097—1820	-0.8	14.01	14.58	-0.54
1000—1700	1820—3210	-1.4	14.38	14.72	-0.34

The mean quantity of nitrogen in the deeper strata proved, accordingly, somewhat lower than there was reason to expect; but this arose from the proportion determined by 5 of the observations, viz. Nos. 17, 22, 33, 36, and 37—all of them referring to samples of water obtained from the tract of ocean investigated in 1877—having been about 1.5° less than could be absorbed at the same temperature under ordinary atmospheric pressure. For the rest, judging from all the other observations, the proportion of nitrogen observed, even at greater depths, will be found to agree with that computed by the formula.

A similar comparison<sup>1</sup> was instituted by Buchanan between his results for the water of the Southern Seas and the figures found by Bunsen for distilled water. The differences resulting from this comparison, more especially for a low temperature, are considerable, the greatest reaching 1° per litre; but, on comparing them with the figures given by the author's formula, they will be found almost to vanish, as appears from the following Table.

Depth in Feet.	Mean Temperature, °F.	Amount of Nitrogen accord. to Buchanan.	Amount of Nitrogen comp. by the Formula.	Difference.
600	14.0	11.26	11.04	-0.22
1200	13.0	11.71	11.41	-0.30
1800	9.9	13.00	12.81	-0.19
2400	5.1	13.10	13.23	0.13
4800	2.5	13.82	13.82	0.00
Greater Depths.	1.5	14.37	14.05	-0.32

Hence the amount of nitrogen, as previously assumed by Dr. Jacobsen and others, can in no wise be affected by the increase of pressure at great depths, but must obviously be dependent on temperature alone. The results of these observations exclude, therefore, the possibility of differences in temperature and pressure at depths below

<sup>1</sup> Ber. Berl. chem. Ges. — 11 — 110.

<sup>1</sup> Ber. Berl. chem. Ges. 11, p. 110.

liggende Lag skulde kunne hidføre en anden Fordeling af Luftten end den, der allerede eksisterer fra den Tid, da Vandet sidste Gang befandt sig i Overfladen udsat for fri Paa- virkning af Atmosfæren. Luftten vil saaledes kun gennem Vandets Circulation kunne naa ned i Dybet, og nogen Udjevning af Luftmængderne vil der kun kunne ske gennem Blanding af de forskelligartede Vandmængder, en Blanding, som under Forudsætning af at der ikke ogsaa foregaar Opvarmning eller Afkøling, ikke vil kunne for- rykke det rette Forhold mellem Temperatur og Kvælstof- mængde, da Kvælstofmængdens Variation med Temperatu- ren fremstilles ved en ret Linie.

Man vil altsaa, dersom disse Forudsætninger holdt Stik, ved en Kvælstofbestemmelse i de dybere liggende Vandlag kunne om end meget naat bestemme, om disse have været Gjenstand for en væsentlig Opvarmning eller Afkøling, siden de sidst befandt sig i Overfladen, forudsat at man kan negligere Virkningerne af Atmosfæretrykkets Forandringer og andre mulige Tilfældigheder, som under Absorptionen i Overfladen vil kunne gjøre sin Indflydelse gjældende.

Grupperer man de her offentliggjorte Observationer efter Vandprovernes Temperatur, viser det sig, at Kvælstofmængden meget naa svarer til den efter denne Tempera- tur af Formelen beregnede, det vil sige, Vandprovernes Temperatur skulde ikke i væsentlig Grad have forandret sig, siden de sidst befandt sig i Overfladen. Måh faar nemlig

Temperatur- interval.	Middlere Temperatur	Middlere Kvælstof- mængde	Beregnet Kvælstof- mængde.	Differens.
under 0°	-1.1	14.32,	14.65	0.33
0—3	1.2	14.19	14.12	-0.07
3—6	4.6	13.38	13.34	-0.04
6—9	7.5	12.00	12.07	-0.13
over 9	11.2	11.03	11.82	-0.11

At Overensstemmelsen for Temperaturerne under 0° ikke er saa fuldstændig som ellers, skyldes ogsaa her de ovenfor nævnte 5 Observationer alle udførte paa Tødtet i 1877. Beregner man derimod den middlere Temperatur og Kvælstofmængde for dette Interval af de paa sidste Aars Tøgt gjorte Observationer, erholder man til Middeltempe- raturen -1.2 Kvælstofmængden 14.59 CC, altsaa kun 0.09 CC, mindre end beregnet.

Benyttes paa samme Maade de af Dr. Jacobsen of- fentliggjorte Observationer til et Overslag over Kvælstof- mængden i Nordsøen, erholder man med runde Tal:

the surface causing a distribution of the air different to that which existed when the water was last at the surface, in direct contact with the atmosphere. Hence the air cannot penetrate to such depths save by the circulation of the water, and an adjustment of the amounts of air can be effected solely by the mixing of the water different in composition, which will not, however, unless we assume a simultaneous increase or decrease of heat, disturb the true relation between the temperature and the amount of nitrogen, since the variation of the latter with the tempera- ture is expressed by a right line.

If, then, these assumptions are found to hold good, it will be possible, when computing the proportion of nitro- gen in the lower strata of the water, to determine — very roughly indeed — whether the latter have experienced any increase or decrease of heat since they were last at the surface, provided we can ignore the effect of change in the atmospheric pressure and of other accidental circum- stances, which, during the process of absorption, may have made their influence felt.

On grouping together according to the temperature of the samples of water examined, the observations published in this Memoir, the proportion of nitrogen will be found to agree very closely with that computed by the formula, showing, as appears from the following Table, that the temperature could have varied but little since the water had been last at the surface.

Intervals of Temperature.	Mean Temperature.	Mean Amount of Nitrogen.	Computed Amount of Nitrogen.	Difference.
below 0°	-1.1	14.32	14.65	0.33
0—3	1.2	14.19	14.12	-0.07
3—6	4.6	13.38	13.34	-0.04
6—9	7.5	12.00	12.07	-0.13
above 9	11.2	11.03	11.82	-0.11

For the temperatures under 0° the agreement is in- deed not so close; but here, too, the cause may be traced to the aforesaid 5 observations from the voyage in 1877. If, however, we compute the mean temperature and the amount of nitrogen for that interval by the results of the observations instituted on the last voyage, the mean tem- perature will be -1.2 and the amount of nitrogen 14.59%, or only 0.09% less than that computed by the formula.

A similar computation with the observations published by Dr. Jacobsen for estimating the amount of nitrogen in the water of the North Sea, will give, in round numbers, the following results: —

Temperatur-interval.	Middlere Temperatur.	Middlere Kvælstof-mængde.	Beregnet Kvælstof-mængde.	Differens.
under 10°	0,5	13,2	12,0	0,3
10—15	12,1	12,0	11,6	0,4
15—20	16,0	11,0	10,5 <sup>1</sup>	0,5

Her findes altsaa overalt en Kvælstofgehalt svarende til en noget lavere Temperatur end den observerede og det i stærkest Grad for de høiere Temperature, eller da Temperaturen aftager med Dybden, for de øverst liggende Vandlag. Naar man erindrer, at Jacobsens Observationer ere udførte i Efterommeren og for det Meste paa Vandprover fra saa smaa Dyb, at Luft- og Vandtemperaturens aarlige Variation kan tænkes at have gjort sig gjældende, vil dette ikke være saa vanskeligt at forklare gennem Vandets Opvarmning i Sommermaanederne, medens Kvælstofmængden maa antages at rette sig efter en Temperatur mindst lige saa lav som den aarlige Middeltemperatur.

At lignende Phenomener ikke ogsaa ere observerede i de øvre Lag af det af den norske Nordhavsexpedition undersøgte Hav, har sin simple Forklæringsgrund deri, at Lufttemperaturen der selv om Sommeren ikke er høiere end Overfladetemperaturen hellere omvendt.

<sup>1</sup> Den for Intervallet fra 0 til 15° udløede Formel er her fundet at gjælde ogsaa fra 15 til 20°.

Intervals of Temperature	Mean Temperature	Mean Amount of Nitrogen	Computed Amount of Nitrogen	Difference
below 10°	0,5	13,2	12,0	0,3
10—15	12,1	12,0	11,6	0,4
15—20	16,0	11,0	10,5 <sup>1</sup>	0,5

The proportion of nitrogen in this Table corresponds accordingly to a somewhat lower temperature than that observed, especially for the higher temperatures, or rather, since the temperature diminishes with the depth, for the upper strata of the water. If, however, we bear in mind that Jacobsen's observations were instituted at the latter end of summer, and the majority with samples of water obtained from such trifling depths that the annual variation in the temperature of air and water probably exerted some influence, this will not be difficult to account for, by reason of the heat stored in the water during the summer months, whereas the amount of nitrogen must be regulated by a temperature at least as low as the mean annual temperature.

That similar phenomena were not observed in the upper strata of the water throughout the tract of ocean investigated on the Norwegian North-Atlantic Expedition, arises simply from the fact, that the temperature of the air in those regions does not even in summer exceed that of the water at the surface, may the reverse is rather the case.

<sup>1</sup> The formula deduced for the interval from 0° to 15° is here assumed to be correct for that extending from 15° to 20°.

## II. Om Kulsyren i Søvandet.

Alle de Chemikere, som for den tyske Pomerania-ekspedition i 1872 stillede Undersøgelser over Luften i Søvandet, idet der foruden Bestemmelser af Surstof-Kvælstofmængden ogsaa samtidig udførte Målinger af den under Udkogningen udløste Kulsyre, og de Quantiteter, man paa denne Maade fandt, bleve ogsaa bestandig opførte blandt Resultaterne som den samlede Mængde Kulsyre, der var opløst i Søvandet enten fri som Gasart eller bunden til Carbonater som sure Salte. De Resultater, som ad denne Vej erholdtes, vise imidlertid bestandig overmaade store Uoverensstemmelser ikke alene mellem de forskellige Forfattere men ogsaa mellem de enkelte Observationer hos en og samme Experimentator, hvor man dog maatte have antaget, at en større Ensartethed i Forsøgenes Udførelse skulde have udjævnet Differentserne.

Som Exempel paa, hvor vidt Uoverensstemmelserne i de ældre Opgaver strække sig, kan anføres Følgende:

I en Liter Overfladevand fandt

Frémy . . . . .	2.2 til 2.8 CC. Kulsyre <sup>1</sup> .
Morren . . . . .	1.6 " 3.9 — <sup>2</sup> .
Lewy . . . . .	2.4 " 3.9 — <sup>3</sup> .
Pisani . . . . .	6.0 " 8.1 — <sup>4</sup> .
Hunter . . . . .	0.8 " 5.9 — <sup>5</sup> .

Desuden fandtes efter en noget anden Fremgangsmaade af

Bischof . . . . .	39.0 CC. <sup>6</sup> .
Vogel . . . . .	55.6 til 116.3 — <sup>7</sup> .

Ved alle disse ældre Undersøgelser, hvor der ved Udkogningerne var anvendt fuldt Atmosfæretryk, og hvor

<sup>1</sup> Compt. rend. 6, p. 616.

<sup>2</sup> Ann. Chim. Phys. [3] 12, p. 5.

<sup>3</sup> Ann. [3] 17, Ann. Chem. Pharm. 58, p. 328.

<sup>4</sup> Compt. rend. 41, p. 552.

<sup>5</sup> Jahresbericht 1869, p. 1279.

<sup>6</sup> Chem. Geologie 1. Aufl. 2, p. 1130.

<sup>7</sup> Schweigg. Journ. 8, p. 351.

## II. On the Carbonic Acid in Sea-water.

The several chemists who, previous to the German Pomerania Expedition (1872), had instituted observations on the air present in sea-water, when measuring the amount of the oxygen and nitrogen also collected the carbonic acid driven off during the process of boiling; and the quantities determined were invariably set down among the results as the total amount of carbonic acid actually existing in the water, either free as gas or contained, to a less extent, also in bicarbonates. The results thus attained vary however to a remarkable extent, and not only as between the different experimentalists individually, — the like is also the case with the observations of one and the same person, although greater uniformity in the mode of operation should apparently have tended to eliminate error.

The following Table will show the wide difference prevailing between the formulae of early authors.

Amount of Carbonic Acid in 1 Litre of Surface-water.

Frémy . . . . .	2.2 to 2.8 CC. <sup>1</sup> .
Morren . . . . .	1.6 " 3.9 — <sup>2</sup> .
Lewy . . . . .	2.4 " 3.9 — <sup>3</sup> .
Pisani . . . . .	6.0 " 8.1 — <sup>4</sup> .
Hunter . . . . .	0.8 " 5.9 — <sup>5</sup> .

The proportion as found by a somewhat different process was as follows

Bischof . . . . .	39.0 CC. <sup>6</sup> .
Vogel . . . . .	55.6 to 116.3 — <sup>7</sup> .

Hence, it appears that the quantity of carbonic acid given off under these early experiments, for which the boil-

<sup>1</sup> Compt. rend. 6, p. 616.

<sup>2</sup> Ann. Chim. Phys. [3] 12, p. 5.

<sup>3</sup> — — — [3] 17, Ann. Chem. Pharm. 58, p. 328.

<sup>4</sup> Compt. rend. 41, p. 552.

<sup>5</sup> Liebig's Jahresbericht 1869, p. 1279.

<sup>6</sup> Chem. Geologie 1. Aufl. 2, p. 1130.

<sup>7</sup> Schweigg. Journ. 8, p. 351.



derfor Temperaturen steg over 100, indveg altsaa altid ved maalelige og ofte endog temmelig betydelige Mængder Kulsyre.

Ved de paa Bomeranexpeditionen i 1871 udførte Luftbestemmelser<sup>1</sup>, hvor den tidligere beskrevne Methode med Gasarternes Udkogning under et ved Vanddamp frembragt Vacuum anvendtes, sønkedes imidlertid Temperaturen ikke ubetydeligt, og det viste sig da, at man ved denne Temperatur temmelig ofte kun fik næsten maalelige smaa Quantiteter Kulsyre addrevet sammen med den øvrige Luft, medens de tidligere Uoverensstemmelser mellem flere med samme Vandprøve, gjentagne Udkogninger ogsaa her gik igjen.

Jacobsen fandt sig derfor ved dette mærkelige Phænomen foranlediget til nærmere at undersøge Kulsyrens Absorptionsforhold ligeoverfor Søvand.

Gjennem de Forsøg, som han i denne Anledning anstillede, viste det sig da, at man ad andre Veie kunde paavise aldeles uventet store Quantiteter Kulsyre i det samme Vand, hvorefter man ved en i flere Timer fortsat Udkogning efter Bunsens Methode kun kunde erholde meget smaa Mængder. Afbestilledes nemlig Søvandet i en kulsyrefri Luftstrøm uden Luftfortynding i en Retorte, indveg der den hele Tid Kulsyre, lige indtil den hele Mængde Vædske var afdestilleret, saaledes at man først ved rigelig Udskilbelse af Salte kunde være fuldstændig sikker paa at have erholdt det samlede Udbytte af Kulsyre addrevet.

Der lod sig under Udkogningen ikke paavise noget Punkt, hvor man kunde tale om en Grænse mellem fri og surt bunden Kulsyre.

Paa denne Maade addrev nu Jacobsen ved fuldstændig Afdestillation af  $\frac{1}{4}$  Litre Søvand i en kulsyrefri Luftstrøm den hele Mængde Kulsyre og opsamlede den efter Pettenkoffers Princip i en afmaalt Mængde titreret Barytvand, som efter endt Operation retitreredes med Oxalsyre, og beregnedes efter disse den samlede Kulsyremængde, som for fortyndet Nord Søvand opgives til omkring 100 Mgr. per Litre.

Samtidig bestemtes ogsaa i Residuet fra Inddampning af circa 10 Litre af det samme Vand den i de neutrale Carbonater indeholdte Kulsyre til i Middel kun omkring 10 Mgr. per Litre.

Ifølge disse Observationer kunde altsaa kun en meget liden Brokdel af den ved Destillationen addrevne Kulsyre betragtes som surt bunden, og Jacobsen imødegaar derfor i sin Afhandling bestemt den af Vierthaler<sup>2</sup> gjorte Antagelse, at al den ved Kogning af Søvandet addrevne Kulsyre skulde være surt bunden. Han anser sig endvidere aldeles sikker for under Inddampningen ikke at have erholdt decomponeret nogen Del af de i Søvandet indeholdte neutrale Carbonater, idet han udtrykkelig siger: "Die ganze Menge der nicht

ing-process was conducted with full atmospheric pressure, or at a temperature of more than 100° C., invariably proved appreciable, may sometimes rather large.

When performing the air-determinations<sup>1</sup> on the 'Pomerania' Expedition in 1871 (by the method, previously described, of boiling out the gaseous elements in a vacuum created by steam), the temperature kept considerably lower, and the quantity of carbonic acid expelled with the other atmospheric elements at a comparatively low temperature was often immeasurably small; moreover, the variable character of the results, alluded to above, on repeating the boiling-process with the same sample of water again asserted itself.

Struck by this remarkable phenomenon, Jacobsen determined to investigate anew the absorptive capacity of sea-water in relation to carbonic acid.

The experiments of that chemist undertaken with the above object in view afforded conclusive proof of the fact, that large quantities of carbonic acid were still present in water from which a very small amount only could be expelled after several hours' protracted boiling by Bunsen's method. On distilling in a retort sea-water exposed to a current of air free from carbonic acid, but not purified, carbonic acid is found to escape so long as any portion of the fluid remains undistilled, an abundance of solid deposit however being the only indication that all or nearly all the carbonic acid present in the water has been driven off.

During the process of boiling no particular moment could be determined marking the escape of the carbonic acid present as gas and of that which has combined with carbonates to form bicarbonates.

In this manner, by distillation in a current of air free from carbonic acid, Jacobsen succeeded in expelling the whole amount of carbonic acid contained in  $\frac{1}{4}$  litre of sea-water, and collected it, by Pettenkoff's method, in a given quantity of titrated baryta water of known strength, which, on the operation being terminated, he retitrated with oxalic acid, computing accordingly the total amount of carbonic acid driven off in the process. Frohstedt's North Sea water contains according to Jacobsen's results about 100<sup>mgr</sup> per litre.

The amount of carbonic acid contained by the neutral carbonates in the residuary deposit from the evaporation of 10 litres of the same water, was also calculated, and found to average only about 10<sup>mgr</sup> per litre.

According to these observations, a very small proportion only of the carbonic acid driven off by distillation could have been present in bicarbonates, and hence Jacobsen emphatically opposes Vierthaler's assumption,<sup>2</sup> that the carbonic acid boiled out of sea-water occurs in that form. Moreover, he feels quite sure that no portion of the neutral carbonates in the water examined was decomposed during the process of boiling. "Die ganze Menge," he says, "der nicht mit Basen zu neutralen Salzen verban-

<sup>1</sup> Ann. Chem. Pharm. 167, p. 1.

<sup>2</sup> Wien. Acad. Ber. [2] = 56 = 479.

Den norske Nordhavsexpedition. Torneø: Chem.

<sup>1</sup> Ann. Chem. Pharm. 167, p. 1.

<sup>2</sup> Wien. Acad. Ber. [2] = 56, p. 479.

mit Basen zu neutralen Salzen verbundenen Kohlensäure erhält man aus dem Meerwasser, wenn dieses unter Durchleiten eines Stromes kohlensäurefreier Luft bis zur reichlichen Abscheidung von Chlornatrium verkocht wird."

Det maatte saaledes fremstille sig som et hoist mærkeligt Phænomen, at den Kulsyre, som dog maatte tænkes opløst i Søvandet paa en eller anden Maade som fri Gasart, ikke skulde lade sig uddrive ved Udkogning efter Bunsens Methode, og at den endogsaa ved Udkogning under fuldt Atmosferetryk og i en kulsyrefri Luftstrøm skulde udvige saa langsomt, at man først ved Concentration til omkring  $\frac{1}{10}$  af det oprindelige Volumen erholdt den sidste Rest udrevet.

Flønt kunne forklare disse Mærkeligheder tillegges Jacobsen Søvandet en enebønnelig Egne til med megen Kraft at kunne tilbageholde sin Kulsyre, en Menning, som han efter nærmere at have fremført sine Grunde mod den af Vierthaler gjorte Antagelse udtrykker med følgende Ord: "Wie man aber auch eine Deutung der starken Absorptionswirkung des Meerwassers, auf die atmosphärische Kohlensäure versuchen möge, jedenfalls kann man die Kohlensäure nicht in demselben Sinne, wie Sauerstoff und Stickstoff, als absorbirtes freies Gas darin annehmen. Man mag einstweilen von einem eigenthümlichen Zustande der Bindung sprechen, bei welchem die Kohlensäure selbst durch stundenlanges Kochen nur sehr unvollständig angedrungen wird. Das Vorhandensein ungeheurer Mengen Kohlensäure im Meerwasser, in einem solchen Zustande, wo sie der Athmungsluft der Seethiere nicht ohne Weiteres zugezählt werden kann, ohne andererseits der Vegetation des Meeres unzugänglich zu sein, ist jedenfalls für das maritime Thier- und Pflanzenleben von höchster Bedeutung."

Jacobsen antager nærmest at maatte henlægge denne enebønnelige Absorptionsegne hos Søvandet til den deri opløste Chlormagnesium og henviser i saa Henseende til Egenskaber hos en Chlormagnesiumopløsning, der indeholder en i Kulsyre opløst Menge kulsur Kalk. En saadan Opløsning kan ifølge ham henstaa i nogen ja endog koges uden at blakkes, først ved meget langt fortsat Concentration nedskaller der sig ren kulsur Magnesia.

Denne Jacobsens Anskuelsesmaade blev senere saa godt som uforandret optagen af den engelske Challenger-expedition's Chemiker, J. Y. Buchanan, som udførte en Række Forsøg<sup>1</sup> for nærmere at bestemme, hvilket eller hvilke af Saltene i Søvandet der skulde være i Besiddelse af denne Egne saaledes at kunne tilbageholde Kulsyren. Han kom i den Henseende til det påfaldende Resultat, at de fleste Salte, som han undersøgte, i mere eller mindre Grad skulde være i Besiddelse af denne Egenskaber dog mest Sulfaterne, saaledes at denne Søvadets stærke Absorptionsegne ligesom Kulsyren af ham henlægges fra Chlormagnesium til Sulfaterne. Ved de af ham udførte

denne Kohlsäure erhält man aus dem Meerwasser, wenn dieses unter Durchleiten eines Stromes kohlensäurefreier Luft bis zur reichlichen Abscheidung von Chlornatrium verkocht wird."

Hence it could not but strike the experimentalist as a remarkable phenomenon, that the carbonic acid, which in some way or other must have been held absorbed by the sea-water in a free gaseous form, should not admit of being boiled out by Bunsen's method, and that even when the boiling-process was conducted with full atmospheric pressure in a current of air free from carbonic acid, it should escape so slowly, that concentration to the extent of about one-tenth of the original volume proved necessary to obtain it all.

To account for this perplexing phenomenon, Jacobsen ascribed to sea-water a peculiar property of retaining its carbonic acid, an assumption which, after setting forth more at large the grounds that led him to oppose Vierthaler's hypothesis, he enunciates in the following terms: — "Wie man aber auch eine Deutung der starken Absorptionswirkung des Meerwassers auf die atmosphärische Kohlensäure versuchen möge, jedenfalls kann man die Kohlensäure nicht in demselben Sinne, wie Sauerstoff und Stickstoff, als absorbirtes freies Gas darin annehmen. Man mag einstweilen von einem eigenthümlichen Zustande der Bindung sprechen, bei welchem die Kohlensäure selbst durch stundenlanges Kochen nur sehr unvollständig angedrungen wird. Das Vorhandensein ungeheurer Mengen Kohlensäure im Meerwasser, in einem solchen Zustande, wo sie der Athmungsluft der Seethiere nicht ohne Weiteres zugezählt werden kann, ohne andererseits der Vegetation des Meeres unzugänglich zu sein, ist jedenfalls für das maritime Thier- und Pflanzenleben von höchster Bedeutung."

Jacobsen is of opinion, that this peculiar absorptive power must be derived from the chloride of magnesia present in sea-water, and draws attention to certain properties possessed by a solution of chloride of magnesia containing carbonate of lime dissolved in carbonic acid. A solution of this kind may, according to his statement, be left exposed for weeks together, may be boiled even, without becoming turbid; nor can it be made to part with pure carbonate of magnesia till after protracted concentration.

Jacobsen's hypothesis was subsequently adopted, almost without modification, by J. Y. Buchanan, chemist to the 'Challenger' Expedition, who instituted a series of experiments<sup>1</sup> with a view to determine which of the salts present in sea-water had this property of retaining carbonic acid. He arrived at the surprising conclusion, that most of the salts examined were in some degree distinguished by this property, chiefly however the sulphates; and the remarkable power possessed by sea-water of retaining carbonic acid he transferred accordingly from chloride of magnesia to the sulphates. Hence, when performing carbonic acid determinations he always precipitated the sulphuric

<sup>1</sup> Proc. Royal Soc. 22, pp. 192 og 483.

<sup>1</sup> Proc. Royal Soc. 22, pp. 192 and 483.

Kulsyrebestemmelser pleiede han derfor altid for Operationens Begyndelse at udfælde Svovlsyren med concentreret Chlorbariumopløsning, forat Kulsyren lettere skulde uddrage, men anvendte forresten den af Dr. Jacobsen angivne Methode, hvorved han har bestemt Kulsyren i Sovandet i de sydlige Have til i Middel 43,26 Mgr. per Litre<sup>1</sup>.

Da jeg Vaaren 1877 opfordredes til at gaa ud som Chemiker paa den norske Nordhavsexpeditions 2det Togt, var der kun levnet mig nogle faa Dage til Forberedelser, og det følger derfor af sig selv, at jeg ikke paa nogen Maade dengang kunde have befattet mig med vidtloftigere Forundersøgelser, og jeg maatte saaledes uden selv at kunne prøve optage de tidligere Metoder uforandrede. Paa Tøgtet i 1877 anvendtes derfor den af Dr. Jacobsen angivne Methode, og bestemtes efter denne gennem en Række omhyggelig udførte Observationer Kulsyregehaltten i det da undersøgte Hav til omkring 100 Mgr. per Litre. Der viste sig imidlertid ved Gjentagelse af samme Observation bestandig Uoverensstemmelser, som ofte vare ikke ubetydelige og engang endog løb op til hele 12 Mgr. per Litre.

Dels læaved dels ved andre Omstændigheder vakte min Mistanke om Tilforladeligheden af den af Dr. Jacobsen i Forslag bragte Methode.

Det syntes mig paa Forhaand overmaade rimeligt, at der hos Sovandet skulde findes en saadan mærkelig Ene til rent mekanisk at tillagelholde den ene Gasart, medens den ingenomløst Virkning skulde ndøve paa de Andre. Heller ikke var der nogensinde gjort noget Forsøg paa at sætte dette Phenomen i Forbindelse med bekjendte chemiske Egenskaber hos nogen af de i Sovandet indholdte Stoffe.

Ved et Tilfælde kom jeg en Dag til at forsøge Sovandets Reaktion paa Lakmus og Rosolsyre og fandt til min store Forundring, at det reagerede bestemt og tydeligt alkalisk, hvad jeg siden har bragt i Erfaring, at allerede v. Bibra<sup>2</sup> og senere E. Guignet og A. Telles<sup>3</sup> har observeret.

Efter mine Forsøg viser to ligestore Prover af en efter Gottlieb's<sup>4</sup> Fremgangsmaade frisk tilberedt Lakmusopløsning, hvoraf den ene tilsættes en tilstrækkelig Mængde Sovand og den Anden et ligestort Volumen rent destilleret Vand, ikke ubetydelige Farvedifferentser. Ligeledes antager en med meget fortyndet Oxidsyre svagt ndsyret passende Portion rent Vand, hvori paa Forhaand er opløst en Draabe Rosolsyre, ved Tilsætning af Sovand strax den bekjendte rødlig-violette Farve.

Paa denne Maade undersøgte paa Expeditionens sidste Togt, hvor der var fuld Anledning til at erholde Vandproverne ganske friske, et meget stort Antal af disse og inden Indtagelse med det samme ovenbeskrevne Resultat.

acid, before commencing the operation, by adding to the water a saturated solution of chloride of barium, in order to facilitate the liberation of the carbonic acid, but, with this exception, adopted the method devised by Dr. Jacobsen, and determined the mean amount of carbonic acid present in the water of the Southern Seas to be 43,26<sup>mgr</sup> per litre.<sup>1</sup>

When invited, in the spring of 1877, to go out as chemist to the Norwegian North-Atlantic Expedition, on the second cruise, I had but a few days in which to make the necessary preparations, and consequently no time being left me for preliminary experiments, I was compelled to adopt unchanged the earlier methods, without testing the accuracy of their results. On the cruise in 1877, I therefore applied Dr. Jacobsen's method, and determined by a series of careful observations the amount of carbonic acid present in the water of the tract then investigated to be about 100<sup>mgr</sup> per litre. But, on repeating the operation with the same sample of water, the results were always found to vary, and frequently indeed considerably; may, on one occasion the difference amounted to as much as 12<sup>mgr</sup> per litre.

Partly for this reason, and partly from other circumstances, I was led to question the trustworthiness of Jacobsen's method.

Now it struck me at once as highly improbable that sea-water should possess so remarkable a power of retaining mechanically one gas, and yet, in this respect, exert no influence whatever on others. Nor had any attempt been made to connect this phenomenon with known chemical properties distinguishing the substances contained in sea-water.

Quite accidentally, I was one day led to investigate the effect of sea-water as a reagent on litmus and rosolic acid, and found its reaction, to my great surprise, distinctly alkaline, which, indeed, as I subsequently learnt, had been already observed, first by von Bibra<sup>2</sup> and later by E. Guignet and A. Telles.<sup>3</sup>

According to my experiments, two equal measures of a solution of litmus, freshly prepared by Gottlieb's method,<sup>4</sup> one of which has added to it a sufficient quantity of sea-water and the other an equal volume of pure distilled water, exhibit considerable difference in colour. Moreover, a proportionate mixture of highly dilute oxalic acid and pure water, the latter having been previously treated with a drop of rosolic acid, will, on the addition of sea-water, immediately assume the well known reddish-violet hue.

In this manner were examined on the last cruise of the Expedition, which afforded excellent opportunities of obtaining the water quite fresh, a very large number of samples, and invariably with the results described above.

<sup>1</sup> Ber. Berl. chem. Ges. 11 — 410.

<sup>2</sup> Ann. Chem. Pharm. 77 — 90.

<sup>3</sup> Compt. rend. 83 — 919.

<sup>4</sup> Journ. für pract. Chem. 107 — 488.

<sup>1</sup> Ber. Berl. chem. Ges. 11, p. 410.

<sup>2</sup> Ann. Chem. Pharm. 77, p. 90.

<sup>3</sup> Compt. rend. 83, p. 919.

<sup>4</sup> Journ. für pract. Chem. 107, p. 488.

Dette synes ogsaa meget vanskeligt at forklare, saafremt det virkelig skulde forholde sig som af Enkelte paa-staaet, at der i Sovandet skulde findes et meget stort Overskud af fri Kulsyre ved Siden af en meget liden Qvantitet af sure Carbonater. Det maatte naerhart synes meget rimeligere at forklare de af Dr. Jacobsen gjorte Observationer derved, at Sovandet under den langvarige Kogning ved en eller anden chemisk Reaction gav Slip paa noget af sin neutralt bundne Kulsyre.

Før at komme paa det Rene med, om dette virkelig forholdt sig saa, gik jeg frem paa følgende Maade:

200 CC. Sovand (af sp. Vægt 1.0267 ved 17.5 C. i Forhold til destilleret Vand af samme Temperatur) afdestilleredes næsten til Torhed i en kulsyrefri Luftstrøm, og opfangedes den anværende Kulsyre i 25 CC. af en Baryt-opløsning, hvoraf 1 CC. svarede til 4.0204 Mgr. Kulsyre. Ved Retitration med Oxalsyre viste det sig, at 19.97 CC. af det anvendte Barytvand var neutraliseret, hvoraf den indvægne Kulsyre beregnedes til 20.2 Mgr. Residuet paa-holdtes nu friskt udkogt Vand, som atter afdestilleredes, hvorved endnu et ubetydeligt Spor af Kulsyre erholdtes. Sluttelig tilsattes circa 0.5 Gr. fuldkommen ren friskt ud-gjdet Soda, hvorpaa det Hele atter fortyndedes med kul-syrefrit Vand til Sovandets oprindelige Volumen og saa af-destilleredes i en kulsyrefri Luftstrøm.

Allerede fra det Oieblik af, da Vædsken var kommen i Kog, begyndte strax en saa voldsom Kulsyreudvikling, at det i Forlaget anbragte Barytvand slap store Mængder uabsorbereede igjennem, og det viste sig efter endt Opera-tion, at kun 1.3 CC. Barytvand var forblevet neutraliseret. Heraf beregnes den absorberede Del af den indvægne Kulsyre til 95.3 Mgr., medens desforuden meget betydelige Mængder gik igjennem, idet nemlig Barytvandet i et for-nuget Rør, som var anbragt foran Forlaget, fuldstændigt var forbrøgt.

Efter Forslag af Professor Waage gjentoges Forsøget med varmt feldt, ved 100° torret kulsur Kalk, hvorat det ogsaa lykkedes at uddrive ikke ubetydelige om end meget mindre Mængder Kulsyre, hvormod der ved et Forsøg med fint pulveriseret Marmor ikke erholdtes noget sikkert Resultat.

Betydningen af disse Observationer kunde ikke være tvivlsom, da det hermed paa det Tydeligste var godtgjort, at den i Sovandet forhaandenvarende Saltblanding ved Kog-hede decomponerede neutrals Carbonater, og dermed ogsaa, at alle de hidindtil gjorte Kulsyrebestemmelser med Hen-syn paa sin Hensigt at bestemme den i Sovandet inde-holte frie og surt bundne Kulsyre vare forfeilede. Hvad angaar de for Publicationen af Dr. Jacobsens Aflandling om Luften i Sovandet indførte Kulsyrebestemmelser, da er det en Selvfølge, at de alle uden Undtagelse maatte være i enhver Henseende fuldstændig værdiløse, idet der ved dem intetsteds er kommen til Anvendelse en Afdestillation til Torhed eller en saa vidt-dreven Concentration, at man

This fact would obviously be most difficult of expla-nation if, as some have affirmed, sea-water does actually contain a very large surplus of free carbonic acid along with an exceedingly small proportion of bicarbonates. A more plausible hypothesis by which to explain Dr. Jacobsen's observations were surely the assumption, that during the protracted process of boiling some of the neutral carbon-ates present in sea-water had been decomposed.

With the object of ascertaining whether such was really the case, I went to work as follows.

Two hundred centim. of sea-water (sp. grav. 1.0267, temp. 17.5 C., as compared with distilled water of the same temperature) were distilled almost to dryness in a current of air free from carbonic acid, and the carbonic acid collected in 25<sup>cc</sup> of baryta water, 1<sup>cc</sup> of which re-presented 4.0204<sup>mgr</sup> carbonic acid. On being retitrated with oxalic acid 19.97<sup>cc</sup> of the baryta water were found not to be saturated, and 20.2<sup>mgr</sup> carbonic acid had accord-ingly been driven off. Water freshly boiled was now poured on the residue, and then evaporated, the result yielding a slight trace of carbonic acid; finally, about 0.5<sup>mgr</sup> purified and freshly heated soda was added, and the whole com-pound again diluted with water, from which all carbonic acid had been expelled, to the original volume of the sample, and then distilled in a current of air free from carbonic acid.

From the very moment at which the fluid began to boil, so rapid was the liberation of carbonic acid that large quantities passed unabsorbed through the baryta water; and, on the operation being terminated, 1.3<sup>cc</sup> only of the baryta water had not been neutralised. Hence the absorbed portion of the carbonic acid was calculated at 95.3<sup>mgr</sup>, exclusive of which a very considerable quantity, as before stated, passed off into the atmosphere, the baryta water, placed in a glass tube (resembling in form the letter *U*) connected with the receiver, being surcharged with the gas.

At Professor Waage's suggestion I repeated the ex-periment with carbonate of lime, precipitated warm and dried at a temperature of 100° C., and succeeded in expel-ling carbonic acid in considerable, though not so large, quantities as before, whereas an experiment with finely pulverised marble gave no positive result.

The importance of these observations was not to be questioned, affording as they did conclusive proof that the saline mixture in sea-water, on the temperature being raised to the boiling point, decomposed neutral carbonates, and likewise that all carbonic acid determinations hitherto at-tempted with the object of measuring the carbonic acid present in sea-water were faulty. As regards the car-bonic acid determinations performed previous to the publi-cation of Dr. Jacobsen's Memoir on the presence of air in sea-water, such must as a matter of course be wholly worthless, the method of distillation to dryness having in no case been adopted, or that of concentrating the fluid till further evaporation ceased to expel carbonic acid. The

ikke ved fortsat Iuddampning skulde kunne have erholdt et større Udbytte af Kulsyre. De af Dr. Jacobsen og J. Y. Buchanan udførte Observationer kunde derimod ikke saa ligefrem forkastes, idet der jo kunde tænkes Mulighed for, at det ved de af dem benyttede Metoder kunde have lykkedes ved den langvarige Kogning at uddrive ogsaa al neutralbunden Kulsyre, i hvilket Fald de af dem opførte Tal i en anden Henseende kunde faa Betydning nemlig som Udtryk for den samlede Sum af den i Sovanlet indeholdte Kulsyre.

Desværre lagde flere Omstændigheder Hindringer i Veien for Afslutningen af mine Forsøg over disse Gjenstande i Vinteren 1877—78, dels var min Tid optaget med andre Arbejder, dels lod min Hølbred den største Del af Vinteren adskilligt tilbage af ønske, saaat mine Forsøg ingenlunde havde den ønskelige Freugang, og jeg blev derfor nødt til at gaa ud ogsaa paa Togtet i 1878 uden nogen paahdelig Methode til Bestemmelse af den i Sovandet indeholdte Kulsyre. Da jeg efter endt Toget om Hosten vendte tilbage, gjenoptog jeg imidlertid atter mine Undersøgelser og bragte dem til Afslutning.

Gjennem en netop da af C. Borchers offentliggjort Afhandling<sup>1</sup> om Bestemmelsen af Kulsyren i naturlige Mineralvande blev jeg gjort opmærksom paa det for Bestemmelse af Kulsyren i Carbonater af Alexander Classen angivne Apparat,<sup>2</sup> som jeg senere i stor Udstrækning har benyttet.

Apparatet i den Form, hvori det her er kommen til Anvendelse, findes sammentillet i Figur 3.

*A* er 2 med Natronkalk fyldte ubøjelige Rør, *B* indeholder Barytvand. *C* er en Erlenmeyers Kolbe paa circa 0.5 Litre, der gjennem et ved Bunden indmündende Rør communicerer med *B*, medens et lige under Kautschukproppen indmündende sætter den i Forbindelse med Kjøleleren *D*, hvis indre Del efter Classen bestaar af et 27—30<sup>mm</sup> vidt Glasrør, hvortil i ovre og nedre Ende er loddet Rør med respective 15 og 7<sup>mm</sup> Diameter. Forlaget *E* er fuldstændig af samme Construction som det af Jacobsen benyttede og er oventil forsynet med det af P. Wagner<sup>3</sup> foreslaaede med Glaskugler fyldte Rør *F*.

Ved *a*, hvor der findes en Indsnævring, er anbragt en noget større Glaskugle, som temmelig nøje dækker over det nederste snevre Rør. Idet det til Opsamling af Kulsyren anvendte titrerede Barytvand holdes ned gjennem *F*, fjernes Proppen *b*, indtil det Meste af Barytvandet har passeret *a*, men sættes derpaa hurtigt i, saaledes at der over de nederste Glaskugler bliver staaende noget Barytvand til en Høide af omtrent 50<sup>mm</sup> over *a*. Dersom nu

series of observations instituted by Dr. Jacobsen and J. Y. Buchanan cannot however be wholly rejected, since the protracted boiling characteristic of the method they adopted may possibly have driven off all the carbonic acid contained in the carbonates, in which case their figures would acquire importance as expressive of the total amount of carbonic acid present in the sea-water examined.

Unfortunately, divers untoward circumstances conspired to prevent my terminating in the winter of 1877—78 the series of experiments I had begun with the object of elucidating this intricate subject, my time, for instance, came to be unexpectedly occupied in other ways, and during the greater part of that period I suffered from ill-health. My observations, therefore, not having progressed so favourably as I at first had reason to anticipate, I was again obliged to set out on the Expedition, in 1878, without having fixed on any reliable method for determining the carbonic acid present in sea-water. On my return however to Christiania in the autumn of that year, I recommenced the said experiments, and succeeded in bringing them to a satisfactory termination.

A paper by C. Borchers, which had just appeared,<sup>1</sup> on the determination of carbonic acid in mineral water, drew my attention to the apparatus — of which I have since made frequent use — devised by Alex. Classen<sup>2</sup> for determining carbonic acid in carbonates.

Figure 3 represents this apparatus as constructed for my experiments.

*A* 2 glass tubes, resembling in form the letter *U*, filled with soda-lime; *B* a vessel for baryta water. *C* an Erlenmeyer flat-bottomed matrass, containing about 0.5 litre, which by means of a tube terminating at the bottom is made to communicate with *B*, a similar tube, issuing immediately beneath the caoutchouc stopper, putting it likewise in communication with the cooler *D*, the inner portion of which, according to Classen, should consist of a glass tube from 27<sup>mm</sup> to 30<sup>mm</sup> in diameter, with tubes, measuring respectively 15<sup>mm</sup> and 7<sup>mm</sup> in diameter, sealed to its upper and lower extremities. The receiver *E* has precisely the same form as that adopted by Jacobsen, and is furnished above with a glass tube, *F*, filled with glass balls, as suggested by P. Wagner.<sup>3</sup>

At the point *a*, where the tube suddenly narrows, is introduced a somewhat larger glass ball, to fill up, as near as may be, the opening of the lower or slender portion of the tube. When the titrated baryta water, which absorbs the carbonic acid, is being poured down through *F*, the stopper *b* has to be taken out, but must be quickly replaced, before the whole of the fluid has passed *a*, in order that the glass balls to a height of about 50<sup>mm</sup> above *a*

<sup>1</sup> Journ. für prakt. Chem. 125, p. 353.

<sup>2</sup> Fresenius Zeitschrift 15, p. 288.

<sup>3</sup> Fresenius Zeitschrift 9, p. 113.

<sup>1</sup> Journ. für prakt. Chem. 125, p. 353.

<sup>2</sup> Fresenius Zeitschrift 15, p. 288.

<sup>3</sup> Fresenius Zeitschrift 9, p. 113.

den nederste Glaskugle slutter godt, vil den gennem *a* passerende Luft spåltes i en Mængde meget fine Båler, som ved at stige op mellem de af Barytvand omgivne Glaskugler bliver fuldstændig kulsyrefri. Det niformige Rør *G* indeholder Barytvand. *H* fører til Aspiratoren.

may be immersed in baryta water. Now, assuming the large glass ball to fit well, the air will pass *a* in the form of minute bubbles, which, having to ascend between the glass balls surrounded by baryta water, must part with the whole of its carbonic acid. The tube *G* contains baryta water; *H* leads to the aspirator.

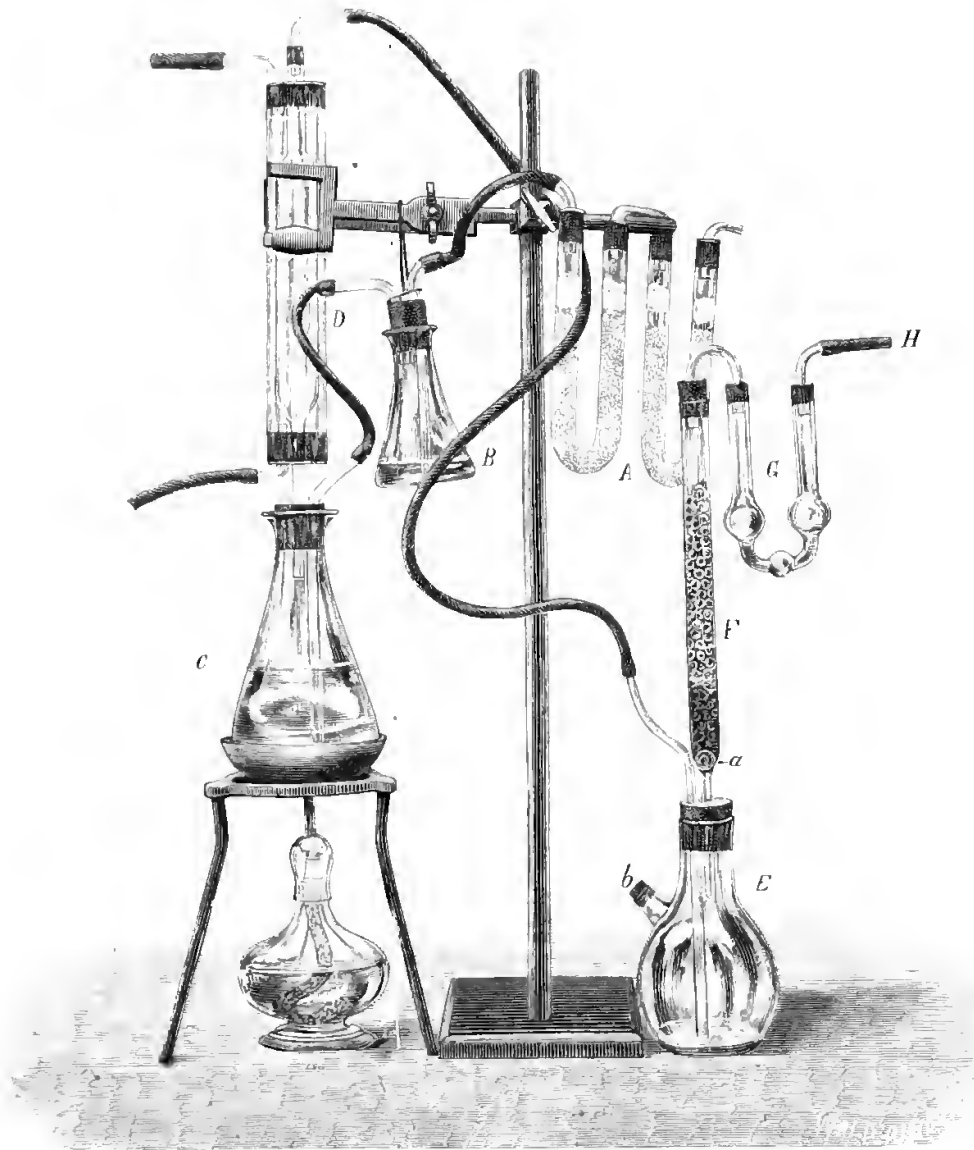


Fig. 3.

Den af Classen foreskædede Kjøler virker saa ndmærket, at man i meget lang Tid kan koge fortyndet Saltsyre i Kolben, uden at det mindste Spor af Chlor kan paavises i Forlaget, forudsat at den gennemledede Luftstrom ikke gives for stor Hastighed, hvad der imidlertid heller ikke er fornødent.

The cooler devised by Classen is so excellent, that diluted hydrochloric acid may be boiled in the matrass for a very considerable length of time without a trace of acid being detected in the receiver, provided that too great rapidity be not given to the current of air; this, however, is quite unnecessary.

Naar Sovandet i dette Apparat kogtes med fortyndet Svovlsyre i en kulsyre-fri Luftstrøm, indveg Kulsyren meget hurtigt, idet 15 Minutters Kogning fuldstændig strak til for at bringe al Kulsyre over i Forlaget. Sovandets Sul-fater viste altsaa i alle Fald ikke ved Tilstedeværelsen af fri Syre de af J. Y. Buchanan observerede Egenskaber. Naar den paa denne Maade uddrevne Kulsyremængde op-samledes og bestemtes, viste den sig altid at stemme nogen-lunde med, hvad man efter den af Dr. Jacobsen anvendte Methode kunde erholde uddrevet, idet de optrædende Af-vigelser snart vare positive snart negative men i Regelen ikke større, end at de for den største Del maatte kunne tilskrives Observationsfeil. Ved den af Buchanan i For-slag bragte Udfældning af Svovlsyren erholdt jeg derimod bestandig betydelig for lave Resultater, hvorom senere.

For samtidig i en og samme Portion at kunne be-stemme baade den neutralbundne og den samlede Mængde Kulsyre, anvendte jeg følgende Fremgangsmaade.

Efterat Apparatet fuldstændig var befriet for kulsyre-holdig Luft, anbragtes i Forlaget paa den for beskrevne Maade 25 CC. Barytvand, hvoraf hver CC. svarede til 4.129 Mgr. Kulsyre, hvorefter der i Kolben *C* holdtes 367.7 CC. af det til Undersøgelse bestemte Sovand tillige-med 10 CC. af en Svovlsyre, hvoraf hver CC. svarede til 4.099 Mgr. Kulsyre. Indholdet i Kolben opdredes nu under Gjennemledning af en meget langsom Luftstrøm til Kogehede og holdtes i Kog i nogen Tid. Efter Forløb af henved 15 Minutter fjernedes atter Varmekilden og Væd-sken afkjøledes, idet Luftstrømmen lidt efter lidt gaves en noget større Hastighed, hvorved den endnu ikke absorberede Kulsyre meget hurtigt bragtes over i Forlaget.

Efter endt Operation bragtes de i *F* værende Glas-kgler tilligemed det ved Rørets Vægge heftende Baryt-vand ned i Forlaget *E*, hvorpaa det Hele retitreredes med en Oxalsyre, hvoraf hver CC. svarede til 3.976 Mgr. Kul-syre, idet alkoholisk Eucemma tjente som Index. Ligeledes skylledes den ved de indre Vægge af Kjøleren heftende Vædske ved lidt kulsyrefrit destilleret Vand ned i Kolben, hvori den overskydende Syre neutraliseredes med en Natron-lud, hvoraf hver CC. svarede til 2.928 Mgr.  $CO_2$ , idet Rosolsyre tjente som Index.

Som Resultat af disse Titreringer erholdtes den sam-lede Kulsyremængde bestemt til omkring 97 Mgr. og den neutralbundne til gjennemsnitlig henved 53 Mgr. pr. Litre. De 44 Mgr. Kulsyre, som udgjør Differensen mellem den samlede Kulsyremængde og den neutralbundne, kan naaben-hart ikke forekomme i Sovandet som fri Gasart, men maa forene sig med de allerede færdigdannede Carbonater under Dannelsen af Bicarbonater, og det viser sig altsaa, at de af Dr. Jacobsen gjorte Observationer meget naturligt lade sig forklare derved, at Sovandet ikke indeholder det mind-ste Spør af fri Kulsyre men hele 53 Mgr. neutralbundne og kun omkring 44 Mgr. surthunden Kulsyre pr. Litre.

On boiling sea-water along with diluted sulphuric acid, exposed to a current of air free from carbonic acid, in this apparatus, carbonic acid escaped very rapidly, the space of 15 minutes sufficing to collect the whole of it in the receiver. The sulphates in sea-water — at least when free acids were present — did not, accordingly, exhibit the properties ascribed to them by J. Y. Buchanan. On col-lecting and determining the carbonic acid driven off by this process, the amount was invariably found to agree with that which could be liberated by Dr. Jacobsen's method, the differences observed having been sometimes positive and sometimes negative, but as a rule not greater than would admit of imputing them chiefly to errors of observation. On precipitating the sulphuric acid as suggested by Buchanan, the results obtained were invariably too low; but to this subject I shall afterwards return.

In order to determine both the proportion of carbonic acid forming the neutral carbonates and the whole amount of carbonic acid contained in one and the same sample of sea-water, I adopted the following mode of procedure.

After expelling from the apparatus all air in which carbonic acid was present, 25 of baryta water were introduced, as previously described, into the receiver, each c.centim. representing 4.129<sup>mgr</sup> carbonic acid; 367.7 of the sea-water to be examined were then poured into the mat-rass (*C*), along with 10 of sulphuric acid, each c.centim. of which represented 4.099<sup>mgr</sup> carbonic acid. The contents of the matrass were now heated, during exposure to a very slow current of air, up to the boiling-point, and kept for some time at that temperature. After the lapse of about 15 minutes, the source of heat was removed and the fluid cooled, the rapidity of the current of air being slightly increased, causing the carbonic acid not yet absorbed to pass off quickly into the receiver.

The operation being terminated, the glass balls in the tube *F*, along with the baryta water adhering to the walls of the tube, were introduced into the receiver *E*, and the whole of its contents re-titrated with oxalic acid, each c.centim. of which represented 3.976<sup>mgr</sup> carbonic acid, a solution of alcoholic eucemma serving as the index. The fluid adhering to the walls of the cooler was likewise washed down into the matrass with a little distilled water free from carbonic acid, and the surplus acid neutralised by the addition of soda-lye, each c.centim. of which represented 2.928<sup>mgr</sup>  $CO_2$ , rosolic acid serving as the index.

As the result of this titration, the total amount of carbonic acid was found to be about 97<sup>mgr</sup> and the pro-portion forming neutral carbonates to average about 53<sup>mgr</sup> per litre. Now, the difference, 44<sup>mgr</sup>, cannot occur free as gas, but will unite with the carbonates to form bicar-bonates; and hence Dr. Jacobsen's observations could be readily explained on the assumption that sea-water contains no trace even of free carbonic acid, but as much as 53<sup>mgr</sup> per litre of carbonic acid forming carbonates and only about 44<sup>mgr</sup> per litre of carbonic acid forming bicar-bonates.

Som man ser, er den her til Bestemmelse af den neutralbundne Kulsyre anvendte Methode i alt væsentligt den samme, som allerede for flere Aar tilbage er beskrevet af Dr. Mohr.<sup>1</sup> Forskjellen stikker kun deri, at jeg har anvendt Classens Kjøler og desuden omløst Salpetersyren med Svovlsyre. Det syntes mig nemlig ikke tilraadeligt at anvende Salpetersyre ligeoverfor et saa stærkt chlorobligt Mineralvand som Søvand, hvori der desuden fandtes en vel merkbar om end temmelig liden Qvæntitet oxyderbare Stofte.

Efter denne Fremgangsmaade har jeg senere ved 78 Observationer bestemt Kulsyren i 64 forskellige Vandprover temmelig jævnt forløbte over det af den norske Nordhavsexpedition undersøgte Felt. Resultaterne findes sammenstillede i Tabel II.

Forst skal i Korthed berøres de Feil, hvormed de i Tabellen opførte Tal kan tænkes behøvede.

Om man vilde antage, at den i Søvandet indholdte Kulsyre ikke forekom opløst som fri Syre, men forefandt som bundet til Baser i Form af Silicater, en Antagelse af meget tvivlsom Berettigelse, vilde man naabenbart efter den ovenfor beskrevne Methode faa noget fejlagtige Resultater, idet den til Kulsyre bundne Mængde Baser vilde findes som bunden til Kulsyren. Forat kunne danne mig en Forestilling om, hvorvidt den Feil, som man under denne Formodning skulde kunne begaa, nogensinde vil kunne tænkes at faa særlig Betydning, har jeg bestemt Kulsyremængden i forskellige af de hjembragte Vandprover, idet følgende Fremgangsmaade er kommen til Anvendelse. 0.5 Litre Søvand inddampedes med lidt Saltsyre i en Platinskaal først over fri Ibl senere paa Vandbad til Torhed og tørredes ved 110—120° C. Saltene udtoges derpaa og pulveriseredes bedst muligt i en vel poleret Agatriseskaal, hvorpaa de atter tørredes ved samme Temperatur, og sluttelig bragtes over i et passende Kar og tilsattes ca. 200 CC. saltsyreløst Vand, hvorved al Gips fuldstændigt opløstes. De paa denne Maade ndskilte Kulsyremængder vare altid meget smaa og maatte nærmest blive at betegne som Spør, idet de, hvor jeg forsøgte at vee dem, kun beløb sig til Brøkdele af Mgr. i den anvendte Portion Vand. Dette stemmer paa det Nøieste med, hvad Thorpe og Morton nylig har fundet i det irske Hav,<sup>2</sup> hvormed de ældre Opgaver giver noget større Tal. Og man vil saaledes se, at der ingensomløst Rimelighed er for, at den i Søvandet indholdte Kulsyremængde skulde bidrage til i mærkelig Grad at gjøre de fundne Resultater upaalidelige.

Naar man skal danne sig en Mening om Nøjagtigheden af disse Observationer, er det imidlertid nødvendigt at tage Hensyn til en anden Omstændighed, som kunde tænkes at have havt sin Indflydelse paa Resultaterne.

As will be seen, the method adopted for the determination of the carbonic acid forming carbonates, was essentially the same as that described by Dr. Mohr<sup>1</sup> several years previously. The only difference lay in my having employed Classen's cooler and made choice of sulphuric acid in preference to nitric. It did not seem advisable to use nitric acid when examining a mineral water so rich in chlorine as is sea-water, and which besides contains a quantity, small indeed but appreciable, of organic matter.

By this process I subsequently determined the carbonic acid in 64 different samples of sea-water, drawn at comparatively regular intervals from the tract of ocean investigated on the Norwegian North-Atlantic Expedition; the number of observations amounted to 78. The results are given in Table II.

I will first say a few words respecting the errors that may possibly affect the accuracy of the figures set down in the Table.

Assuming the silicic acid in sea-water not to occur as a free acid, but combined with bases in the form of silicates, an hypothesis of very doubtful value, the results obtained by the method described above would be obviously to some extent inaccurate, inasmuch as the bases combined with silicic acid must in that case have behaved as if originally combined with carbonic acid. In order to ascertain what importance could possibly be attached to an error arising on such an assumption, I determined the amount of silicic acid in divers of the samples of sea-water brought home with me, adopting for that purpose the following method. Five-tenths of a litre of sea-water mixed with a little hydrochloric acid were evaporated to dryness in a platinum dish, at first over a common fire and then in a water-bath, and dried at a temperature of 110°—120° C. The salts were then taken out and transferred to a well polished agate dish, in which they were finely pulverised, and again dried at the same temperature; finally they were placed in a suitable vessel, and mixed with about 200<sup>cc</sup> of water containing hydrochloric acid, which thoroughly dissolved all the gypsum. The amounts of silicic acid thus precipitated were invariably very small, indeed but little more than traces: for, on attempting to weigh them, they proved to be but fractions of a milligramme. This result agrees exactly with the observations of Thorpe and Morton on water from the Irish Sea,<sup>2</sup> whereas the figures in earlier statements are somewhat higher. Hence, there is no reason whatever to assume, that the silicic acid present in sea-water should to any considerable extent influence the results obtained.

When judging of the accuracy of these observations, regard must, however, be had to another circumstance that might possibly in some measure affect the results. The water examined did not consist of freshly drawn samples,

<sup>1</sup> Mohr's Titrimethode 3te Aufl. — 524.

<sup>2</sup> Ann. Chem. Pharm. 158 — 122.

<sup>1</sup> Mohr's Titrimethode 3te Aufl. p. 524.

<sup>2</sup> Ann. Chem. Pharm. 158, p. 122.



Tabel II.

No.	Stat. No.	Nordlig Breddel. (North Latitude)	Længde fra Greenwich. (Longitude from Greenwich)	Dybde hvorfra Pro- ben hentet. (Depth from which the Sam- ples were collected)		Tempe- ratur. Celsus.	Neutral-	Surtbun-	Ammekunde (Alm. S.)
				Engelske Favn. (English Fathoms)	Metre. (Metres)		Isuden Kalsye. Mg. per Litre.	den Kalsye. Mg. per Litre.	
1	—	Løderen.			0	0	?	52.3	41.1
2	51	05 53'	7 18'	W.	1163	2127	-1.1	52.0	40.7
3	52	05 47.5	3 7		1861	3493	-1.2	52.7	40.0
4	52	05 47.5	3 7		1861	3493	-1.2	52.0	40.1
5	53	05 13.5	0 33	E.	1530	2814	-1.3	53.1	43.8
6	53	05 13.5	0 33		0	0	0.5	54.3	40.4
7	143	06 58	10 33		180	340	0.2	53.8	43.3
8	143	06 58	10 33		0	0	8.2	53.4	41.5
9	183	06 50.5	6 15		1000	2020	-1.2	52.0	41.8
10	183	06 50.5	6 15		0	0	8.0	53.5	44.8
11	184	7 0 4	0 50		1517	2820	-1.3	53.0	45.5
12	184	7 0 4	0 50		600	1097	0.0	52.4	44.7
13	184	7 0 4	0 50		0	0	7.6	53.8	40.0
14	187	06 51.5	14 41		1335	2441	-1.1	53.8	43.1
15	180	06 41	15 42		800	1573	-1.1	53.0	45.5
16	180	06 41	15 42		800	1573	-1.1	52.7	43.0
17	180	06 41	15 42		0	0	0.0	54.2	41.8
18	215	7 0 53	2 0	W.	0	0	8.0	54.2	41.4
19	215	7 0 53	2 0		200	360	2.8	52.6	—
20	215	7 0 53	2 0		200	360	2.8	52.0	46.8
21	217	7 1 0	5 8		0	0	4.0	52.7	41.3
22	220	7 0 50	7 51		340	622	-0.6	54.3	46.4
23	220	7 0 50	7 51		340	622	-0.6	54.0	46.0
24	220	7 0 50	7 51		340	622	-0.6	54.7	—
25	220	7 0 50	7 51		0	0	3.0	52.2	40.7
26	220	7 0 50	7 51		0	0	3.0	52.2	41.6
27	237	7 0 41	10 10		0	0	3.0	53.4	42.4
28	237	7 0 41	10 10		0	0	3.0	54.5	39.7
29	240	06 2	11 26		0	0	4.2	55.0	44.4
30	240	06 2	11 26		0	0	4.2	55.4	—
31	—	08 33	7 25		0	0	0.6	53.0	45.0
32	—	08 33	7 25		0	0	0.6	53.0	43.0
33	243	08 32.5	6 26		1385	2533	-1.3	53.7	42.4
34	245	08 21	2 5		0	0	0.0	53.8	45.2
35	245	08 21	2 5		0	0	0.0	53.8	41.2
36	247	08 5.5	2 24	E.	500	914	-0.4	53.0	47.3
37	247	08 5.5	2 24		0	0	0.4	54.0	47.2
38	264	7 0 50	35 37		0	0	5.2	51.8	42.3
39	264	7 0 50	35 37		80	157	1.0	52.0	43.2
40	275	7 4 8	31 12		0	0	2.0	53.0	45.3
41	284	7 3 1	12 58		0	0	6.8	52.0	43.2
42	205	7 1 50	11 40		0	0	7.0	52.8	42.4
43	205	7 1 55	11 30		100	183	3.2	51.0	42.8
44	205	7 1 55	11 30		600	1007	-0.8	52.0	43.7
45	205	7 1 50	11 40		1110	2030	1.3	53.8	43.1
46	207	7 2 36.5	5 12		0	0	4.0	52.6	43.7
47	207	7 2 36.5	5 12		1280	2341	-1.4	52.1	43.4
48	208	7 2 52	1 50.5		1500	2743	-1.5	52.2	42.0
49	300	7 3 10	3 22	W.	0	0	0.7	48.6	43.4
50	300	7 3 10	3 22		0	0	1.7	48.4	42.0
51	303	7 5 12	3 2	E.	0	0	3.3	52.2	47.0
52	303	7 5 12	3 2		0	0	3.3	54.8	48.0
53	303	7 5 12	3 2		150	274	-1.1	51.8	43.0
54	304	7 5 3	4 51		300	549	-0.8	52.2	42.5
55	304	7 5 3	4 51		300	549	0.8	52.3	45.1
56	304	7 5 3	4 51		1735	3173	-1.5	52.4	43.0
57	300	7 5 0	10 27		1334	2440	-1.3	52.0	40.5
58	323	7 2 53.5	21 51		223	408	1.5	53.1	42.1

100 Dige and Kanten at Greenland Sound.  
12500 to 10000 fath. - 10000 to the bottom of the

No.	Stat. No.	Nørdlig Bredde. (North Latitude.)	Længde fra Greenwich. (Longitude from Greenwich.)	Dybde hvædet Proven hentet. (Depth from which the Samples were collected.)		Temperatur. Celsus.	Neutral-	Surtlue-	Anmærkninger. (Remarks.)
				Fagelske Favn. (English Fathoms.)	Metre. (Metres.)		Kulsyre. (Carb. Acid total present, forming Bicarbonates.)	Kulsyre Mgr. per Litre.	
50	335	70° 10' 5	14° 30'	E.	0	0	5.4	53.4	42.7
60	347	70 10.5	7 47		1120	2013	-1.5	52.2	41.0
64	347	70 10.5	7 47		0	0	4.4	52.6	41.0
62	340	70 30	2 57		1487	2710	-1.5	51.0	43.5
63	350	70 20	0 20	W.	0	0	3.0	54.0	47.2
64	350	70 20	0 20		300	549	-1.1	53.2	45.8
65	350	70 20	0 20		300	549	-1.1	53.3	46.0
66	350	70 20	0 20		1080	3083	-1.5	51.0	43.0
67	350	70 20	0 20		0	0	3.3	51.0	42.8
68	352	77 50	3 20	E.	0	0	3.0	52.3	41.5
69	352	77 50	3 20		300	549	-0.8	52.6	46.0
70	355	78 0	8 32		0	0	4.0	52.4	43.2
71	355	78 0	8 32		048	1734	-1.3	51.8	44.0
72	301	70 8.5	5 28		0	0	4.2	52.4	42.7
73	301	70 8.5	5 28		005	1055	-1.2	51.0	46.1
74	302	70 50	5 40		0	0	5.2	52.0	43.2
75	302	70 50	5 40		450	830	-1.0	51.8	44.0
76	303	80 0	8 15		200	475	1.1	52.0	44.0
77	308	78 43	8 20		315	507	1.0	52.0	42.4
78	373	78 10	14 20		120	210	0.8	51.4	44.4

Forsøgene ere nemlig ikke liden indførte paa Vandproverne strax efter deres Optagelse men først, efterat de have henstaaet i kortere eller længere Tid. Angaaende Tidsrummet, hvori de enkelte Vandprøver have henstaaet før Bestemmelsen, kan anføres Følgende: No. 1, en Vandprøve, som Hr. Dampskibsfører E. Røstrup viste mig den Velvillie at skaffe mig, har kun henstaaet nogle Dage, de øvrige Prøver have henstaaet, No. 2-6 i ca. 2 $\frac{1}{4}$  Aar, 7-37 i ca. 1 $\frac{1}{4}$  Aar og 38-78 i 2 til 4 Maanedre paa et kjøbt Sted opbevarede paa Flasker, der vare forsynede med vel isolerede Glaspropper. Der taalder sig altsaa en Mulighed for, at der ved Oxydation af de i Sø vandet værende, aldrig manglende, organiske Bestanddele kunde have dannet sig en mindre Quantitet Kulsyre paa Bekostning af den opløste Surstoffmængde, en Proccs, der naturligvis kun har Indflydelse paa den surt bundne Kulsyre, snarere ikke Oxydationen skulde skride saa vidt frem, at ogsaa Surstoffet i Svovlsyren skulde medgaa til Dannelsen af Kulsyre, i hvilket Fald den dannede Kulsyre maatte træde ind som neutralbundet istedetfor den destruerede Mængde Svovlsyre. En saa vidt fremskreden Oxydation kan midlertid ikke tænkes mulig, medmindre man til Prop i Flaskerne anvender Kork, da den i Sø vandet opløste Surstoffgas og mere end tilstrækkelig til at oxydere alle de opmindelig tilstedeværende organiske Bestanddele. Det kan ogsaa bemærkes, at det ikke i nogen af de undersøgte Vandprøver har været muligt at paaise det mindste Spor af Svovlvandstid. Før saa nogenlunde at fixere de Mængder Kulsyre, som paa denne Maade skulde kunne dannes, har jeg anmodet min Ven Schmelek, som har været beskæftiget med Undersøgelse af de faste Bestanddele i Vandet i det af Expeditionen befærede Hav, og som saaledes ogsaa har

having all of it been allowed to stand over for a longer or shorter period. With respect to the interval that had elapsed before commencing the determinations, the following particulars can be given: — No. 1, a sample of sea-water which Captain E. Røstrup had the kindness to procure me, did not stand over for more than a few days; of the remaining samples, Nos. 2-6 were preserved for about two years and a quarter, Nos. 7-37 for about one year and a quarter, and Nos. 38-78 from two to four months, all of them in a cool spot, and in bottles furnished with ground glass stoppers. Hence it is just possible that oxidation of the organic matter never absent in sea-water may have produced a small quantity of carbonic acid, by reducing the amount of oxygen, a process which of course could only affect the carbonic acid forming bicarbonates, unless indeed oxidation were so far advanced, that the oxygen in the sulphuric acid should also contribute to the formation of carbonic acid, in which case such carbonic acid would reimplace the sulphuric acid decomposed. But this advanced stage of oxidation is clearly impossible unless the bottles are corked, since the oxygen in sea-water is more than sufficient to oxidize all organic matter originally present. I can also observe, that in none of the samples of water examined was it possible to detect the slightest trace of sulphuretted hydrogen. With the object of determining approximately what proportion of carbonic acid could result from this process, I requested my friend Mr. Schmelek — whose labours have been chiefly confined to the examination of the solid matter present in the water of the seas explored on the Expedition, and who accordingly instituted a series of experiments to ascertain the amount of organic substances it contained — to furnish

ndført en Række Forsøg til Bestemmelse af de organiske Stoffes Mængde, om at meddele mig de forordnede Data. Ifølge ham ere de organiske Stoffes Mængde kun underkastet meget smaa Variationer, og affarver 1 Litre Sovand gennemsnitlig 3 Mgr. Kamaleon, som under Fændsætning af Reduction til Oxydulsalt kun kan afgive henimod 0,8 Mgr. Surstof, hvoraf det lettelig vil kunne indsees, at den dannede Mængde Kulsyre ikke kan være meget stor, naar Surstofforbruget selv ved en saa energisk Oxydation som ved Anvendelse af Kamaleon er saa lidet. Og hvad der især tyder paa, at den Oxydation, som kan foregaa ved Vandprovens Henstand under ordinære Forhold, fuldstændig maa kunne negligeres, er den Omstændighed, at Schmeleck har fundet Sovandets Evne til at affarve Kamaleon ligesom, hvadenten Vandproven undersøges frisk eller først efter aarelang Henstand.

At noget af Kulsyren ved den lange Henstand skulde være fordampet, er der heller ingen Rimelighed for, naar man erindrer, at Sovandet er en alkalisk Vædske, som ikke indeholder det mindste Spor af fri Kulsyre, og som med saadan Kraft holder paa sin surt løsnede Kulsyre, at den i timevis kan koges i det af Jacobsen angivne Luftudkøgningsapparat med det Resultat, at kun en meget liden Brokdel uddrives. Der er altsaa en stor Fare for det Mødsatte, nemlig at der skulde kunne absorberes noget af Atmosfærens Kulsyre, men for Undgaaelsen af denne Feilkilde er der sørget ved omhyggelig Opbevaring paa velproppede Flasker.

Resultaterne synes heller ikke at tyde paa, at Henstanden skulde have været til Skade for Vandprovernes Bælgelighed, idet de alle uden Hensyn til den meget forskellige Varighed af det Tidsrum, hvori de have henstaaet, vise nogenlunde det samme Resultat, og jeg tror saaledes ikke at tage meget Feil, naar jeg anser de af mig ndførte Observationer som i alt Væsentligt ligesaa gode, som om de havde været ndførte omhaad paa friskt optagne Vandprøver.

Hvad angaar de af selve Methoden og Experimentationen flydende Observationsteil, da vil de hyppigt ndførte Controlbestemmelser kunne give de forordnede Bidrag til Bestemmelsen af deres Størrelse, saaledes er ved 13 Controlbestemmelser for den neutralt løsnede Kulsyres Vedkommende den gennemsnitlige halve Different mellem 2 paa samme Vandprøve ndførte Observationer løstent til 0,11 Mgr. per Litre (Maximum 0,6) og for den surt løsnede Kulsyres Vedkommende til 0,59 Mgr. per Litre (Maximum 1,35). Foruden den variable Feil vil der midlertid i sidste Tilfælde ogsaa være en constant, idet det ikke lader sig indgaa, at man ved Arbejde i en kulsyreholdig Atmosfære vil erholde noget om end meget lidet for høje Resultater. Naar Feilene ved Bestemmelsen af den surt løsnede Kulsyre er tunden at være størst, da er Grunden dertil for en stor Del at søge deri, at man ved Retitration med Natriumlid, især naar Rosolsyre anvendes som Index, erholder en meget skarp Enderaction, medens dette paa lang Vei ikke i samme Grad er Tilfælde, hvor Baryt re-

me with the necessary data. According to his observations, the amount of organic matter varies but very slightly. 1 litre of sea-water discolouring on an average 3<sup>mg</sup> permanganate of potash; and this quantity, assuming extreme reduction, cannot give off more than about 0,8<sup>mg</sup> of oxygen. Hence it is obvious that the amount of carbonic acid cannot be very large, considering the limited consumption of oxygen even with the use of permanganate of potash. But that the oxidation which can ordinarily result from allowing the water to stand over may be altogether ignored, is more particularly indicated by the fact of Schmeleck having found the property in sea-water of discolouring permanganate of potash to be invariably the same, whether the samples are freshly drawn or have been preserved for years together.

Nor is there reason to assume, that any portion of the carbonic acid should have escaped by evaporation during the long interval, if we bear in mind that sea-water is an alkaline fluid, which does not contain the smallest trace of free carbonic acid, and which retains that present in bicarbonates with such vigour, that it may be boiled for hours together in the apparatus devised by Jacobsen for boiling out air and not part with more than a mere fraction. Nay, there is obviously danger of the reverse, viz. that some of the carbonic acid present in the atmosphere will be absorbed; but that source of error was effectually avoided by keeping the water in bottles provided with tight-fitting glass stoppers.

Judging, too, from the results, which were very nearly the same for all the samples, irrespective of the difference in the length of the period during which they had been preserved, the interval that had elapsed previous to examination did not appear to have had any injurious effect on the water for experimental purposes, and hence I feel tolerably convinced that my observations in all essential particulars are as reliable as if they had been conducted on board with freshly drawn water.

With respect to the errors of observation involved in the method itself, numerous test-determinations will serve as an approximate standard by which to compute their magnitude; thus, for instance, half the difference between two observations with the same sample of water was found, for the carbonic acid forming carbonates, to be 0,11<sup>mg</sup> per litre (maximum 0,6), and for the carbonic acid forming bicarbonates to be 0,59<sup>mg</sup> per litre (maximum 1,35). Exclusive of the variable error there will also, in the latter case, be a constant one, inasmuch as the results of experiments performed in an atmosphere containing carbonic acid must necessarily be somewhat, if but a very little, too high. When the error in the determination of the carbonic acid forming bicarbonates is found to be greatest, the reason will be chiefly this, that retitration with soda-lye, more especially if rosolic acid has been selected as the index, gives rise to a very decided terminal reaction, which does not result on the baryta water being titrated with oxalic acid; the reaction is then much less obvious. It must be likewise

titreres med Oxalsyre. Tillige bør det erindres, at de som Udtryk for den surt bundne Kulsyre opførte Tal indeholde Feilene saavel i Bestemmelsen af den neutralt bundne som den samlede Kulsyremængde.

Som man let vil overbevise sig om, vise de i Tabellen opførte Tal især for den neutralt bundne Kulsyres Vedkommende en mærkelig Overensstemmelse, naar nemlig 2 Observationer, begge udførte paa en Vandprøve hentet hæ ved Grønlandsisen, udtages, ligger i alle de øvrige 63 Vandprøver den neutralt bundne Kulsyre mellem Grænserne 51,4 og 55,4 Mgr. per Litre, saaledes at den største Differenti kan beløbe sig til 4 Mgr., hvad der man siges at være meget lidt i Betragtning af, at disse Tal ere fremkomne ved Undersøgelse af et Hav paa betydeligt over 200 geografiske Mile i Udstrækning saavel i syd og nord som øst og vest. Hvad derimod den surt bundne Kulsyre angaar, da ere de optrædende Differentier betydelig større og beløbe sig i Ydertilfældene til omkring 8 Mgr. pr. Litre.

Jeg har længe læstret mig for at opdage nogen Lovmæssighed i disse Variationer, uden at det dog saaledes som for Luftens Vedkommende har lykket at erholde klare og paaalidelige Resultater i sin Henseende og det ligegyldigt, hvad enten man vælger Dybdeforholdene eller den geografiske Beliggenhed til Udgangspunkt for sin Betragtning.

Da saaledes ingen Del af det undersøgte Felt udmærker sig fremfor den anden ved nogen tydelig Forskjellighed i Kulsyregehalt, og da de optrædende Differentier overalt ere smaa, ville de erholdte Resultater naturligst være at benytte til Udlædning af Gjennemsnitsværdier, der kunne opføres som Udtryk for Kulsyregehalt i det undersøgte Hav i sin Helhed betragtet. De Gjennemsnitsværdier, som saaledes blive at opstille som Hovedresultater, ere for den neutralt bundne Kulsyres Vedkommende

$$52,78 \pm 0,083 \text{ Mgr. pr. Litre}$$

med en sandsynlig Afvigelse herfra af en enkelt Observation af  $\pm 0,662$  Mgr. pr. Litre og for den surt bundne Kulsyres Vedkommende

$$43,64 \pm 0,16 \text{ Mgr. pr. Litre}$$

med en sandsynlig Afvigelse herfra af en enkelt Observation af  $\pm 1,26$  Mgr. pr. Litre.

Da det først var bragt paa det Rene, at de af Dr. Jacobsen iagttagne Egenskaber hos Søvandet skæves sig derfra, at den i Søvandet eksisterende Saltblanding ved Kogehede decomponerede neutrale Carbonater, maatte det ogsaa fremstille sig som en meget interessant Opgave at finde den nærmere Forklaring dertil.

Den nærmestliggende Tanke, som i denne Anledning først paatvang sig mig, var den at søge Grunden i Chlor-magnesiumens bekjendte Egenskaber. At denne under Kogningen selv ved Tilstedeværelsen af Overskud af Chlor-natrium skulde have Tilbøielighed til lidt efter lidt at spalte sig, og at der af den dannede Saltsyre skulde kunne uddrives noget Kulsyre, kunde jo ikke synes umuligt. Der

børne in mind, that the figures representing the carbonic acid forming bicarbonates also include the error in both titrations.

A glance at the Table will show that the figures therein set down, more particularly those representing the carbonic acid forming carbonates, exhibit a remarkable uniformity: save in 2 observations, both with a sample of water drawn in close proximity to the ice off the coast of Greenland, the carbonic acid forming carbonates determined in the remaining 63 samples lies between the limits 51,4<sup>mgr</sup> and 55,4<sup>mgr</sup> per litre and the greatest difference amounts therefore to only 4<sup>mgr</sup>, which must be regarded as very small, considering that the said figures refer to the examination of water from a tract of ocean which, measured both from north to south and from east to west, extends for considerably more than 200 geographical miles. As regards the carbonic acid forming bicarbonates, the differences in the amounts determined are, however, much greater, reaching 8<sup>mgr</sup> per litre.

I have long had my attention directed to the possible discovery of a law controlling these variations, similar to that which I found to regulate those of air, but have not yet succeeded in obtaining conclusive results; and it is quite immaterial whether depth or geographical position be made the basis of investigation.

The water in no part of the ocean-tract explored being characterised by properties plainly distinguishing it from that of any other, and the differences in the results obtained having invariably proved small, the latter will obviously serve for the computation of average formulae representing the amount of carbonic acid present in the water of the sea investigated. These average formulae, set down accordingly as the final results, were found to be —

$$52,78 \pm 0,083^{\text{mgr}} \text{ per litre}$$

for the carbonic acid forming carbonates, with a probable error in a single observation of  $\pm 0,662$  per litre; and

$$43,64 \pm 0,16^{\text{mgr}} \text{ per litre}$$

for the carbonic acid forming bicarbonates, with a probable error in a single observation of  $\pm 1,26^{\text{mgr}}$  per litre.

Having now obtained conclusive proof that the properties observed by Dr. Jacobsen in sea-water were the result of the property possessed by the saline compounds present therein of decomposing at the boiling-point neutral carbonates, the next step was to find a satisfactory explanation of the interesting phenomenon.

My first thought in this direction was to seek the cause in the known properties of chloride of magnesia, Assuming this body to have a tendency of gradually decomposing during the process of boiling, carbonic acid might possibly be driven off by the hydrochloric acid formed. Against such an hypothesis, however, various objections may be raised, Dr. Jacobsen and others having shown that sea-

lader sig imidlertid reise Indvendinger mod denne Betragtningssaaade, idet det af Dr. Jacobsen med Flere er paavist, at Sovand lader sig indklempe til Torhed og Saltene endog tørre ved en Temperatur af 180° C., men at nogen synderlig Mængde Saltsyre forflygtiger sig, og det er i Virkeligheden heller ikke formodent at ty til Chlormagnesiums Dissociation før at finde den rimeligste Forklaringsgrund. Man behøver blot at hælde sig til den kulsure Magnesia og dens Egenskaber, saaledes som de ere kjendte af Arbejder udførte af de mest berømte Chemikere.

Ifølge Angivelser af Berzelius,<sup>1</sup> H. Rose,<sup>2</sup> Fritzsche,<sup>3</sup> Nørgaard<sup>4</sup> og L. Joulin<sup>5</sup> er den ved høiere Temperatur dannede kulsure Magnesia altid mere eller mindre basisk, ja ifølge Berzelius og H. Rose er selv de ved Blanding af Magnesiumopløsninger med kulsure Alkaler i Kolden dannede Blandfald mere kulsyrefattige end mættet kulsur Magnesia. Der findes om den kulsure Magnesia et meget stort Antal tildeels meget modstridende Angivelser, og der er, eftersom Fremstillingsmaaden er varietet, erholdt meget forskjelligt sammensatte Salte, hvis procentiske Sammensætning ifølge Analyserne stemme meget daarligt overens med den af de opstillede Formler beregnede. Disse Forbindelser ere ogsaa af enkelte Forfattere betragtede som basiske Salte af variabel Sammensætning og anses af L. Joulin endog for en Blanding af voxende Mængder Oxyd og Carbonat. Det vilde fare for langt her'at gjennege de talrige over dette Emne forfattede Afhandlinger, og jeg skal derfor indskrænke mig til at henviser til Gmelin-Kraut's Handbuch der Chemie 6te Aufl. 2 432, hvor det Vsesentligste findes i Uddrag. Det man dog være mig tilladt at citere nogle Udtalelser af H. Rose, som jeg nylig blev opmærksom paa, Udtalelser, som vise at Videnskaben allerede meget længe har været i Besiddelse af Materiale til Forklaringen af de af Dr. Jacobsen gjorte Observationer. H. Rose siger (Pogg. Ann. [3] 23 p. 417) Følgende:

„Als das Gesetz der einfachen chemischen Proportionen aufgestellt und hinreichend durch Versuche bewiesen worden war, ergab sich die Neutralität zweier sich zersetzender Salzlösungen als eine ganz natürliche Folge des Gesetzes der bestimmten Verhältnisse, in denen sich alle Körper, also auch Säuren und Basen, mit einander verbinden.

Aber das Gesetz, dass durch Zersetzung zweier neutraler Salze nach ihrer Auflösung in Wasser wiederum zwei neutrale Salze entstehen, ist nicht richtig, wenigstens nicht in der Allgemeinheit, wie es bisher ohne den geringsten Widerspruch angenommen worden ist.

Es ist bemerkenswerth, dass die so ausserordentlich vielen Ausnahmen, die bei diesem Gesetze stattfinden, nicht früher aufgefallen sind, obgleich mehrere derselben schon seit langer Zeit bekannt waren. Nur eine fast einzeln stehende

water admits of being evaporated to dryness, and the residue even dried at a temperature of 180° C. without volatilising any considerable quantity of hydrochloric acid. But it is not necessary to seek in the properties of chloride of magnesia the most plausible means of explanation, we need only keep to the carbonate and its properties, as determined by the most renowned Chemists.

According to the statements of Berzelius,<sup>1</sup> H. Rose,<sup>2</sup> Fritzsche,<sup>3</sup> Nørgaard,<sup>4</sup> and L. Joulin,<sup>5</sup> carbonate of magnesia formed at a high temperature invariably contains less carbonic acid than the neutral salt may, according to Berzelius and Rose the precipitate resulting from the mixture of carbonate of potash, when added, with solutions of magnesia, contains less carbonic acid than saturated carbonate of magnesia. For carbonate of magnesia we have a very large number of conflicting statements, and the compounds obtained have been found to vary greatly with the mode of operation, the proportion of their constituents, too, often agreeing but very indifferently with that computed by the formulae. By some authors these combinations have been regarded as basic salts, varying in their component parts; nay by L. Joulin, as consisting of constant mixtures of some oxide and carbonate. I lack space here to notice the numerous memoirs treating of this subject, and shall therefore merely refer the reader to Gmelin-Kraut's 'Handbuch der Chemie' 6te Auflage, 2, p. 432, in which copious extracts from them will be found. I cannot however refrain from quoting certain remarks by H. Rose, on which a short time since I happened to light,

remarks showing science to have been long in possession of materials amply sufficient to explain Dr. Jacobsen's observations. In Pogg. Ann., [3] 23, p. 417, H. Rose observes as follows:—

„Als das Gesetz der einfachen chemischen Proportionen aufgestellt und hinreichend durch Versuche bewiesen worden war, ergab sich die Neutralität zweier sich zersetzender Salzlösungen als eine ganz natürliche Folge des Gesetzes der bestimmten Verhältnisse, in denen sich alle Körper, also auch Säuren und Basen, mit einander verbinden.

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<sup>1</sup> Berzelius Jahresbericht, 17, p. 178.

<sup>2</sup> Pogg. Ann. 83, p. 417.

<sup>3</sup> Pogg. Ann. 37, p. 310.

<sup>4</sup> K. Danske Vid. Selsk. Skrift, [5] 2, p. 54 (1850).

<sup>5</sup> Ann. Chim. Phys. [4] 30, p. 271.

<sup>1</sup> Berzelius Jahresbericht, 17, p. 178.

<sup>2</sup> Pogg. Ann. 83, p. 417.

<sup>3</sup> Pogg. Ann. 37, p. 310.

<sup>4</sup> K. Danske Vid. Selsk. Skrift [5] 2, p. 54 (1850).

<sup>5</sup> Ann. Chim. Phys. [4] 30, p. 271.

Ausnahme erregte vor längerer Zeit ein allgemeines Aufsehen. Als man fand, dass eine Auflösung von gewöhnlichem phosphorsäurem Natron, welche für sich geröthetes Lackmuspapier bläut, mit einer Auflösung von salpetersäurem Silberoxyd, welche das Lackmuspapier unverändert lässt, versetzt, einen Niederschlag von gelbem phosphorsäurem Silberoxyd und eine Flüssigkeit giebt, welche gebläutes Lackmuspapier röthet, konnte diese Erscheinung nicht früher genügend erklärt werden, als bis die interessanten Untersuchungen von Clarke, und die sinnreiche Deutung derselben durch Graham bekannt wurde.

Aber vor weit längerer Zeit schon hatte man Erscheinungen beobachtet, die eben so räthselhaft waren, als der beschriebene Fall. Man hatte schon oft bemerkt, dass aus der Auflösung eines neutralen kohlensäuren Alkalis durch Zersetzung vermittelt einer Auflösung eines neutralen Salzes von Magnesia, von Zinkoxyd oder von einem andern ähnlich zusammengesetzten Metalloxyd Kohlendioxid entwickelt werde, besonders wenn die Fällung des kohlensäuren Oxyds in der Wärme geschieht, und eine grosse Reihe von Versuchen, die man besonders in neuerer Zeit angestellt hat, hat ergeben, dass die meisten der kohlensäuren unlöslichen Salze, welche man durch Zersetzung neutraler Salzaufösungen erhält, nicht die entsprechende Zusammensetzung des kohlensäuren Alkalis haben, das zu ihrer Erzeugung angewandt worden ist. Sie enthalten weniger Kohlensäure, aber obgleich die Untersuchungen oft von sehr bewährten Chemikern angestellt worden sind, so hat man ihre Zusammensetzung sehr wenig übereinstimmend gefunden."

H. Rose har ogsaa ved Forsøg, som han sammesteds beskriver, fundet, at varmt koldt basisk kulsur Magnesia indeholder mindre Kulsyre, naar den efter Fældningen koges nogen Tid, end naar den strax gjøres til Gjenstand for Analyse.

Det kan efter dette ikke være tvivlsomt, at den kulsure Magnesia ved høiere Temperaturer decompneres og antager noget forskjellige Sammensætninger, eftersom den koges kortere eller længere Tid. Rigtig nok er det ikke nogensteds ved de tidligere Forsøg påvist, at man på denne Maade kan få Magnesia fuldstændig befriet for Kulsyre, men man må ogsaa her tage Hensyn til, at man ved de tidligere Forsøg visselig overalt har arbejdet med temmelig store Mængder Bundfald, der naturligvis ikke med samme Lethed som Småportioner vil kunne erholdes decompnerede.

Føret påvise, at små Mængder kulsur Magnesia ved Kogning lader sig omvandle til fuldstændig rent Oxyd, gik jeg frem på følgende Maade. Af fuldstændig rent friskt nedkølet Soda atyeneses 0.422 Gr. og opløstes i 100 CC. kulsyreftit destilleret Vand, ligeledes tilberedtes en 13  $\frac{1}{100}$  indeholdende Opløsning af almindelig rent svovlsur Magnesia, som i Forveien ved gjentagne Omkrystallisationer var befriet for alle Fremrensninger. En Blanding af 15 CC. af Sodaopløsningen med 50 CC. af Bittersaltopløsningen fortyndet med noget over  $\frac{1}{4}$  Litre friskt mlkøgt endnu varmt Vand kogtes i en kulsyreftit Luftstrøm i Classens

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Moreover, H. Rose also found, by experiments which he has described in the same paper, that basic carbonate of magnesia, precipitated warm, contains less carbonic acid when boiled for some time after precipitation than when at once subjected to analysis.

From what has been stated above, carbonate of magnesia is evidently decomposed at a high temperature, and enters into a variety of very different combinations according to the duration of the boiling-process. True, none of the earlier experiments have shown that all the carbonic acid present in magnesia can be expelled by this method; but those experiments were conducted, we must remember, with a comparatively large amount of precipitate, which necessarily proves less easy to decompose than do small quantities.

In order to show that small quantities of carbonate of magnesia may be transformed by boiling into pure oxide, I went to work as follows. In 100<sup>cc</sup> of distilled water free from carbonic acid were dissolved 0.422<sup>gr</sup> of freshly heated carbonate of soda; a solution was likewise prepared containing 13 per cent of ordinary sulphate of magnesia, which by repeated crystallization had been previously freed from all impurities. A mixture consisting of 15<sup>cc</sup> of the solution of soda and 50<sup>cc</sup> of a solution of Epsom salts diluted with a little more than  $\frac{1}{4}$  of a litre of freshly boiled water, still warm, was boiled in Classen's ap-

Apparat i omkring 2 Timer, idet den indvægende Kulsyre som før opfangedes og bestemtes ved titreret Barytvand. I den anvendte Mængde Sodaopløsning var indeholdt 63.3 Mgr. Soda svarende til 26.3 Mgr. Kulsyre, medens der ved to Experimenter paa denne Maade fandtes uddeivet den ene Gang 26.8 og den anden 27.7 Mgr. Ved Forsøgets Gjentagelse med en lidt større Quantitet paa udvundet Soda fandtes uddeivet 34.1 Mgr. Kulsyre istedetfor beregnet 33.2. Under Kogningen var Opløsningen i Begyndelsen fuldstændig klar, hvorpaa der efter cirka  $\frac{1}{2}$  Times Forløb begynder at fremkomme et Blandtild af Magnesia, hvori der trods af anvendt Mængde ikke lykkedes mig at paaise det mindste Spor af Kulsyre. Den løselig kulsyre Magnesia er nemlig ifølge H. Rose og flere ikke ubetydelig opløselig saavel i Vand som i forskellige Salte, saaledes at der af smaa Mængder med Blandtild fremkommer, og det er derfor ikke uanfæleligt, at Oxydet ved saa fortyndede Opløsninger, som her ere anvendte, ikke udfældes, figned det ved Kogningen er betriet for sin Kulsyre.

Koges Søvand under Concentration, kan man meget let komme til at overse denne Udskillelse af Magnesia, idet denne først indtræder efter nogen Tids Forløb, saaledes at man kan antage Blakningen fremkommen ved Udfældning af Gips i den concentrerede Vædske. Udskillelsen vil ogsaa, naar Inddampningen foregaar i aabent Kar, forsøkes betydeligt, idet Kulsyrens Indvægen foregaar meget langsommere i en kulsyreholdig Atmosfære end i en kulsyrefri Luftstrøm, og det kan derfor ikke formodes, at denne Udfældning af Magnesia af kogende Søvand, saavnt mig bekendt, ikke tidligere er observeret, naar indtages, at Usighe<sup>1</sup> i det tørrede Residuum har paavist fri Magnesia. Dersom man imidlertid koger Søvand uden Concentration i en kulsyrefri Atmosfære med anvendt Kjoler, saaledes som det let kan ske ved Classens Apparat, fremtræder Phænomenet meget tydeligt paa samme Maade som ved Kogning af en Blanding af Sulfat og Bittersalt, idet der efter cirka  $\frac{1}{2}$  Times Kogning begynder at afskille sig et Blandtild bestående af ren kulsyre- og kalkfri Magnesia ved Siden af et lille Spor af Kiselvæde hidrørende fra det benyttede Glaskar. Om man samtidig optager og bestemmer den indvægende Kulsyre, viser det sig, at den Villighed, hvormed Kulsyren indvæger, ikke saameget afhænger af Concentrationsgraden som af Vægheden af det Tilsætt, hvori Kogningen fortsættes, da ogsaa paa denne Maade cirka 2 Times Kogning strækker til for at skaffe en fuldstændig kulsyrefri Vædske.

Det vil forhaabentlig hermed kunne ansees indstændig godtgjort, at Søvandets Evne til ved Kogning at decan-

paratus for 2 hours exposed to a current of air free from carbonic acid, the carbonic acid driven off being collected and determined as before by titrated barvta water. The portion of the solution of carbonate of soda employed contained 63.3<sup>mg</sup> of that substance, representing 26.3<sup>mg</sup> carbonic acid; and two experiments performed by this method gave respectively 26.8<sup>mg</sup> and 27.7<sup>mg</sup> as the amount of the latter driven off. On repeating the experiment with a somewhat larger quantity of carbonate of soda, carefully weighed, 34.1<sup>mg</sup> were found to have been liberated, whereas the exact proportion would have been 33.2<sup>mg</sup>. During the process of boiling, the fluid at first remained perfectly clear; but after the lapse of about half an hour magnesia began to be precipitated, in which with the most delicate tests I failed to detect the smallest trace of carbonic acid. According to H. Rose and other authors basic carbonate of magnesia is to a considerable extent soluble alike in water and in solutions of divers salts, so that small quantities give no precipitate and hence it is not surprising that with a solution so diluted as that made use of for these experiments, the oxide should not have been precipitated before it had given off all its carbonic acid.

If sea-water be boiled during concentration, this precipitation of magnesia may be easily overlooked, since it does not take place till after the lapse of some time, and the turbidness of the concentrated fluid might therefore be ascribed to the deposit of gypsum. When the water, too, is evaporated in an open dish, the precipitation will be considerably retarded, since the carbonic acid escapes much more slowly in an atmosphere containing carbonic acid than in a current of air from which all carbonic acid has been expelled and this accounts for the precipitation of magnesia in boiled sea-water, so far as I am aware, not having been previously observed, except at least by Usighe,<sup>1</sup> who detected the presence of free magnesia in the dried residue. When, however, sea-water is boiled without being concentrated in an atmosphere free from carbonic acid, and with the cooler inverted, which it easily may be with Classen's apparatus, the phenomenon appears with great distinctness, as is the case on boiling a mixture of soda and Epsom salts for after about half an hour's boiling a precipitate begins to form, consisting of pure magnesia, with no admixture of lime and carbonic acid and a trace only of silicic acid, the latter arising from the glass vessel employed in the operation. If the carbonic acid be simultaneously collected and determined, the readiness with which it escapes is found to depend not so much on the degree of concentration as on the duration of the boiling-process, about 2 hours proving amply sufficient to obtain a fluid free from the smallest trace of carbonic acid.

From what has been stated, there is, we think, conclusive proof, that the property possessed by sea-water of

<sup>1</sup> Journ. for pract. Chem. 16 p. 106.

<sup>2</sup> Journ. for pract. Chem. 16 p. 106.

ponere neutrale Carbonater man blive at tilskrive gradvise Omsætninger mellem de i Søvandet eksisterende kulsure Salte og Magnesiaforbindelserne, og de af Dr. Jacobsen hos Søvandet nægtagne Egenskaber man derfor ogsaa i mere eller mindre Grad tillige alle andre magnesiholdige Mineralvande, eller naar man lægger Roses ovennævnte Ildtabelser til Grund, alle Saltopløsninger, forsaavidt de foruden Alkalier og Joralkalier tillige indeholder opløselige Salte af nogen af de svagere Baser, som med Kulsyren danne ubestandige Forbindelser. Denne Omstændighed vil saaledes uden videre stemple sig godt som alle de til Bestemmelse af Forholdet mellem den frie og løslig Kulsyre i Mineralvande anvendte tidligere Metoder som mere og mindre upaalidelige hvooverfor magnesiholdige Mineralvande, idet man ved dem til Bestemmelse af neutraliteten Kulsyre enten anvender Residuet fra Inddampning eller paa anden Maade benytter sig af Kogning, hvor den efter det forhen udviklede vil være utilladelig.

Det vil sluttelig ikke være paa urette Sted kortelig at berøre de Synsmaader, som fra ældre Tider har været gjort gjældende, hvad angaar de i Søvandet indeholdte Carbonater.

Efter de Fremgangsmaader, hvorved disse af ældre Forfattere ere bestemt, kunde de naturligvis kun erholdes adskilte i Form af kulsur Kalk eller, som af enkelte ogsaa taaleet, lidt kulsur Magnesia, men deraf følger ingenlunde, at de med Nødvendighed oprindelig skulde forekommet i Søvandet under denne Form, ja dette er saa langt fra sikkert, at jeg meget mere skulde være tilbøjelig til at tro, at saa ikke er Tilfælde. Koger man nemlig Søvand i det af Dr. Jacobsen beskrevne Luftudkogningsapparat, undviger der, som allerede for bemærket, meget smaa Quantiteter Kulsyre, idet man kan fortsætte Kogningen med velende Afkøling en hel Time uden at fra mlbrevet mere end en Broked af Milligram pr. Litra. Kogepunctet vil her i Begyndelsen ligge meget lavt, men stiger, efterhaanden som den undvigende Luft og den dannede Vanddamp forøger Trykket, meget hurtigt, saaledes at jeg allerede under den første Halvdel af Operationen har observeret en Temperatur af 89° C. Naar saaledes de i Søvandet indeholdte sure Carbonater vise en saa haardtøkket Modstand mod Decomposition, at de i en hel Time skulde sig godt som aldeles uden Virkning kunne udsettes for en Temperatur af omkring 90° C., da synes mig denne Egenskab at passe meget bedre paa surt kulsurt Natron end paa sur kulsur Kalk, og det vilde desuden falde vanskeligt at forklare Søvandets tydelige alkaliske Reaction, medmindre man kunde antage, at Carbonaterne i det Mindste for en ikke ringe Del bestod af Alkalisalte.

Med Hensyn paa Quantiteten af de i Søvandet forekommende kulsure Salte, da stemme de derover eksisterende Opgaver meget daarligt overens, de lyde i Regelen paa Spor undertiden endog paa Intet, medens der af enkelte igjen er opført forholdsvis store Mængder. Saaledes finder

decomposering when boiled neutral carbonates, arises from the slow reciprocal action of the carbonates and salts of magnesia it contains, and the properties observed by Dr. Jacobsen in sea-water must therefore to a greater or less extent distinguish all mineral waters containing magnesia compounds, or, according to Rose, in his statements quoted above, all solutions of salts, provided they contain, exclusive of sodium, potassium, lime, barium, and strontium, also soluble salts of some one of the weaker bases, which along with carbonic acid form inconstant combinations. Hence, this circumstance clearly shows, that of the numerous methods devised for determining, in mineral waters, the relative proportion of free carbonic acid and that present in carbonates nearly all are, when magnesia is present, unreliable, since for the determination of the carbonic acid present in carbonates, either the residue from evaporation or some other result of boiling is had recourse to, which has been shown to be inadmissible.

Finally, it will not be out of place to notice the views originally entertained with regard to the carbonates present in sea-water.

By the process according to which the earlier chemists determined these compounds, they could of course obtain them only in the form of carbonate of lime, or, as found by some observers, along with a little carbonate of magnesia; but from this it does not by any means follow that they necessarily occur in that form in sea-water; nay, I am myself inclined to believe that such is not the case. On boiling sea-water in the apparatus described by Dr. Jacobsen, very small quantities only of carbonic acid are found to escape; the fluid may be alternately boiled and cooled for an hour together without liberating more than a fraction of a milligramme per litre. The boiling-point with this method will at first be very low, but, on the pressure being increased by the escape of the air and the formation of steam, rapidly rise; even in the first half of the operation I have observed a temperature of 89° C. The vigorous resistance to decomposition thus exhibited by the bicarbonates in sea-water, which admits of their being exposed almost without effect for an hour together to a temperature of nearly 90° C., would rather seem to indicate bicarbonate of soda than bicarbonate of lime; and besides, the decided alkaline reaction of sea-water would be difficult to explain unless by assuming the carbonates — or a considerable portion of them at least — to consist of carbonate of soda and potash.

With regard to the proportion of carbonates present in sea-water, the results as yet obtained agree but very indifferently; the majority of observers have detected traces only or none whatever, whereas some allege to have found comparatively large quantities, as will be seen from the following Table.



von Bilra<sup>1</sup> Intet.

Robinet og Løfort<sup>2</sup> i det røde Hav Spor.

Pisani<sup>3</sup> ved Bujuk-Déré i Bosporns 0,1569 Gr. pr. Litre.  
C. Knauss<sup>4</sup> 0,011 Gr. pr. Litre.

Thorpe og Morton<sup>5</sup> i det irske Hav 0,04754 i 1000 Dele Vand.

Dr. Jacobsen i Nordsøen 0,018—0,028 Gr. pr. Litre.

Vierthaler<sup>6</sup> i Adriaterhavet 0,315 Gr. pr. Litre.

F. Wibel<sup>7</sup> i det joniske Hav Intet

og Buchanan<sup>8</sup> i de sydlige Have enten Intet eller og meget smaa Mængder.

Saa store Forskjelligheder vilde naturligvis være meget mærkelbende, i Fald man kunde anse Resultaterne af disse Observationer for aldeles correcte, hvad der imidlertid ikke er muligt, da alle uden Undtagelse ere udførte efter Metoder, som kun for aldeles specielle Sammensætninger af Havvandet kunde føre til nogenlunde rigtige Resultater.

Ved de tidligere i denne Afhandling beskrevne Forsøg er det godtgjort, at Søvandet (under enhver Omstændighed det af Forfatteren undersøgte) ved Kogning i kulsyre-fri Luft taber al neutralbundne Kulsyre, og det maa endvidere ved de af v. Bilra og Buchanan udførte Observationer anses fuldt bevist, at almindeligt Oceanvand ved Inddampning til Torhed selv i en kulsyreholdig Atmosfære indertiden kan give et fuldstændig kulsyre-frit Residuum, medens det ganske ligesaa ofte ikke vil være Tilfælde, idet der ofte af Buchanan og altid af Jacobsen er fundet Carbonater i Residuet. Hvor den neutralbundne Kulsyre under Inddampningen bortdrives, vil der til Gjenjæld altid tilføjes den æquivalente Mængde Magnesia, som naar Residuet lønstaar i kulsyreholdig Luft for Bestemmelsen, vil kunne gjenoptage en Del Kulsyre, og det er derfor let forklarligt, at man ved Anvendelse af Inddampning vil kunne erholde meget forskjellige Resultater selv i Søvand af fuldstændig identisk Sammensætning.

En til Bestemmelse af Carbonaterne hyppig anvendt Methode er den, hvorefter Søvandet koges i ca. 1 Time under stadig Fornyelse af det forbrændte Vand, hvorefter det afskiltede Bundfald frafiltreres og veies, saaledes som Vierthaler og flere har gjort, medens T. E. Thorpe og E. H. Morton af den i Søvandet oprindelig indeholdte Kalkmængde og den i Vædsken efter Frafiltration af det ved Kogningen afskiltede Bundfald tilbageværende beregner den kulsure Kulks Mængde.

Von Bilra:<sup>1</sup> none.

Robinet and Løfort,<sup>2</sup> in the Red Sea traces.

Pisani,<sup>3</sup> near Bujuk-Déré in the Bosporns, 0,1569<sup>o</sup> per litre.  
C. Knauss:<sup>4</sup> 0,011<sup>o</sup> per litre.

Thorpe and Morton,<sup>5</sup> in the Irish Sea 0,04754 in 1000 parts of water.

Dr. Jacobsen, in the North Sea 0,018—0,028<sup>o</sup> per litre.

Vierthaler,<sup>6</sup> in the Adriatic Sea 0,315<sup>o</sup> per litre.

F. Wibel,<sup>7</sup> in the Ionian Sea, none.

Buchanan,<sup>8</sup> in the Southern Seas: none at all or traces only.

Differences so considerable would indeed be extraordinary, assuming the results of the observations to be quite correct: this, however, is simply impossible, since they were all without exception obtained by methods none of which, save for sea-water of a particular composition, can lead to results even approximately reliable.

By the experiments previously described in this Memoir, it has been shown that sea-water — at least that examined by the author — can, by boiling in an atmosphere free from carbonic acid, be made to part with all of its carbonic acid that is present in carbonates, and moreover, the observations of v. Bilra and Buchanan have furnished conclusive proof, that ordinary ocean-water when evaporated to dryness even in a atmosphere containing carbonic acid, sometimes gives a residue in which no trace of carbonic acid can be detected, but the reverse will, perhaps, no less frequently prove to be the case, seeing that Buchanan has often, and Jacobsen always, found carbonates present in the residue. When the neutral carbonates are decomposed during the process of evaporation, an equivalent proportion of magnesia will invariably be precipitated, which, in the residue being allowed to stand over previous to determination in an atmosphere containing carbonic acid, may possibly absorb some carbonic acid, and hence, when recourse is had to evaporation, very different results may obviously be obtained even with water identical in composition.

A method frequently adopted for determining the proportion of carbonates, is to boil the sea-water for about an hour, while steadily adding freshwater in place of that evaporated, after which the precipitate is filtered off and weighed, as done by Vierthaler and others; T. E. Thorpe and E. H. Morton calculate the proportion of carbonate of lime by comparing the amount of lime originally present in the water with that contained in the fluid after filtering off the precipitate.

<sup>1</sup> Ann. Chem. Pharm. 77 — 390.

<sup>2</sup> Compt. rend. 62 — 136.

<sup>3</sup> Compt. rend. 41 — 532.

<sup>4</sup> Petersh. Acad. Bull. 2 — 203 (1860).

<sup>5</sup> Ann. Chem. Pharm. 138 — 122.

<sup>6</sup> Wien. Acad. Ber. [2] — 56 — 479.

<sup>7</sup> Ber. Berl. chem. Ges. 6 — 184.

<sup>8</sup> Proc. Roy. Soc. 24 — 664.

<sup>1</sup> Ann. Chem. Pharm. 77, p. 390.

<sup>2</sup> Compt. rend. 62, p. 136.

<sup>3</sup> Compt. rend. 41, p. 532.

<sup>4</sup> Petersh. Acad. Bull. 2, p. 203 (1860).

<sup>5</sup> Ann. Chem. Pharm. 138, p. 122.

<sup>6</sup> Wien. Acad. Ber. [2] '56, p. 479.

<sup>7</sup> Ber. Berl. chem. Ges. 6, p. 184.

<sup>8</sup> Proc. Roy. Soc. 24, p. 664.

Det er af samme Grund som ovenfor klart, at denne Fremgangsmaade for almindeligt Oceanvands Vedkommende vil føre til aldeles værdiløse Resultater, uden at det dog med Sikkerhed kan påstås, at dette i samme Udstrækning skulde være Tilfælde for det af Vierthaler undersøgte Vand, som hør en fra almindeligt Søvand meget forskjellig Sammensætning. Efter de talrige og værdifulde Analyser af Søvand, som vi skylder Professor Forchhammer, indeholder Vandet i de store Verdenshøve uden synderlig store Variationer i de enkelte Bestanddeles indbyrdes Forhold gjenemsnitlig

Chlor + Brom . . . . .	1,895 %
Svovlsyre (SO <sub>2</sub> ) . . . . .	0,225 -
Magnesia . . . . .	0,210 -
Kalk . . . . .	0,056 -

medens Vierthaler i Adriaterhavet har fundet

Chlor + Brom . . . . .	2,264 %
Svovlsyre . . . . .	0,262 -
Magnesia . . . . .	0,237 -
Kalk . . . . .	0,371 -

Denne uforholdsmæssig store Forøgelse af Kalkmængden uden tilsvarende Forøgelse af Svovlsyremængden vil hidrøre til, at det af Vierthaler undersøgte Vand vil have en meget større Tilhængselighed til ved Kogning at afskille kulsur Kalk, hvad der i ikke ringe Grad kan tænkes at forrykke de almindelige Phenomener.

Hvad angaar de af Thorpe og Morton udførte Observationer, da er der i en Henseende en væsentlig Forskel mellem de af disse Forfattere og de af mig erholdte Resultater. Jeg havde allerede før jeg blev opmærksom paa den af dem offentliggjorte Afhandling, lagt Mærke til, at der af Søvand ved Kogning i en kulsyret Luftstrøm i Classen's Apparat udfældtes et Bimdfæld af Magnesia, indeholdende lidt fra Glasset hidrørende, Kiselsyre, men jeg havde aldrig deri kunnet paaise hverken Kulsyre eller Kalk og det, maaske om Kogningen afløedes paa et tidligere eller senere Stadium, hvadenten den neutraliserede Kulsyre var helt eller kun delvis bortdrevet. Rigtignok anfører Thorpe og Morton intetsteds udtrykkelig, at de have undersøgt det afskillede Bimdfæld paa Kalk, men det fremgaar indirekte med stor Bestemthed, af hvad der forresten er bemærket, at saa man have været Tilfælde.

At Vierthaler kunde få udfældt kulsur Kalk af et saa idærmt sammensat Søvand som det i Adriaterhavet flydende, kunde ikke vække Forundring, men at det samme fandtes at være Tilfælde med Vandet i det røde Hav, som ved livlige Strømme stadig optager friske Vandmængder fra det store Verdenshav, og som i sin Sammensætning viser sig saa analogt det af den norske Nordhavsexpedition undersøgte, forekom mig meget påfaldende. Jeg har derfor gjentaget Thorpe og Mortons Forsøg aldeles ubændrede paa flere af de fra den norske Expedition hændte Vandprover, men erholdt altid det samme Resultat, at det i det afskillede Bimdfæld trods af anvendt Meie ikke lykkedes at paaise Spor hverken af Kulsyre eller Kalk. Af det forhen Udviklede vil det fremgaa, at man af de ældre Angi-

For the same reason, as explained above, the said process with ordinary ocean-water will give results absolutely worthless; this cannot however be affirmed with certainty of Vierthaler's observations, the water he examined having been very different in composition from ordinary sea-water. According to the numerous and valuable analyses of sea-water for which we are indebted to Professor Forchhammer, the water of the great oceans, the component parts of which vary but little in their relative proportion, is generally found to contain —

Chlorine + Bromine . . . . .	1,895 per cent.
Sulphuric Acid (SO <sub>2</sub> ) . . . . .	0,225 - —
Magnesia . . . . .	0,210 - —
Lime . . . . .	0,056 - —

whereas the water of the Adriatic Sea, according to Vierthaler's observations, contains —

Chlorine + Bromine . . . . .	2,264 per cent.
Sulphuric Acid . . . . .	0,262 - —
Magnesia . . . . .	0,237 - —
Lime . . . . .	0,371 - —

This disproportionately large amount of lime without a corresponding increase in the amount of sulphuric acid will give the water examined by Vierthaler a tendency, when boiled, to precipitate carbonate of lime, which must to a considerable extent have a disturbing influence on the phenomena.

With regard to the series of observations instituted by Thorpe and Morton, there is, in one respect, an essential difference between their results and mine. Previous to my reading their Memoir, I had become aware of the fact, that, on boiling sea-water exposed to a current of air free from carbonic acid in Classen's apparatus, there results a precipitate of magnesia, containing a little silicic acid, derived from the glass; but I have never succeeded in detecting therein the presence of carbonic acid or lime; the result is precisely the same whether the boiling be interrupted at an early or a late stage of the process, or whether all or part only of the carbonates be decomposed. True, Thorpe and Morton nowhere distinctly state their having examined the precipitate for lime; but from what is observed in other respects, this must obviously have been the case.

That Vierthaler should have succeeded in precipitating carbonate of lime from water so exceptionally composed as is that of the Adriatic Sea, cannot surprise us; but that the same result should have been obtained with water from the Irish Sea, which by reason of rapid currents is continually receiving a large influx of water from the Atlantic Ocean, and which in its composition exhibits so great an analogy with that examined on the Norwegian North-Atlantic Expedition, does, to me, indeed appear strange. I have therefore repeated the experiments instituted by Thorpe and Morton, adopting their method without the slightest modification; but the results obtained were invariably the same; even with the most delicate tests I failed to detect the smallest traces of carbonic acid or

velser Intet med Bestemthed kan slutte om Carbonaternes Mængde i de store Verdenshave. Det synes dog, som om de af Buchanan indførte Bestemmelser af Kulsyren i Atlanterhavet, (hvorved han inddamper efter forudgaaende Til sætning af Chlorbarium og tilslut med stærk Saltsyre fælgjes har bestræbt sig for at paavise Kulsyre i Residnet), med Sikkerhed skulde fastsætte en øvre Grænse for den tilstedeværende Carbonatmængde, men dette er i Virkeligheden ikke Tilfælde.

Som bekendt beskytter opløselige Sulfater Carbonater mod Decomposition endog, naar til Udtrivelse af Kulsyren anvendes saa radicale Midler som concentreret Svovlsyre, saaledes at man endog af den Grund har fundet det fornødent at modificere den af Fresenius og Will angivne Methode til Bestemmelse af Kulsyren i neutrale Carbonater.<sup>1</sup> De af Buchanan foretagne Undersøgelser efter Kulsyre i Residnet kan derfor ikke betragtes som Bevis for, at den ikke skulde have været tilstede, og det fremgaar ogsaa tydeligt af hans egne Udtalelser, at han selv har været af samme Mening.

Foraf fra Rede paa, hvorvidt en ved Kogning bevirket Decomposition af de i Søvandet indeholdte neutrale Carbonater foregaar i større Udstrækning ogsaa, naar der i Vædsken findes opløselige Sulfater, har jeg indført nogle Forsøg efter den af Buchanan foreslaaede Fremgangsmaade. Af nogle Vandprover, som undersøgte efter den af mig benyttede Methode, viste sig at indeholde en Sum af surt- og neutraltbundne Kulsyre af 96 Mgr. pr. Litre og derover, erholdtes ved Inddampning til Torhed efter Til sætning af Chlorbarium indrevet kun henimod 50 Mgr., ved en enkelt Undtagelse erholdtes engang over 50 Mgr. pr. Litre. Det vil sige, den indvorne Kulsyremængde var ikke synnerlig højere end den af Buchanan for Vandet i Æquatorene angivne og beløb sig til kun få Mgr. over, hvad den surtbundne Kulsyre efter paalidelige Observationer skulde beløbe sig til, de endnu i Residnet tilbageværende Carbonater lykkedes det heller ikke mig at paavise.

Spørgsmaalet om Carbonaternes Mængde i de sydlige Have maa derfor endnu betragtes som uløst.

Forhaabentlig reterer endnu en Del af de fra Challengerexpeditionens Togter hjembragte Vandprover, og man vil i saa Fald ved Undersøgelse af disse kunne give Bidrag til Besvarelsen af disse Spørgsmaal.

Ellerat Ovenstående var nedskrevet paa Norsk, men førend det endnu var oversat paa Tysk, ankom hertil 2det og 3die Hefte for 1879 af Fresenius' Zeitschrift für anal. Chem., hvori E. Boddig offentliggjør en Afhandling,<sup>2</sup> hvoraf det sees, at han ved Arbejde med naturlige Mineralvande har observeret Omsætninger mellem kulsur Kalk og svovl-

of lime. From what has been already explained, it is obvious that nothing definite can be inferred from earlier statements respecting the proportion of carbonates in the water of the great oceans. The carbonic acid determinations performed by Buchanan with water from the Atlantic Ocean (he had recourse to evaporation, adding first chloride of barium, and then attempting, unsuccessfully, to detect carbonic acid in the residue by means of strong hydrochloric acid) would appear to fix a limit for the maximum amount of carbonates contained in sea-water; but such is not really the case.

The presence of insoluble sulphates serving, as is known, to protect carbonates against decomposition, even when concentrated sulphuric acid is made use of to expel the carbonic acid, it was necessary for this reason alone to modify the process devised by Fresenius and Will for determining carbonic acid in neutral carbonates.<sup>1</sup> Hence, the experiments performed by Buchanan with a view to detect carbonic acid in the residue, cannot be regarded as affording conclusive proof of its absence; indeed, he himself, as appears from his statements, is clearly of the same opinion.

In order to ascertain whether the decomposition by boiling of the neutral carbonates in sea-water also took place to a considerable extent when insoluble sulphates were present in that fluid, I made a few experiments by Buchanan's process. From several samples of sea-water which, examined by the method I adopted, were found to contain 96<sup>000</sup> of carbonic acid per litre, I succeeded, by evaporation to dryness, after adding a solution of chloride of barium, in liberating about 50<sup>000</sup> only, with a solitary exception, when the amount exceeded 50<sup>000</sup> per litre. The proportion of carbonic acid expelled was accordingly not much greater than that determined by Buchanan in water from the Equatorial Seas, and but a few milligrammes in excess of what the carbonic acid forming bicarbonates, according to trustworthy observations, should have been, of the carbonates said to be still present in the residue, I failed to detect any trace.

The amount of the carbonates contained in the water of the Southern Seas must, therefore, be still regarded as an open question.

It is to be hoped, that some of the samples of water collected on the 'Challenger' Expedition still remain, in which case their examination will serve to throw further light on the subject.

After this Memoir had been written in Norwegian, but previous to its translation into German, the 2nd and 3rd Parts of Fresenius' Zeitschrift für anal. Chemie for 1879 came to hand, in which E. Boddig has published a paper<sup>2</sup> on transformations, observed by him in mineral waters, resulting from the reciprocal action of carbonate of

<sup>1</sup> Fresenius, Quant. Analyse, 5te Aufl. 364 fbl.

<sup>2</sup> Fresenius' Zeitschrift, 18 — 196.

<sup>1</sup> Fresenius, Quant. Analyse, 5te Aufl. 364 fbl.

<sup>2</sup> Fresenius' Zeitschrift, 18, p. 196.

sur Magnesia, som fuldstændig svare til, hvad jeg efter de foran beskrevne Observationer har fundet for Søviands Vedkommende. Disse Omsætninger kunne saaledes, idet de ere næftagne af to af hinanden uafhængigt arbejdende Chemikere, uden videre Begrundelse antages fuldstændig factiske.

Det vil id dette Bøhligs Arbejde sees, at han allerede Sommeren 1878 over det samme Thema har publiceret en Afhandling,<sup>1</sup> som jeg ikke tidligere har været opmærksom paa. Den vilde dog ikke have nogen væsentlig Indflydelse paa mine Undersøgelser, saadan de vigtigste af de Observationer, der ligger for mig frem til de samme Resultater, som Bøhlig først har beskrevet, allerede vare udførte 3-4 Maanedes, førend hans første Afhandling forelaa trykket.

lime and sulphate of magnesia, which precisely agree with those I have described as occurring in sea-water. These transformations having accordingly been observed by two chemists working independently of each other, may without further proof be accepted as facts.

From the said paper, it appears that Bøhlig published a treatise on the same subject in the summer of 1878,<sup>1</sup> to which my attention had not previously been directed. It would not, however, have materially influenced my experiments, the most important of the observations that led me to the results which Bøhlig was the first to describe, having been instituted 3 or 4 months before his first treatise had left the press.

<sup>1</sup> Fresenius' Zeitschrift 17 = 301.

<sup>1</sup> Fresenius' Zeitschrift, 17, p. 20.

### III. Om Saltholdigheden af Vandet i det norske Nordhav.

Hvor det gjælder at tilveiebringe Oplysninger om Variationerne af Salthængslerne i Havvandet, kan man til sine Salthestemmelser benytte flere forskjellige Methoder, som hver især tilligere har fundet udstrakt Anvendelse. Den nærmest liggende af disse bestaar i Vandets Ablaapning og derpaa følgende Tørring og Veining af de som Residuum tilbageblivende Salte, en Fremgangsmaade, som rigtignok directe fører til Maalet, men som til Gjengjæld ogsaa fordrer temmelig meget Arbeide. Som mere milde men ogsaa ulige mindre besværlige Methoder kan ogsaa anvendes Bestemmelse af Havvandets Chloræmængde<sup>1</sup> eller Egenvægt, hvorefter man gennem passende bestemte Coefficienter kan beregne den samlede Salthængsle, forudsat, at man kan antage et constant indbyrdes Forhold mellem de i Søvandet indeholdte faste Bestanddele. Den første af disse Methoder medfører foruden Besværligheder ved Udørelsen ogsaa den Ulempe, at den ikke lader sig anvende ombord paa et Fartoi i aaben Sø, hvor Skibets Byggesel forbyder Brugen af Vægt, medens Egenvægtsbestemmelser ved Hjælp af Areometre og volumetriske Chlorbestemmelser meget letvandt og med temmelig stor Nøjagtighed kan udføres ombord selv i temmelig uroligt Veir.

Hvor man derfor ikke tror sig sikker paa at kunne opbevare Vandproverne i længere Tidsrum uden derved at risikere, at de undergaa Forandringer, som kunde ytre en skadelig Indflydelse paa Resultaterne af de erholdte Salthestemmelser og, hvor man som Følge deraf maa lægge Hovedvægten paa en hurtig Undersøgelse af Vandproverne i frisk Tilstand, bliver man saaledes adskillende henvist til Brugen af Chlorbestemmelser eller Egenvægtsbestemmelser som Maal for den samlede Saltgehalt.

Paa det første af den norske Expedition's Togter blev af Svendsen, hvem de chemiske Observationer dengang vare

<sup>1</sup> Saavel her som overalt senere forstås ved Chloræmængde den samlede Chlor- og Bromæmængde.

### III. On the Amount of Salt in the Water of the Norwegian Sea.

When seeking to investigate the degree in which the proportion of salt varies in sea-water, choice may be made for performing the salt-determinations between several methods, each of which has in turn been extensively adapted. The most simple process, is first to evaporate the water, and then dry and weigh the salts left in the residue, a mode of operation which, though leading direct to the desired result, involves considerable labour. Two other methods, not so direct, but far less tedious, consist in determining either the specific gravity of the water or the amount of chlorine<sup>1</sup> it contains, from which, by means of proper coefficients, the total amount of salt may be computed, provided always that a constant proportion can be assumed to exist between the solid constituents of sea-water. The first process is attended, irrespective of the troublesome mode of operation, with another drawback, viz. the impracticability of adopting it on board ship in the open sea, where the motion of the vessel altogether precludes the use of the balance, whereas both specific gravity determinations, with the hydrometer, and volumetric determinations of chlorine, may be performed at sea with the greatest ease, and very considerable accuracy, even in comparatively rough weather.

Hence, when there is reason to fear that the samples of water cannot be preserved for any length of time without exposing them to chemical change, which might exert a disturbing influence on the results; and whenever, accordingly, weight must be chiefly attached to their immediate examination, the only practicable standard of measurement for computing the total amount of salt will be that furnished by determinations of chlorine or of specific gravity.

On the first voyage of the Norwegian Expedition, Svendsen, who then, as previously stated, did the chemical

<sup>1</sup> By "the amount of chlorine," here and elsewhere throughout this Memoir, is understood the total amount of chlorine and bromine.

overdragne, til Undersøgelser over Saltgehalten udelukkende anvendt Egenvægtsbestemmelser, hvorimod jeg paa de to sidste Togter ved Siden af disse ogsaa har udført et større Antal Chlorititreringer for gjennem denne Control at give Resultaterne en større Sikkerhed.

Til Undersøgelser over den i Søvandlet indholdte Chlormængde medhavdes paa de to sidste Togter foruden Søopløsning af saadan Styrke, at 1 CC. af denne centrent svarede til 1 CC. Søvand, ogsaa 2 paa første Togt indsamlede Vandprover, bestemt til som Normaler at tjene til den nøjagtigere Fastsettelse af Søopløsningens Styrke. Disse Normalers Chlormængde i Procenter blev ved omhyggeligt udførte Venningsanalyser hvert Aar bestemt saavel for Expeditionens Idrøise som efter dens Hjemkomst bestandig med meget nær det samme Resultat, hvorhos tillige deres Egenvægter ved Hjælp af Areometret omleed aflestes. Til Brug ved alle omleed udførte Chlorititreringer tjente kun to Buretter af lignende Construction og Størrelse, de samme, som af Stipendiat A. Helland anvendtes ved de Bestemmelser af Chlormængderne i Overfladevandet i Atlanterhavet, som denne foretog i Aaret 1875 paa en Reise til Grønland, de ldeve at han den Gang calibrerede ved Hjælp af Kviksølv og befundne særdeles tjendige for Ojemedet.

Ved Buretternes Brug fyldtes den ene med Søopløsning den anden med det til Undersøgelse bestemte Søvand, hvorefter en passende Portion Søvand fra den ene under Omrystning tilsattes Søopløsning fra den anden, indtil al Chlor var udfælt, idet chromsurt Kali tjente som Index. Begge Buretters Stand aflestes nu, og nogle Draaber Søvand tilsattes ietter til Afsløvning, hvorefter paany fulgte Tilsætning af Søopløsning og Afsløvning af Buretternes Stand o. s. v. Gjennem en Række af 4 à 5 paa hinanden følgende lignende Afsløvninger erholdtes paa denne Maade de fornødne Data til Beregning af det Volum Søvand, som i hvert enkelt Tilfælde svarede til 1 CC. Søopløsning.

Paa denne Maade sammenlignedes paa den ene Side Søvandsproverne og paa den anden Side ogsaa fra Tid til anden de medbragte Normaler med Søopløsningen, idet der altid sørgedes for, at Vandprovernes og Oplosningernes Temperatur ikke fjernede sig synderlig meget fra hinanden. Buretterne ldeve for at tilveiebringe en ledst mulig Aildevning hyppig rensede med concentreret Svovlsyre.

At de gjennem disse Observationer erholdte Tal er senere Søvandets Chlormængde Jeregnet efter følgende Formel

$$p = \frac{KSP}{ks}$$

hvor  $p$  betegner den undersøgte Vandproves Chlormængde i Procenter,  $k$  det Antal CC. af samme, der svare til 1 CC. Søopløsning og  $s$  dens Egenvægt ved 17.5 C.,  $P$  Middeltallet mellem de to Udveisen og efter Hjemkomsten i Normalen fundne Chlormængder,  $K$  det Antal CC., som af denne svarer til 1 CC. Søopløsning og  $S$  dens Egen-

work, made exclusive use of specific gravity determinations; but for a considerable number of my own observations, on the last two cruises, I also adopted titration for chlorine as a means of testing the general accuracy of the results.

For estimating the amount of chlorine in sea-water, I took with me, on the two last cruises, besides a solution of silver of such strength that 1<sup>cc</sup> of the fluid about corresponded to 1<sup>cc</sup> of sea-water, also 2 samples of water collected on the first voyage, to serve as a normal standard by which to determine the strength of the solution of silver. Each year, both previous to the departure of the Expedition and after its return, the chlorine in these standard samples was carefully determined by weighing, and the percentage calculated accordingly, their specific gravity too, as shown by the areometer on board, having been likewise noted down. For all chlorine-titrations performed at sea, there were only two burettes in use, similar alike in size and construction. — those used by Mr. Helland for determining the amount of chlorine in the surface-water of the Atlantic on a voyage to Greenland in 1875; he had calibrated them by means of mercury, and they proved excellently adapted for the purpose.

When using the burettes, one was filled with solution of silver and the other with the sea-water selected for examination, after which solution of silver was added to a proper quantity of the sea-water, while shaking the flask in which the titration was performed till all chlorine had been precipitated, chromate of potassium serving as the index. The height of the fluid in both burettes was now read, and a few drops of sea-water added to the mixture, to decolor it, after which solution of silver was again added, and the height of the fluids read as before, &c. After the height had been thus read 4 or 5 times in succession, the necessary data were obtained for computing the volume of sea-water, which in each individual case corresponded to 1<sup>cc</sup> solution of silver.

In this manner, were compared on the one hand the freshly drawn samples of sea-water, and on the other, from time to time, also the standard samples, with the solution of silver, care being taken to keep the samples of water and the solution as near as possible at the same temperature. In order to prevent any portion of the fluid from adhering to the burettes, they were frequently rinsed with concentrated sulphuric acid.

With the figures obtained from these observations, the amount of chlorine in sea-water was afterwards determined by the following formula —

$$p = \frac{KSP}{ks}$$

in which  $p$  signifies the percentage of chlorine in the sample of water examined,  $k$  the proportion in cubic centimetres representing 1<sup>cc</sup> of the solution of silver, and  $s$  the specific gravity of the water at 17.5 C.;  $P$  the mean between the amounts of chlorine found in the standard sample before the departure and after the return of the

vægt ved  $17^{\circ} 5$  C. Disse Observationer bleve dog selv paa de to sidste Togter ikke anstillede i samme Udstrækning som Egenvægtsbestemmelserne, der ogsaa oprindeligt vare bestemte til i første Række at tjene som Maal for den samlede Saltgehalt.

Expeditionen var for Egenvægtsbestemmelser forsynet med flere Sæt Glasareometre fra Dr. Kuehler i Hmenau, indrettede til at vise Søvandets Egenvægt ved  $17^{\circ} 5^1$ , saaledes at et Sæt viste Egenvægter fra 1 til 1.007, et andet fra 1.006 til 1.013, et tredje fra 1.012 til 1.019, et fjerde fra 1.018 til 1.025 og et femte fra 1.024 til 1.031. Areometrene vare inddelte i Delstreger af Værdi 0.0002, medens Afstanden mellem disse Delstreger paa Scalaen løb sig til meget nær  $1.5^{mm}$ , saaledes at man maatte kunne aflæse uden stor Feil det 5te Decimal. Under Aflesningen af Vandprovernes specifikke Vægt anbragtes disse i en i dalelt Slingreløide opbængt Glas cylinder, hvis indre Diameter løb sig til omtrent det tredobbelte af Areometrets Corpus, hvorefter dette omhyggeligt renses og afførret neddykkedes i Vædsken og tillodes at svømme frit i nogen Tid, indtil det havde antaget Vandets Temperatur. Aflesningen foretoges nu langs den indre Rand af Vædskens Niveau, idet samtidig Vandets Temperatur iagttoges paa et controlleret Thermometer, inddelt i Delstreger af Værdi 0.2.

Paa Grund af det at Expeditionen benyttede Dampskibets fortrinlige Egenskaber som Solskil reddte disse Observationer i nogenlunde roligt Veir ingenlunde Vanskeligheder, selv naar Kursen sættes ret mod Vinden, hvorimod Skibets Dayning i meget haardt Veir altid ytrede sig i mærkbare om end smaa Bevægelser hos Areometret. Hvor Vandproverne optoges i saa roligt Veir, at Bestemmelsen paa Grund deraf kunde medføre foretaget Usikkerhed, bleve de altid hensatte nogle Dage, indtil de kunde undersøges under mere gunstige Vilkaar.

Disse saaledes aflæste Egenvægter maas imidlertid i 2 Henseender forbedres, idet man paa den ene Side maas anvende passende Correctioner for at faa de ved meget forskellige Temperaturer aflæste Egenvægter reducerede til den fælles Normaltemperatur  $17^{\circ} 5$ , og paa den anden Side maas løsrive dem for Areometrenes constante Feil.

Hvad for det Første Correctionerne for Temperaturen angaar, da give de af flere Videnskabsmænd udførte Bestemmelser af Søvandets Volumforandring med Temperaturen Midlerne til at beregne disse, idet lænde Hubbard<sup>2</sup>, L. F.

Expedition, K these amounts in cubic centimetres corresponding to 1<sup>cc</sup> of the solution of silver, and S the specific gravity of the standard sample at  $17^{\circ} 5$  C. These observations, however, were not instituted even on the two last voyages to the same extent as those based on determinations of specific gravity, the method by which, as originally agreed upon, the total amount of salt was to be chiefly computed.

For performing specific gravity determinations, the Expedition had been supplied by Dr. Kuehler of Hmenau with divers sets of glass areometers, adapted to show the specific gravity of sea-water at  $17^{\circ} 5^1$ , one set indicating specific gravities from 1 to 1.007, another from 1.006 to 1.013, a third from 1.012 to 1.019, a fourth from 1.018 to 1.025, and a fifth from 1.024 to 1.031. The areometers were graduated in degrees of 0.0002, the interspaces on the scale measuring however very nearly  $1.5^{mm}$ ; and hence you could read off with comparative accuracy to the fifth decimal. When about to read the specific gravity, the samples of water were poured into a glass cylinder suspended in gimlets, the inner diameter of the cylinder being triple that of the areometer, which, carefully wiped and dried, was immersed in the fluid and suffered to float freely for some time till of the same temperature as the water. The specific gravity was now read in the ordinary way, the temperature of the water, as shown by a tested thermometer graduated in fifths of a degree Centigrade, being simultaneously observed.

The steamer selected for the Expedition being an excellent sea-boat, these observations were attended with no difficulty whatever in moderately fair weather, even when steaming dead against the wind, pitching, however, was found to have a distinctly disturbing effect on the areometer, and therefore all samples of water drawn when it was in any way violent, so as to give reason for apprehending greater uncertainty in the determinations if performed at once, were stored for a few days, till the weather had improved.

These readings of specific gravity have, however, a twofold need of correction, arising on the one hand from the very different temperatures at which the specific gravities were read, involving the necessity of their reduction by proper corrections to the normal temperature  $17^{\circ} 5$ , and on the other, the constant error of the areometer, which has also to be eliminated.

As regards the corrections for temperature, these may be computed by the determinations performed by divers men of science of the extent to which the volume of sea-water varies with the temperature, Hubbard,<sup>2</sup> L. F.

<sup>1</sup> Næst her som ofte senere bruges Betegningsmaaden Egenvægt ved  $\frac{r^m}{p^m}$ , da næsten decaud Egenvægt ved  $r^m$  i Forhold til destilleret Vand af  $T^m$  som Edded. Alle Temperaturangivelser i denne Afhandling ere udtrykte i Grader Celsius.

<sup>2</sup> Maury's Sailing Directions, 1858, — 1 — 247.

<sup>1</sup> The expression, specific gravity at  $\frac{r^m}{p^m}$  signifies specific gravity at  $r^m$ , with distilled water of  $T^m$  as the unit of comparison. All statements of temperature in this Memoir are given in degrees Celsius.

<sup>2</sup> Maury's Sailing Directions, 1858, 1, p. 247.

Ekman<sup>1</sup> og Thorpe og Rücker<sup>2</sup> har givet meget fuldstændige Tabeller over Søvandets Volumina ved forskellige Temperaturer, hvorhos tillige ogsaa Dr. Karsten<sup>3</sup> har opstillet en Correctionstabel, hvorefter man kan reducere de ved vilkårlige Temperaturer afleste Egenvægter til 17.5. Sammenstiller man de Corrections, som efter disse Lagtægelser kunne beregnes, erholder man imidlertid især for de lavere Temperaturer meget daarligt overensstemmende Værdier, idet der kan optræde Differenter, der endog kan overskride 0.0004, mellem de af Ekman's og Hubbard's Observationer beregnede Corrections, hersker der den største Overensstemmelse, men ogsaa her gaar Differentserne paa enkelte Puncter op til meget nær 0.0001. I Betragtning af disse tildels temmelig betydelige Uoverensstemmelser mellem de hidtil publicerede Undersøgelser af denne Art kunde det ikke findes uløseligt endnu engang at gjenoptage Bestemmelserne af Søvandets Volumina ved forskellige Temperaturer, og jeg besluttede mig derfor til gennem egne Undersøgelser at forvisse mig om, hvilken af de opstillede Tabeller der bedst svarede til Udvidelsen af det i det norske Nordhav liggende Vand. Dels i dette Øjemed dels for at bestemme de benyttede Arcometres Corrections og de Constante, hvormed Chlorprocenterne og Decimalerne i Egenvægten maatte multipliceres for at give Saltmængden, har jeg anstillet Undersøgelser med følgende Vandprover.

Station.	Bredde	Længde fra Greenwich	Dybde	
			Eng. Fm.	Meter.
245	68° 21'	2° 5' V.	0	0
247	68 5.5	2 24 O.	500	941
253	Skjærstadfjord.		0	0
254	67° 27'	13° 25'	0	0
284	73 1	12 58	0	0
300	73 10	3 22 V.	0	0
349	76 30	2 57 O.	1487	2719
362	79 50	5 49	0	0

hvilke jeg for Kortheds Skyld i den Orden, hvori de her findes opførte, vil betegne med I, II o. s. v. indtil VIII. Til Bestemmelse af Søvandets Udvidelse benyttede jeg et Sprengel's Pycnometer<sup>4</sup>, forarbejdet af to Stykker meget tynde Glasrør af et og samme Rør med en indvendig Diameter af omtrent 13<sup>mm</sup>. Rørene vare nedentil sammenloddede ved Hjælp af et snævert kort u-formig højt Glasrør og oventil paaloddede knæformig bojede solide Capillarrør med meget fin Aabning. Ved Paalodningen af disse Glasrør blev der saa meget som muligt draget Omsorg for, at kun en liden Del af de videre Rør udsattes for Opvarmning over Blæselampen, forat ikke Apparatet derved skulde

Ekman<sup>1</sup>, and Thorpe and Rücker<sup>2</sup> having prepared comprehensive Tables to show the volume of sea-water at different temperatures; Dr. Karsten<sup>3</sup>, too, has published a Table of Corrections by which specific gravities read at any temperature may be reduced to 17.5. Meanwhile, on comparing together the corrections computed from these observations, the values obtained, more especially for low temperatures, are found to agree but very indifferently, the difference in some cases exceeding even 0.0004. The agreement is closest between the corrections computed from Ekman's and Hubbard's observations; but here, too, the difference for some temperatures amounts to very nearly 0.0001. Considering, therefore, the want of uniformity, in some cases very considerable, exhibited by such observations of this kind as had till then been made public, it could not be deemed superfluous to investigate anew by a further series of experiments the variation in volume which sea-water is found to undergo at different temperatures; and hence I determined on ascertaining from the results of my own observations which of the aforesaid Tables corresponded best with the expansion of the water in the Norwegian Sea. Partly with this object in view, and partly in order to determine the corrections for the arcometers and the constants by which the percentages of chlorine and the decimals of specific gravity had to be multiplied when computing the amount of salt, I examined the following samples of water: —

Station.	Latitude.	Longitude from Greenw.	Depth	
			Eng. Fath.	Meters.
245	68° 21'	2° 5' W.	0	0
247	68 5.5	2 24 E.	500	941
253	The Skjærstad Fjord.		0	0
254	67° 27'	13° 25'	0	0
284	73 1	12 58	0	0
300	73 10	3 22 W.	0	0
349	76 30	2 57 E.	1487	2719
362	79 50	5 49	0	0

which I will indicate, for the sake of brevity, by the Roman numbers from I to VIII, and in the order in which they are given here. For determining the expansion of the sea-water, I made use of Sprengel's pycnometer<sup>4</sup> the instrument was constructed of two pieces of glass tubing, cut off from the same length, with an inner diameter of about 13<sup>mm</sup>. These tubes were sealed together at their lower ends by means of a short, narrow glass tube, bent into the form of the letter U, and had strong knee-shaped capillary tubes sealed on to their upper extremities. When sealing on these glass tubes, the greatest care was taken to confine the heat from the glass-blower's lamp to as small a portion

<sup>1</sup> Kungl. Svenska Vetenskapsak. Handl. 1870. — 1.

<sup>2</sup> Proc. Roy. Soc., 24. p. 159.

<sup>3</sup> Tafeln zur Berechnung der Beobachtungen an den Küstenstationen u. s. w. Kiel 1874.

<sup>4</sup> Pogg. Ann. 150. — 459.

<sup>1</sup> Kungl. Svenska Vetenskapsak. Handl. 1870. 1.

<sup>2</sup> Proc. Roy. Soc., 24. p. 159.

<sup>3</sup> Tafeln zur Berechnung der Beobachtungen an den Küstenstationen u. s. w. Kiel 1874.

<sup>4</sup> Pogg. Ann. 150. p. 459.



antage en anden Udvidelsecoefficient end den, det anvendte Glasrør oprindelig havde. Pyknometret blev først omkring 4 Maaned, efterat det var blest taget i Brug til de Forsøg, som her skulle beskrives, forat ikke den for alle Glasgjenstande eendammelige Contraction gennem de første Maaned efter deres Blesning skulde bidrage til i mærkelig Grad at forandre dets Vidum under Observationernes Udførelse. Pyknometret benyttedes ved de første Forsøg uden nogen Sikkerhedskugle, men maatte senere, hvor det fyldtes ved lavere Temperaturer, forsynes med en saadan, indrettet til at trækkes ind over det ydre Capillarrør. Apparatet uden Sikkerhedskugle vil jeg for Kortheds Skyld betegne som Pyknometer No. 1 og med Sikkerhedskugle som Pyknometer No. 2. Ved Hjælp af disse udførtes følgende Forsøg i den Orden, hvori de her findes opførte.

Pyknometer med Indhold.	Vægt Gr.	I Luft af sp. Vægt.
1. Pykn. No. 1 tomt . . . . .	15.9222	0.001200
2. — - 1. " " " " " " . . . . .	15.9223	0.001200
3. — - 1 med rent Vand af 17.5 . . . . .	44.3153	0.001200
4. — - 1 " " " " " " " 17.5 . . . . .	44.3159	0.001201
5. — - 1 " " " " " " " 17.5 . . . . .	44.3151	0.001201
6. — - 1 " III . . . . .	44.8097	0.001201
7. — - 1 " III . . . . .	44.8093	0.001201
8. — - 1 " VII . . . . .	45.0742	0.001200
9. — - 1 " VII . . . . .	45.0738	0.001200
10. — - 2 tomt . . . . .	18.5665	0.001194
11. — - 2 med I . . . . . af 0. . . . .	47.7869	0.001198
12. — - 2 " I . . . . . " 0. . . . .	47.7873	0.001198
13. — - 2 " I . . . . . " 0. . . . .	47.7871	0.001199
14. — - 2 " I . . . . . " 17.5 . . . . .	47.7249	0.001201
15. — - 2 " I . . . . . " 17.5 . . . . .	47.7249	0.001201
16. — - 2 " I . . . . . " 20. . . . .	47.7085	0.001198
17. — - 2 " I . . . . . " 20. . . . .	47.7087	0.001198
18. — - 2 " I . . . . . " 8. . . . .	47.7696	0.001200
19. — - 2 " I . . . . . " 8. . . . .	47.7702	0.001200
20. — - 2 " I . . . . . " 4. . . . .	47.7819	0.001200
21. — - 2 " I . . . . . " 4. . . . .	47.7808	0.001200
22. — - 2 " I . . . . . " 13. . . . .	47.7487	0.001198
23. — - 2 " I . . . . . " 13. . . . .	47.7481	0.001198
24. — - 2 med rent Vand . . . . . af 0. . . . .	46.9773	0.001194
25. — - 2 " " " " " " " 0. . . . .	46.9770	0.001194
26. — - 2 tomt . . . . .	18.5658	0.001191
27. — - 1 " " " " " " " " . . . . .	15.9216	0.001191
28. — - 2 " " " " " " " " . . . . .	18.5659	0.001231
29. — - 1 " " " " " " " " . . . . .	15.9213	0.001231

Til Bestemmelse af Udvidelsecoefficienten af det anvendte Glas forarbejdedes af det samme Glasrør et andet engrenet Pyknometer nedentil tilsaltet og ovenfor forsynet med et Capillarrør, idet der ogsaa her sørges for Opvarmning af en saa liden Del af Røret som muligt. Ved

as possible of the wider tubes, lest it should give to the apparatus a coefficient of expansion different to that which the glass tubes originally had. The pycnometer was not made use of for the experiments to be described here, till about 4 months after the tubes of which it consisted had been sealed together; for the contraction peculiar to all articles of glass throughout the first few months after they have been blown might otherwise have occasioned an appreciable change in its volume during the progress of the observations. For the first experiments, the pycnometer was used without a receiver, but subsequently, when filled at a lower temperature, one had to be provided, adapted so as to admit of its being drawn over the capillary tube. The apparatus when used *without* a receiver I shall designate for the sake of brevity 'Pycnometer No. 1,' and when used *with* a receiver, 'Pycnometer No. 2.' By means of this instrument the following experiments were performed, in the order in which they are here arranged.

Pycnometer with Contents.	Weight in Grammes.	In Air with a Sp. Gr. of . . . . .
1. Pycn. No. 1 empty . . . . .	15.9222	0.001200
2. — - 1 " " " " " " " " . . . . .	15.9223	0.001200
3. — - 1 with pure water of 17.5 . . . . .	44.3153	0.001200
4. — - 1 " " " " " " " 17.5 . . . . .	44.3159	0.001201
5. — - 1 " " " " " " " 17.5 . . . . .	44.3151	0.001201
6. — - 1 " III . . . . .	44.8097	0.001201
7. — - 1 " III . . . . .	44.8093	0.001201
8. — - 1 " VII . . . . .	45.0742	0.001200
9. — - 1 " VII . . . . .	45.0738	0.001200
10. — - 2 empty . . . . .	18.5665	0.001194
11. — - 2 with I . . . . . of 0. . . . .	47.7869	0.001198
12. — - 2 " I . . . . . " 0. . . . .	47.7873	0.001198
13. — - 2 " I . . . . . " 0. . . . .	47.7871	0.001199
14. — - 2 " I . . . . . " 17.5 . . . . .	47.7249	0.001201
15. — - 2 " I . . . . . " 17.5 . . . . .	47.7249	0.001201
16. — - 2 " I . . . . . " 20. . . . .	47.7085	0.001198
17. — - 2 " I . . . . . " 20. . . . .	47.7087	0.001198
18. — - 2 " I . . . . . " 8. . . . .	47.7696	0.001200
19. — - 2 " I . . . . . " 8. . . . .	47.7702	0.001200
20. — - 2 " I . . . . . " 4. . . . .	47.7819	0.001200
21. — - 2 " I . . . . . " 4. . . . .	47.7808	0.001200
22. — - 2 " I . . . . . " 13. . . . .	47.7487	0.001198
23. — - 2 " I . . . . . " 13. . . . .	47.7481	0.001198
24. — - 2 with pure water . . . . . af 0. . . . .	46.9773	0.001194
25. — - 2 " " " " " " " 0. . . . .	46.9770	0.001194
26. — - 2 empty . . . . .	18.5658	0.001191
27. — - 1 " " " " " " " " . . . . .	15.9216	0.001191
28. — - 2 " " " " " " " " . . . . .	18.5659	0.001231
29. — - 1 " " " " " " " " . . . . .	15.9213	0.001231

For determining the coefficient of expansion of the glass, a single-branched pycnometer was constructed, of the same length of glass tubing, with the lower opening sealed up and the upper extremity bearing a capillary tube, care being taken, as before, not to heat a greater part of the large tube than

Hjælp af dette Apparat, som ved et Stykke Kautschukrør var forlændet med et lidet Reservoir, bestemt til Opfangelse af den ved mlig Opvarmning udskudte Del af Indholdet, bestemtes nu Udvidelsescoefficienten af det anvendte Glasrør med rensset Kviksølv, som nogen Tid før Forsøgenes Udførelse under Følgesning påfyldtes Pyknometret. Med dette Apparat, som jeg vil betegne som Pyknometer No. 3, udførtes til den Ende følgende Vejninger:

Pyknometer med Indhold.	Vægt Gr.	I Luft at sp. Vægt.
30. Pykn. No. 3 tomt . . . . .	10,8654	0,001214
31. — - 3 " . . . . .	10,8653	0,001214
32. — - 3 med Kviksølv af 0° . . . . .	105,0265	0,001215
33. — - 3 " " " 0 . . . . .	105,0265	0,001215
34. — - 3 " " " 20 . . . . .	105,3588	0,001205
35. — - 3 " " " 20 . . . . .	105,3502	0,001205
36. — - 3 " " " 15 . . . . .	105,4003	0,001205
37. — - 3 " " " 0 . . . . .	105,0276	0,001205
38. — - 3 tomt . . . . .	10,8650	0,001203
39. — - 3 med rent Vand af 4° . . . . .	24,4621	0,001202
40. — - 3 " " " " 4 . . . . .	24,4634	0,001190

Alle disse Vejninger ere udførte efter Substitutionsmetoden ved Aflesning af Syngninger paa en Vægt, hvis Følsomhed uden Belastning løb sig til 1,4 Mgr. pr. Delstreg og for stigende Belastning temmelig jævnt aftog indtil 1,9 Mgr. ved 200 Gr. Belastning. Til disse saavel som alle finere Vejninger, som jeg har foretaget i Anledning af disse Arbejder, benyttedes en Platinalodsats fra Delenil i Paris, hvis Correctioner jeg i Forveien havde bestemt ved flere vel overensstemmende Vejninger paa en af P. Bunge forarbejdet fortrinlig Vægt, hvis Følsomhed for de her omhandlede Belastninger løb sig til omkring 0,14 Mgr. Ved Vejningerne iagttoges altid Temperatur og Barometerstand af Luften i Veiværelset, hvorimod dens Fugtighedsgrad i Mangel af Observation passende ansattes, en Mangel, der ikke har nogen mærkelig Indflydelse paa Forsøgenes Paalidelighed, da selv en saa grov Feil i Ansættelsen af Luftens relative Fugtighed som 25 % under de her omhandlede Forhold kun virker paa det endelige Resultat med en lidet Feil i 6te Decimal. Efter disse Data er Luftens specifikke Vægt under Vejningerne paa vandig Maade beregnet og opført i Tabellen. Pyknometret blev for hver særskilt opført Vejning indstillet paa ny for Temperaturen 0° i finstedt Is og forøvrigt i Vandbad, hvis Temperatur under stadig Omrøring holdtes constant, ligesom det mindst en Gang for hver anden Vejning tomtes og fyldtes igjen med det Sovand, hvis Vægt skulde bestemmes. Ingen Indstilling toges for god, med mindre det lykkedes i mindst 15 Minutter at holde Temperaturen saa constant, at Thermometret ingensinde viste Variationer af 0,1 eller derover. Til Brug ved Aflesning af Vandbadets Temperatur tjente

absolutt unødvendigt. With this apparatus, which was connected by a caoutchouc tube with a small receiver for collecting any portion of the contents that, in the event of the instrument becoming warmer might possibly be expelled, the coefficient of expansion of the glass tube was now determined by means of purified mercury, which, shortly before the commencement of the experiment, had, when boiling out the air, been introduced into the pycnometer. With this apparatus, which I will designate 'Pycnometer No. 3,' were performed the following determinations of weight: —

Pycnometer with Contents.	Weight in Grammes.	In Air with a Sp. Gr. of
30. Pycn. No. 3 empty . . . . .	10,8654	0,001214
31. — - 3 " . . . . .	10,8653	0,001214
32. — - 3 with mercury of 0° . . . . .	105,0265	0,001215
33. — - 3 " " " 0 . . . . .	105,0265	0,001215
34. — - 3 " " " 20 . . . . .	105,3588	0,001205
35. — - 3 " " " 20 . . . . .	105,3502	0,001205
36. — - 3 " " " 15 . . . . .	105,4003	0,001205
37. — - 3 " " " 0 . . . . .	105,0276	0,001205
38. — - 3 empty . . . . .	10,8650	0,001203
39. — - 3 with pure water " 4° . . . . .	24,4621	0,001202
40. — - 3 " " " " 4 . . . . .	24,4634	0,001190

These weight-determinations were all performed according to the substitution method, by reading the oscillations of a balance, the sensibility of which, when not loaded, amounted to 1,4<sup>mgr</sup> for every division of the scale, diminishing, on being loaded with successive weights, at a comparatively uniform rate down to 1,9<sup>mgr</sup>, when loaded with 200<sup>gr</sup>. For the above-mentioned as for all accurate weight-determinations involved in these labours, I made use of a set of platinum weights procured from Delenil in Paris, the corrections of which I had previous to starting on the Expedition computed from a series of closely agreeing determinations of weight performed with an excellent balance (made by P. Bunge), its sensibility when loaded to the extent here specified being nearly 0,14<sup>mgr</sup>. When performing the weight-determinations, the temperature and the atmospheric pressure in the room were always observed, but the relative humidity not having been found by observation had to be roughly estimated, a source of inaccuracy which however can exert no appreciable influence on the trustworthiness of the experiments, seeing that an error of even 25 per cent in the computation of the relative humidity of the atmosphere would affect the final result only by occasioning a very small error in the 6th decimal. From these data, the specific gravity of the air during the process of weighing was computed in the usual manner, and entered in the Table. For each successive determination, the pycnometer was placed in finely crushed ice, to give it the temperature of 0°, and for every other required, in a water-bath, which by constant stirring was kept at an equal temperature; it was emptied,

et Thermometer, inddelt i Delstreges af Værdi 0,2 med en Længde af 0,68<sup>mm</sup>, hvis Correctioner bestemtes ved gjentagne Sammenligninger med det hervedværende meteorologiske Instituts Normalthermometer, som til det Brug velvillig blev mig laant af Institutets Bestyrer, Professor Dr. Mohr.

Af Observationerne 32 til 37 kan først Udvildelsen af det til Pyknometrene benyttede Glasrør beregnes, og man erhobber, naar de af Willner<sup>1</sup> beregnede Værdier for Kviksølvets Udvildelse lægges til Grund, som Udtryk for Glassets midlere Udvildelsescoefficient mellem 0 og 15: 0,0000267 og mellem 0 og 20: 0,0000274. Man kan desuden ogsaa benytte Observationerne 3, 4 og 5 i Forbindelse med 24 og 25 til Beregning af Glassets Udvildelse og erholder, naar man anvender de af Hällström<sup>2</sup> og Rosetti<sup>3</sup> bestemte Værdier for Vandets Udvildelse, meget vel overensstemmende Tal, som i Mådel, fastsatte Glassets midlere Udvildelsescoefficient mellem 0 og 17,5 til 0,0000275. Efterat man heraf har bestemt en passende Værdi for Glassets Udvildelse, hvorved naturligvis de med Kviksølv indførte Bestemmelser fortrinsvis maa komme i Betragtning, kan man nu skride til Udvildelsen af de videre Resultater af Forsøgene. Man maa imidlertid her tage Hensyn til, at Observationerne 1, 2, 10, 26, 27, 28 og 29 tydeligt bevise, at Pyknometret under Forsøgene har tabt omkring 0,7 Mgr. i Vægt, hvad der rimeligvis skriver sig fra Oplosning af en Del af Glasret paa de ydre Vægge paa Grund af den stadige Omrøring i Bålet. Den herved formaaelige Usikkerhed kan dog betydelig reduceres, naar man beregner Pyknometrets Vægt til enhver Tid under Forudsætning af, at Vægttabet er proportionalt med Observationernes Antal, idet Usikkerheden da kun nok vil influere paa 5te Decimal. Under denne Forudsætning har jeg senere beregnet følgende Resultater, idet jeg paa enkelte Steder har tilladt mig smaa Approximationer, som imidlertid kun kan virke paa de endelige Værdier med en liten Feil i 6te Decimal.

Egenvægt ved	17,5	af III	1,01739.
	17,5		
	17,5	af VII	1,02669.
	17,5		
	17,5	af I	1,02691.
	17,5		
	0	af I	1,02845.
	0		

<sup>1</sup> Pogg. Ann. 153, p. 440.

<sup>2</sup> Disse Værdier ere ogsaa af Ekman benyttede til Bestemmelse af Udvildelsen af det Dilatometer, som denne til sine Forsøg over Søvandets Udvildelse har anvendt.

<sup>3</sup> Ann. Chim. Phys. [4] 17, p. 372.

too, at least once for every other determination, and again filled with the sea-water the volume of which had to be found. These observations were in no case considered satisfactory unless the temperature of the water-bath had been kept comparatively uniform for at least 15 minutes, the greatest variation indicated by the thermometer during that interval never having exceeded 0,1. For reading the temperature of the water-bath, a thermometer graduated in divisions of 0,2, measuring each 0,68<sup>mm</sup>, was made use of, the instrument having been previously corrected by frequent comparison with the standard thermometer of the Norwegian Meteorological Institute, which the Director, Professor H. Mohr, had kindly lent me for that purpose.

Nos. 32—37 are the first of the observations by which the expansion of the glass in the pycnometer may be computed; and, taking the values found by Willner<sup>1</sup> for the expansion of mercury as the basis of calculation, the mean coefficient of expansion of the glass between 0 and 15 will be 0,0000267, and between 0 and 20: 0,0000274. Moreover, Nos. 3, 4, and 5, in conjunction with Nos. 24 and 25, will also serve for determining the expansion of the glass, and, adopting the values computed by Hällström<sup>2</sup> and Rosetti<sup>3</sup> for the expansion of water, very closely agreeing results will be obtained, the figures expressing the average mean coefficient of expansion of the glass between 0 and 17,5 being 0,0000275. After a proportionate value of the expansion of the glass has been found, for computing which preference should be given to the determinations performed with mercury, we may proceed to deduce the further results of the experiments. Meanwhile, regard must be had to the fact, of which the observations 1, 2, 10, 26, 27, 28, and 29 afford conclusive proof, that the pycnometer had lost about 0,7<sup>mg</sup> in weight during the progress of the experiments, some portion of the outer surface of the glass having probably been dissolved, a result of the constant motion of the water surrounding the instrument when in the water-bath. The uncertainty thus occasions may however be very considerably reduced by computing the weight of the pycnometer for every experiment on the assumption that the loss of weight is proportional to the number of observations, in that case it will hardly influence the 5th decimal. On the basis of this assumption, I subsequently computed the following results, introducing here and there slight approximations, which, however, can affect the final result only by occasioning a small error in the 6th decimal.

Specific Gravity at	17,5	af III	1,01739.
	17,5		
	17,5	af VII	1,02669.
	17,5		
	17,5	af I	1,02691.
	17,5		
	0	af I	1,02845.
	0		

<sup>1</sup> Pogg. Ann. 153, p. 440.

<sup>2</sup> These values were also adopted by Ekman for determining the expansion of the dilatometer which he used when investigating the expansion of sea-water.

<sup>3</sup> Ann. Chim. Phys. [4] 17, p. 372.

og som Control paa det benyttede Kviksølvs Renhed dettes Egenvegt ved  $\frac{0^{\circ}}{4}$  til 13,5963 samt Søvandets Volumina ved forskjellige Temperaturer til

$t^{\circ}$	0	4	8	13	17,5	20
$V_t$ af I	1,000000	1,000308	1,000794	1,001654	1,002605	1,003227

Til Udjevning af den efter disse Observationer optrukne Curve har jeg benyttet de mindste Kvadraters Methode, idet jeg har sat Ligningen for Søvandets Volum ved  $t$  under Formen

$$V_t = 1 + at + bt^2 + ct^3,$$

Betningsligningerne blive

$$\begin{aligned} a + 4b + 16c - 0,000077 &= 0 \\ a + 8b + 64c - 0,00009925 &= 0 \\ a + 13b + 169c - 0,00012723 &= 0 \\ a + 17,5b + 306,25c - 0,000148857 &= 0 \\ a + 20b + 400c - 0,00016135 &= 0 \end{aligned}$$

hvorat Systemerne

$$\begin{aligned} 5a + 62,5b + 955,25c - 0,00013687 &= 0 \\ 62,5a + 955,25b + 16132,37c - 0,008588 &= 0 \\ 955,25a + 16132,37b + 286702c - 0,1392135 &= 0 \end{aligned}$$

som ved Elimination giver

$$\begin{aligned} a &= 0,0000527328 \\ b &= 0,00000617375 \\ c &= -0,000000037516 \end{aligned}$$

eller ved Afrunding

$$V_t = 1 + 0,000052733t + 0,0000061738t^2 - 0,00000003752t^3,$$

Efter denne Formel har jeg beregnet følgende Tabel, hvori Søvandets Volum findes opført for hver hel Grad (sesaa for Temperaturerne under 0), naagt Formelens Gyldighed for dette Strog ikke er støttet ved nogen Observation.

$t$	$V_t$	$t''$	$V_t$	$t''$	$V_t$
-4	0,99989	5	1,00041	14	1,00185
-3	0,99990	6	1,00053	15	1,00205
-2	0,99992	7	1,00066	16	1,00227
-1	0,99995	8	1,00080	17	1,00250
0	1,00000	9	1,00095	17,5	1,00261
1	1,00006	10	1,00111	18	1,00273
2	1,00013	11	1,00128	19	1,00297
3	1,00021	12	1,00146	20	1,00322
4	1,00031	13	1,00165		

and, as a test of purity, the specific gravity of the mercury at  $\frac{0^{\circ}}{4}$  was found to be 13,5963, and the volume of sea-water at different temperatures —

$t^{\circ}$	0	4	8	13	17,5	20
$V_t$ of I	1,000000	1,000308	1,000794	1,001654	1,002605	1,003227

For smoothing the curve laid down from these observations, I adopted the method of the least squares, giving the equation for the volume of the sea-water at  $t''$  the form —

$$V_t = 1 + at + bt^2 + ct^3,$$

The conditional equations will be —

$$\begin{aligned} a + 4b + 16c - 0,000077 &= 0 \\ a + 8b + 64c - 0,00009925 &= 0 \\ a + 13b + 169c - 0,00012723 &= 0 \\ a + 17,5b + 306,25c - 0,000148857 &= 0 \\ a + 20b + 400c - 0,00016135 &= 0 \end{aligned}$$

from which are deduced —

$$\begin{aligned} 5a + 62,5b + 955,25c - 0,00013687 &= 0 \\ 62,5a + 955,25b + 16132,37c - 0,008588 &= 0 \\ 955,25a + 16132,37b + 286702c - 0,1392135 &= 0 \end{aligned}$$

and these equations give by elimination —

$$\begin{aligned} a &= 0,0000527328 \\ b &= 0,00000617375 \\ c &= -0,000000037516 \end{aligned}$$

or, rounded off,

$$V_t = 1 + 0,000052733t + 0,0000061738t^2 - 0,00000003752t^3,$$

By means of this formula I determined the results set forth in the following Table, which shows the volume of sea-water, computed for every degree, including temperatures below 0°, although the applicability of the formula to the latter has not been ascertained from observation.

$t''$	$V_t$	$t''$	$V_t$	$t''$	$V_t$
-4	0,99989	5	1,00041	14	1,00185
-3	0,99990	6	1,00053	15	1,00205
-2	0,99992	7	1,00066	16	1,00227
-1	0,99995	8	1,00080	17	1,00250
0	1,00000	9	1,00095	17,5	1,00261
1	1,00006	10	1,00111	18	1,00273
2	1,00013	11	1,00128	19	1,00297
3	1,00021	12	1,00146	20	1,00322
4	1,00031	13	1,00165		

Til Sammenligning hidsettes her de af Ekman fundne Værdier for Vædmet af 4 Vandprover *A*, *B*, *C* og *D* af respective Egenvægter ved  $\frac{15^\circ}{15^\circ}$ : 1,01603, 1,01982, 1,02306, og 1,02605.

<i>t</i>	$V_t$ af <i>A</i>	$V_t$ af <i>B</i>	$V_t$ af <i>C</i>	$V_t$ af <i>D</i>
—5	1,000145	1,000001	0,000083	0,000002
—4	1,000087	1,000020	0,000050	0,000084
—3	1,000044	0,000004	0,000048	0,000004
—2	1,000015	0,000083	0,000053	0,000022
—1	1,000001	0,000085	0,000009	0,000055
0	1,000000	1,000000	1,000000	1,000000
1	1,000010	1,000035	1,000043	1,000002
2	1,000047	1,000083	1,000100	1,000130
3	1,000090	1,000142	1,000158	1,000220
4	1,000154	1,000213	1,000249	1,000315
5	1,000223	1,000290	1,000344	1,000421
6	1,000305	1,000390	1,000450	1,000537
7	1,000390	1,000495	1,000597	1,000661
8	1,000504	1,000612	1,000690	1,000801
9	1,000621	1,000730	1,000830	1,000948
10	1,000740	1,000877	1,000985	1,001104
11	1,000888	1,001020	1,001145	1,001272
12	1,001038	1,001185	1,001315	1,001449
13	1,001190	1,001354	1,001495	1,001635
14	1,001370	1,001533	1,001683	1,001831
15	1,001551	1,001719	1,001880	1,002038
16	1,001742	1,001925	1,002085	1,002250
17	1,001943	1,002134	1,002290	1,002473
18	1,002153	1,002353	1,002520	1,002705
19	1,002373	1,002582	1,002740	1,002949
20	1,002601	1,002819	1,002984	1,003195
21	1,002839	1,003062	1,003227	1,003453
22	1,003085	1,003321	1,003474	1,003719
23	1,003340	1,003588	1,003728	1,003993
24	1,003602	1,003861	1,003988	1,004275
25	1,003875	1,004144	1,004253	1,004565

For den af mig undersøgte Vandprøve *F* er efter de tidligere beskrevne Observationer fundet Egenvægten 1,02601 ved  $\frac{17,5^\circ}{17,5^\circ}$  eller 1,02707 reduceret til  $\frac{15^\circ}{15^\circ}$ , medens Ekman for Vandprøven *D* har fundet Egenvægten 1,02605 ved  $\frac{15^\circ}{15^\circ}$ , og det fremgaar saaledes, at Undersøgelserne for disse Vandprovers Vedkommende meget godt kunne gjøres til Gjenstand for Sammenligning. En saadan Sammenligning viser let, at der paa alle Puncter selv for Temperaturerne under 0<sup>o</sup> existerer en tilfredsstillende Overensstemmelse, idet Differentserne i Regelen ikke overstige 0,00001 og for de høiere Temperaturer, hvor de antage sin største Værdi, kun gaa op til omtrent 0,000025, en Overensstemmelse, som, naar Heusyn tages til Forskjellen mellem Vandprøvernes Egenvægter, end yderligere kan reduceres. Med de ovenfor nævnte af andre Chemikere indførte Undersøgelser

For comparison with these figures, are annexed the values found by Ekman for the volume of 4 samples of sea-water, *A*, *B*, *C*, and *D*, their specific gravity at  $\frac{15^\circ}{15^\circ}$  being respectively 1,01603, 1,01982, 1,02306, and 1,02605.

<i>t</i>	$V_t$ af <i>A</i>	$V_t$ af <i>B</i>	$V_t$ af <i>C</i>	$V_t$ af <i>D</i>
—5	1,000145	1,000001	0,000083	0,000002
—4	1,000087	1,000020	0,000050	0,000084
—3	1,000044	0,000004	0,000048	0,000004
—2	1,000015	0,000083	0,000053	0,000022
—1	1,000001	0,000085	0,000009	0,000055
0	1,000000	1,000000	1,000000	1,000000
1	1,000010	1,000035	1,000043	1,000002
2	1,000047	1,000083	1,000100	1,000130
3	1,000090	1,000142	1,000158	1,000220
4	1,000154	1,000213	1,000249	1,000315
5	1,000223	1,000290	1,000344	1,000421
6	1,000305	1,000390	1,000450	1,000537
7	1,000390	1,000495	1,000597	1,000661
8	1,000504	1,000612	1,000690	1,000801
9	1,000621	1,000730	1,000830	1,000948
10	1,000740	1,000877	1,000985	1,001104
11	1,000888	1,001020	1,001145	1,001272
12	1,001038	1,001185	1,001315	1,001449
13	1,001190	1,001354	1,001495	1,001635
14	1,001370	1,001533	1,001683	1,001831
15	1,001551	1,001719	1,001880	1,002038
16	1,001742	1,001925	1,002085	1,002250
17	1,001943	1,002134	1,002290	1,002473
18	1,002153	1,002353	1,002520	1,002705
19	1,002373	1,002582	1,002740	1,002949
20	1,002601	1,002819	1,002984	1,003195
21	1,002839	1,003062	1,003227	1,003453
22	1,003085	1,003321	1,003474	1,003719
23	1,003340	1,003588	1,003728	1,003993
24	1,003602	1,003861	1,003988	1,004275
25	1,003875	1,004144	1,004253	1,004565

According to the observations previously described the specific gravity of sample *A*, was, at  $\frac{17,5^\circ}{17,5^\circ}$  1,02601, or, reduced to  $\frac{15^\circ}{15^\circ}$ , 1,02707, and Ekman found the specific gravity of sample *D* to be 1,02605 at  $\frac{15^\circ}{15^\circ}$ . Hence the results, so far at least as these samples are concerned, very well admit of being compared, satisfactory agreement exists even for temperatures below 0<sup>o</sup>, since the difference does not as a rule exceed 0,00001, and for the highest temperatures, at which it is greatest, it amounts to only 0,000025; nay, these figures may be still further reduced by taking into account the specific gravities of the samples. With the results of the above-mentioned observations substituted by other chemists, those here described agree but indifferently. According to the formula deduced by

stemme de her beskrevne Resultater kun maadeligt overens. Både den af Wackerbarth efter Ekman's Observationer beregnede Formel og Temperaturen for Tæthedsmaximum hos Søvand af Egenvægt 1.02707 = - 4.04, medens Ligningen  $\frac{dT}{dt} = 0$  med de af mig fundne Coefficienter giver Temperaturen -4.45.

Paa Grund af denne gennemførte Overensstemmelse mellem Ekman's og mine Resultater, har jeg ikke fundet det fornødent at bestemme Udvidelsen af Vandprover af lavere Egenvægt, men har uden videre anvendt Ekman's Observationer paa de faa Puncter, hvor jeg til Reduction af de paa den norske Nordhavsexpedition afviste Egenvægter har havt Brug for dem. Ved Hjælp af de ovenfor opførte Værdier for Søvandets Volumina ved forskjellige Temperaturer kan man nu beregne de Correctioner, hvormed de ved vilkaarlige Temperaturer afviste Egenvægter man forbedres forat reduceres til  $\frac{17.5}{17.5}$ . Correctionerne, hvori ogsaa indgaar et Led, der afhænger af Areometret's Udvidelsescoefficient,<sup>1</sup> findes sammenstillede i nedenstående Tabel.

$t$	Correction	$t$	Correction
0	-0.00224	12	-0.00104
2	-0.00214	14	-0.00060
4	-0.00201	16	-0.00031
6	-0.00183	18	0.00011
8	-0.00161	20	0.00056
10	-0.00134		

Hvor den Temperatur, hvorved Aflesningen foretages, ikke fjerner sig meget fra Normaltemperaturen 17.5, kan disse Correctioner, der strengt taget kun gjælde for Søvand af Egenvægt omkring 1.027, ogsaa uden mærkelig Feil anvendes for Vandprover af en derfra temmelig forskjellig Egenvægt. Hvor derimod den Temperatur, hvorved Aflesningen foretages, ligger langt fra 17.5, ere disse Correctioner kun gyldige for et meget begrænset Interval.

Efterat saaledes de afviste Egenvægter ved Anbringe af disse Correctioner ere reducerede til Normaltemperaturen, staar det endnu tilbage at befrie dem for de ved de benyttede Areometre heftende constante Feil.

Til Aflesning af saa godt som alle paa Expeditionen bestemte Egenvægter benyttedes kun 3 Areometre, to paa første Tozt og et paa de to sidste. Af de to først nævnte, der af Svendsen for Udvoisen vare udvalgte af de øvrige, fordi de havde vist sig at stemme særdeles vel overens, er desværre det ene senere bleven knust, det andet er endnu i Behold og er sammen med det paa sidste Tozt benyttede bleven corrigeret af mig.

A. Wackerbarth from Ekman's observations, the temperature for the maximum density of sea-water with a specific gravity of 1.02707 is -4.04, whereas the equation  $\frac{dT}{dt} = 0$  gives, with my coefficients, a temperature of -4.45.

Relying, then, on the close agreement between Ekman's results and my own, I have not determined the expansion in samples of sea-water with a lower specific gravity, but have adopted Ekman's observations, for reducing, when needful, the specific gravities read on the Norwegian North-Atlantic Expedition. By means of the values, tabulated above, for the volume of sea-water at different temperatures, the corrections which serve to reduce specific gravities read at any given temperature to  $\frac{17.5}{17.5}$  may be computed. These corrections, into which the coefficient of expansion of the areometer<sup>1</sup> enters as a factor, are given in the following Table.

$t$	Corrections	$t$	Corrections
0	-0.00224	12	-0.00104
2	-0.00214	14	-0.00060
4	-0.00201	16	-0.00031
6	-0.00183	18	0.00011
8	-0.00161	20	0.00056
10	-0.00134		

When the temperature is not far removed from the normal temperature, 17.5, these corrections, which, strictly speaking, apply only to sea-water with a specific gravity of about 1.027, may, without involving any appreciable error in the result, be likewise adopted for samples of water whose specific gravity differs considerably from that expressed by the above formula; but when, on the other hand, the temperature at which the specific gravity is read and that of 17.5 lie far apart, the interval for which these corrections will serve is but very limited.

After reducing by means of these corrections the specific gravities to the normal temperature, there still remains to eliminate the constant error of the areometer.

For reading almost all of the specific gravities determined on the Expedition, only 3 areometers were made use of, two on the first cruise and one on the two last. Of the two former, which, having been found to agree uncommonly well, Mr. Svendsen had selected previous to his departure, one was unfortunately afterwards broken; the other is still in perfect order, and was, together with that made use of on the last voyage, corrected by myself.

<sup>1</sup> Som saadan benyttedes 0.000021.

<sup>1</sup> That adopted was 0.000026.

Correctionernes Bestemmelse udførtes ved Hjælp af Vandproverne I og VII, hvis Egenvægte tidligere ere bestemte til 1,02691 og 1,02669 ved  $\frac{17,5}{17,5}$ . For det paa første Toigt anvendte Aarometer erholdtes saaledes gjennem 5 Aflesninger i I Correctionen = 0,00023 og gjennem 12 Aflesninger i VII ligeledes = 0,00023. Paa samme Maade bestemtes det andet Aarometers Correctioner ved 5 Aflesninger i I til = 0,00037 og ved 8 Aflesninger i VII til = 0,00038. Under disse Aflesninger var Vædsken altid bragt til 17,5 eller en meget nærliggende Temperatur, hvorfra Aflesningerne efter de forhen gængsige Correctioner reduceredes til Normaltemperaturen. Gjennem flere Rækker Aflesninger i Vandproven I ved forskjellige Temperaturer har jeg tillige forvissat mig om, at den ved Beregning af Correctionstabellen benyttede Udvidelsescoefficient for Aarometrene er passende valgt.

Hermed er givet de fornødne Data til Reduction af de paa den norske Nordhavsexpedition afleste Egenvægter, og jeg gaar dernæst over til Bestemmelsen af Relationerne mellem Saltgehalten, Chlorindholdet og Egenvægten.

Til Bestemmelse af Saltmængden har, saavidt jeg ved, tidligere kun været benyttet den simpleste Methode, bestaaende i Afdampning af Vandet og Residnets Torrering ved en passende Temperatur, som af de forskjellige Chemikere er bleven valgt noget forskjelligt fra 150°—180°. Denne Methode har jeg imidlertid af flere Grunde fundet lidt tilfredsstillende, hvad man ogsaa paa Forhaand maatte vente. Efter Graham<sup>1</sup> og andre taler nemlig den svovlsure Magnesia, om hvis Tilstedeværelse i Søvandet der vel ikke kan reises Tvivl, først ved en Temperatur af over 200° sit sidste Mødekyll Vand, medens man paa den anden Side allerede ved en Temperatur af betydeligt under 200° maa befrygte en delvis Decomposition af den i Saltene tilstedeværende Chlormagnesium. Efter de Forsøg, som jeg anstillede, viste det sig, at Saltene selv efterat være torrede ca. 20 Timer i Luftbad ved en Temperatur fra 170°—180° endnu indeholdt ikke ubetydelige Mængder Vand (omkring 15 Mgr. pr. Gr. Salt), medens de torrede ved lidt lavere Temperatur indeholdt noget mere. Samtidig undersøgte ogsaa Saltene paa fri Magnesia, hvorved jeg i Strid med ældre Angivelser fandt, at de bestandig selv ved Torrering ved 160° til 170° indeholdt i hvert fald store Quantiteter, saant der for hvert Gr. torret Salt fandtes en Magnesiamaenge tilstrækkelig til at neutralisere over 20 Mgr. HCl (ved Torrering ved 180° fandt jeg endog en enkelt Gang 40 Mgr.). Bestemmelsen af den frie Magnesia foretoges ved Saltenes Oplosning i en afmaalt Mængde titreret Svovlsyre og derpaa følgende Retitration med fortyndet Natronind af bekendt Styrke. Ved Anvendelse af Rosedsyre som Index erholdtes her en meget skarp Enderreaction.

The determination of the corrections was performed with the water of samples I and VII, whose specific gravity at  $\frac{17,5}{17,5}$  had been found to be respectively 1,02691 and 1,02669. For the areometer used on the first voyage, 5 readings with the water of sample I gave the correction = 0,00023, and 12 readings with the water of sample VII likewise = 0,00023; in the same manner, the corrections for the other areometer were determined, by 5 readings with the water of sample I, to be = 0,00037, and by 8 readings with the water of sample VII, to be = 0,00038. For these readings, the fluid was always brought to 17,5, or as near that temperature as possible, the readings having in the latter case to be reduced, by means of the corrections given above, to the normal temperature. Several series of readings with the water of sample I, at different temperatures, convinced me that the coefficient of expansion for the areometer which I had computed for preparing the Table of Corrections was practically correct.

Having now specified the data necessary for reducing the specific gravities read on the Norwegian North-Atlantic Expedition, I shall proceed to determine the relation between the specific gravity of sea-water and the amount of salt and chlorine it contains.

For determining the amount of salt, the only method formerly resorted to was, so far as I am aware, the simplest, viz. that of evaporating the water and then drying the residue at a proper temperature, which has been variously fixed by different chemists at from 150° to 180°. This method, however, has proved in several respects defective, as was indeed to be expected. According to Graham<sup>1</sup> and others, sulphate of magnesia, the presence of which in sea-water can hardly admit of doubt, does not part with its last molecule of water till exposed to a temperature of more than 200° whereas, on the other hand, it is highly probable that partial decomposition of the chloride of magnesium contained in the salt takes place considerably below 200°. Even after the salts had been dried for about 20 hours in an air-bath at a temperature of 170°—180°, they were still found to contain, according to my experiments, a considerable quantity of water (about 15<sup>mg</sup> salt per gramme); dried at a lower temperature, the amount was somewhat greater. I also tested the salts for free magnesia, and found, in direct opposition to earlier statements, that, even when dried at 160°—170°, they invariably contained a very large amount, the quantity of magnesia to every gramme of dried salt being sufficient to neutralize more than 20<sup>mg</sup> HCl (once, when dried at 180°, even 40<sup>mg</sup>). For determining the free magnesia, the salts were dissolved in a given quantity of titrated sulphuric acid, and the fluid then retitrated with dilute soda-lye of known strength. With rosolic acid as the index, the final reaction was very decided.

<sup>1</sup> Phil. Mag. J. 6. = 422.

<sup>2</sup> Phil. Mag. J. 6. p. 422.

Forat undgaa de her omtalte Feil, benyttedes til Bestemmelse af Saltmængden i Søvandet følgende Fremgangsmaade.

I en med tætsluttende Låg forsynet tyk, veiet Porcellaindigel indvoiedes 30 til 40 Gr. Søvand, som afdunstedes paa Vandbad. Efterat Saltene vare nogenlunde vel tørrede, oploedes Digelen med Laaget paa ca. 5 Minutter over en Bunsens Lampe, alkjoledes og veiedes paany. Derefter bestemtes paa den forud beskrevne Maade den ved Decomposition af Chlor-magnesium dannede frie Magnesia, hvorved de til Beregning af den samlede Saltgehalt fornødne Data erhøldtes.

I en tidligere Afhandling<sup>1</sup> har jeg paavist, at Carbonaterne i Søvandet ved Kogning omsætter sig til kulsur Magnesia, som ved Inddampning eller under enhver Omstændighed ved Glødning efterlader Magnesia, og man skulde altsaa strengt taget for den saaledes dannede Del af den frie Magnesia beregne en anden Correction end for den ved Decomposition af Chlor-magnesium dannede Hovedmængde. Den Feil, man begaar, ved at undlade dette er imidlertid baade meget nær constant og desuden saa liden, at den uden videre kan negligeres, idet den kun bidrager til at formindske den samlede Saltgehalt med omkring 0,0015 %. Det er saaledes fuldstændig tilstrækkeligt til den ved Veivægen fundne Mængde tørret Salt at addere 1,375 Gange den ved Titrationen bestemte Mængde fri Magnesia, for af det saaledes fremkomne Tal at beregne Saltgehalten i Procenter.

Med denne Methode kan der dog reises Indvendinger, idet det kunde befrygtes, at mindre Quantiteter Chlor-natrium, Chlor-magnesium eller Chlor-kalium under Glødningen kunde forlygtiges, eller at en Del af den svovlsure Magnesia ved den høie Temperatur kunde decomponeres og give Anledning til Tab af Svovlsyre. Man kan imidlertid let forvise sig om, at dette ved Anvendelse af en tyk Porcellaindigel med tætsluttende Låg ikke bevirker nogen Feil af mærkelig Indflydelse. Saaledes fandt jeg, at 1,2 Gr. af en passende Blanding af Chlor-kalium og Chlor-natrium ved  $1\frac{1}{2}$  Times stærkest mulig Glødning over en Bunsens Lampe i den samme Digel, som jeg benyttede til mine Saltbestemmelser, kun tabte 2 Mgr. i Vægt, det vil sige, Blandingen tabte ved Glødningen ikke fuldt 0,14 Mgr. pr. 5 Minutter. Ligeledes paavistes ved Bestemmelse af Svovlsyre og Magnesia samvel i det benyttede Søvand som i det gløiede Residuum, at man selv ved en meget længere fortsat Glødning end den, der udføres forat skaffe fuldstændig vandfrit Salt, ikke risikerer nogen skadelig Feil foranlediget ved Forlygtigelse af Chlor-magnesium eller Decomposition af svovlsur Magnesia.

In order to guard against the above-mentioned errors, the following mode of operation was adopted for determining the amount of salt in sea-water.

From 30<sup>gr</sup> to 40<sup>gr</sup> of sea-water were introduced into a thick porcelain crucible of known weight, furnished with a tight-fitting cover, and evaporated on a water-bath. So soon as the salt was sufficiently dry, the crucible, with the cover on, was heated for about 5 minutes over one of Bunsen's gas-burners, then cooled and weighed with its contents. The free magnesia liberated by the decomposition of the chloride of magnesium was now determined in the manner previously described, and the last factor necessary for computing the total amount of salt accordingly found.

In a former paper<sup>1</sup> I drew attention to the fact, that the carbonates present in sea-water are transformed during the process of boiling into carbonate of magnesia, which after evaporation, or, at least, on the salt being thoroughly heated, leaves a residue of magnesia; and hence the proportion of free magnesia thus formed would, strictly speaking, seem to involve the need of a correction different from that adopted for the principal amount liberated by the decomposition of the chloride of magnesium. But the error which arises from applying the same correction to both is, on the one hand, very nearly constant, and, on the other, so small as to admit of being safely ignored, seeing that it reduces the total amount of salt only about 0,0015 per cent. It is, therefore, amply sufficient, if to the amount of dried salt found by weighing be added 1,375 times the amount of the free magnesia determined by titration: the figure thus obtained will serve to compute the percentage of salt.

This method certainly is so far open to objection, that small quantities of chloride of sodium, chloride of magnesium, or chloride of potassium may be volatilized during the process of heating, or some portion of the sulphate of magnesia be decomposed at the high temperature, and thus occasion a loss of sulphuric acid. The error, however, arising from this source will not exert any appreciable influence on the result, provided the crucible used for the operation be of thick porcelain, and have a tight-fitting cover. Thus, for instance, I found that 1,2<sup>gr</sup> of a proportionate mixture of chloride of potassium and chloride of sodium, on being heated for the space of an hour and a quarter over one of Bunsen's gas-burners in the crucible I had used for my salt-determinations, lost only 2<sup>mg</sup> in weight, or 0,14<sup>mg</sup> every 5 minutes. Moreover, it was manifest on determining the sulphuric acid and magnesia both in the water itself and in the heated residue, that, even in the event of the heating-process being much more protracted than is necessary to obtain salt free from the smallest trace of water, no serious error can result from the volatilization of chloride of magnesium or the decomposition of sulphate of magnesia.

<sup>1</sup> Om Kulsyren i Søvandet, Side 40 ovenfor.

<sup>2</sup> On the Carbonic Acid in Sea-Water," p. 40.



At Methoden giver indbyrdes vel overensstemmende Resultater, viser de tidligere Saltbestemmelser, som udførtes med samme Vandprøver. Saaledes fandtes ved nedenstaaende Forsøg

Proc. Salt i II	$\begin{cases} 3,525 \\ 3,517 \end{cases}$	Proc. Salt i VII	$\begin{cases} 3,514 \\ 3,516 \\ 3,515 \end{cases}$
— — — III	$\begin{cases} 2,303 \\ 2,299 \end{cases}$		$\begin{cases} 3,501 \\ 3,507 \\ 3,508 \end{cases}$
— — — IV	$\begin{cases} 3,386 \\ 3,385 \end{cases}$	— — — VIII	$\begin{cases} 3,500 \\ 3,502 \\ 3,506 \\ 3,500 \\ 3,501 \end{cases}$
— — — V	$\begin{cases} 3,530 \\ 3,533 \end{cases}$		
— — — VI	$\begin{cases} 3,276 \\ 3,279 \end{cases}$		

Resultaterne ere, som man ser, allerede her temmelig vel overensstemmende, men kunde visselig gives en endnu større Nøjagtighed, om man vilde arbeide med noget større Quantiteter Savand.

For Vandprøverne III og VII er Egenvægten ved 17,5 allerede tidligere ved Hjælp af Pyknometer bestemt til respective 1,01730 og 1,02669, for Vandprøverne IV, V, VI og VIII er den funden ved gjentagne Aflæsninger paa et af de corrigerede Areometre, medens den for Proven II kun blev bestemt ved en enkelt Aflæsning. Saaledes bestemtes meget omhyggeligt samtlige Vandprøvers Chlor-mængder. Heraf kan

$$\text{Chlorcoefficienten} = \frac{\text{Saltmængden}}{\text{Chlormængden}}$$

og

$$\text{Egenvægtscoefficienten} = \frac{\text{Saltmængden}}{\text{Egenvægten}} - 1$$

herregnes, saaledes som det er gjort i nedenstaaende Tabel.

No.	Egenvægt ved 17,5	Chlor-mængde	Salt-mængde	Egenvægtscoefficient	Chlor-coefficient
II	1,02070	1,047	3,524	1,31,0	1,808
III	1,01730	1,274	2,304	1,32,3	1,810
IV	1,02573	1,868	3,386	1,31,0	1,813
V	1,02076	1,056	3,532	1,32,0	1,806
VI	1,02488	1,809	3,278	1,31,8	1,812
VII	1,02069	1,047	3,515	1,31,7	1,805
VIII	1,02655	1,038	3,503	1,31,9	1,808

Som det heraf fremgaar, er både Chlor- og Egenvægtscoefficienterne tiltrods for Saltgehaltens Forskjellighed overalt meget nær constante, saa at Variationerne

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That the results obtained by this method must be regarded as agreeing very closely *inter se*, is shown by the numerous salt-determinations performed with the same samples of water.

Per cent. of Salt in II	$\begin{cases} 3,525 \\ 3,517 \end{cases}$	Per cent. of Salt in VII	$\begin{cases} 3,514 \\ 3,516 \\ 3,515 \end{cases}$
— — — III	$\begin{cases} 2,303 \\ 2,299 \end{cases}$		$\begin{cases} 3,501 \\ 3,507 \\ 3,508 \end{cases}$
— — — IV	$\begin{cases} 3,386 \\ 3,385 \end{cases}$	— — — VIII	$\begin{cases} 3,500 \\ 3,502 \\ 3,506 \\ 3,500 \\ 3,501 \end{cases}$
— — — V	$\begin{cases} 3,530 \\ 3,533 \end{cases}$		
— — — VI	$\begin{cases} 3,276 \\ 3,279 \end{cases}$		

These figures, it will be seen, differ but little *inter se*, and by increasing the quantity of water greater accuracy could no doubt be attained.

For samples III and VII, the specific gravity at 17,5, respectively 1,01730 and 1,02669, had been previously determined by means of the pycnometer; for samples IV, V, VI, and VIII, it was found by repeated readings of one of the corrected areometers, whereas for sample II it was determined by one reading only. The amount of chlorine, too, in each sample was carefully determined. From these data may be computed the

$$\text{Coefficient of Chlorine} = \frac{\text{Amount of Salt}}{\text{Amount of Chlorine}}$$

and the

$$\text{Coefficient of Specific Gravity} = \frac{\text{Amount of Salt}}{\text{Specific Gravity}} - 1$$

as set forth in the following Table.

No.	Spec. Grav. at 17,5	Percentage of Chlorine	Percentage of Salt	Coefficient of Spec. Grav.	Coefficient of Chlorine
II	1,02070	1,047	3,524	1,31,0	1,808
III	1,01730	1,274	2,304	1,32,3	1,810
IV	1,02573	1,868	3,386	1,31,0	1,813
V	1,02076	1,056	3,532	1,32,0	1,806
VI	1,02488	1,809	3,278	1,31,8	1,812
VII	1,02069	1,047	3,515	1,31,7	1,805
VIII	1,02655	1,038	3,503	1,31,9	1,808

It thus appears, that the coefficients both of chlorine and specific gravity, notwithstanding the difference in the percentage of salt, are always very nearly constant,

rimeligst bliver at tilskrive Observationsteil. Som Chlor-coefficient kan heraf opstilles

$$1,809 \pm 0,00076$$

med en sandsynlig Feil af en enkelt Bestemmelse af  $\pm 0,002$  og som Egenvægtscoefficient

$$131,9 \pm 0,058$$

med en sandsynlig Feil af en enkelt Bestemmelse af  $\pm 0,15$ .

Disse Værdier stemme især for Chlorcoefficientens Vedkommende ganske vel overens med tidligere fundne Værdier, saaledes har både Forchhammer og Ekman i Middelværdi fundet 1,811, medens de af Andre opstillede Egenvægtscoefficienter overalt ere noget mindre end den af mig fundne.

Ved Hjælp af disse Coefficienter har jeg af de paa Expeditionens Togter udførte Chlor- og Egenvægtsbestemmelser beregnet Vandprovernes Saltgehalt og sammen med Originalobservationerne opført dem i nedenstående Tabel.

Egenvægterne ere i Regelen kun aflæste med 4 Decimaler, det 5te er kun opført, hvor det havde en Værdi nær 5, saa at det kunde være Tvivl underkastet, om der ved Afrunding skulde formindskes eller forhoies. I de reducerede Egenvægter findes ligeledes kun opført 4 Decimaler, hvor det uden Tvivl kunde afgjøres, til hvilken Side Afrundingen skulde finde Sted, hvormed der i modsat Fald ogsaa der er tilføjet et 5te. De med <sup>2</sup> betegnede Egenvægter ere aflæste paa Arcometre, hvis Correction ikke er bleven bestemt. Til Optragelse af de til Undersøgelse af Saltindheden bestemte Vandprover er foruden det tidligere beskrevne, af Wille konstruerede, Apparat ogsaa paa grundere Vand ofte benyttet den af Ekman angivne fortrinlige Vandhenter, som imidlertid ifølge den Fremgangsmaade, hvorefter Dylledøminger paa den norske Expedition foretoges, ikke egnede sig til Brug ved større Dyl.

Ved Velvillie af Professor Mohr har jeg faaet opgivet de undersøgte Vandprovers Temperatur i Havet, hvorved det er bleven muligt ogsaa at tilføie en Rubrik for deres Egenvægter ved denne Temperatur i Forhold til rent Vand af 4°. Af de i Tabellen gjengivne Observationer ere alle indtil No. 149 udførte paa 1ste Toigt af Svendsen, alle fra 149 til 225 paa 2det Toigt af mig, de øvrige ere udførte paa sidste Toigt af Schmeleck og mig i Fællesskab, saaledes at det største Antal skyldes Schmeleck, der dette Aar medfulgte Expeditionen.

and, hence the variation in the results should most probably be ascribed to errors of observation. The coefficient of chlorine may accordingly be taken at —

$$1,809 \pm 0,00076$$

with a probable error in a single determination of  $\pm 0,002$ , and the coefficient of specific gravity, at —

$$131,9 \pm 0,058$$

with a probable error in a single determination of  $\pm 0,15$ .

These values agree closely, in particular as regards the coefficient of chlorine, with those previously found. Thus, for instance, the mean value found both by Forchhammer and Ekman was 1,811, whereas the coefficient of specific gravity given by former observers is somewhat lower than mine.

By means of these coefficients I have computed from the determinations of chlorine and specific gravity the amount of salt in the samples of water collected on the Expedition, and have set down the observations and their results in the accompanying Table, which calls for a brief explanation.

The specific gravities are as a rule not read to more than 4 decimals, a fifth being added only in the event of its having a value of 5, in which case it is often doubtful whether, when rounding off the figures, there should be increase or diminishment. The reduced specific gravities, too, are expressed with 4 decimals only, wherever it was manifest in which direction the rounding off had to be made; when such is not the case, a fifth has been added. An asterisk at the side of a specific gravity denotes that the latter was determined with an areometer for which no correction had been found. Besides the instrument devised by Wille, of which a description has been given, Ekman's excellent apparatus was likewise made use of, in comparatively shallow localities, for collecting the samples of sea-water in which to determine the amount of salt; the mode of sounding practised on the Norwegian North-Atlantic Expedition would not admit of its adoption for greater depths.

Professor Mohr has kindly furnished me with the temperatures of the samples of water *in situ*, which has enabled me to give an additional column for the specific gravities at these temperatures as compared with pure water of 4°. Of the observations given in the Table, those extending from No. 1 to No. 149 were performed on the first voyage, by Mr. Svendsen; those extending from No. 149 to No. 225, on the second voyage, by myself; the remainder were taken on the last voyage, by Mr. Schmeleck and myself conjointly, the greater number, however, by Mr. Schmeleck, who that year accompanied the Expedition.

<sup>1</sup> Rent Vand af 4° er ved denne Reduction valgt som Enhed, fordi den allerede tidligere er anvendt af J. Y. Buchanan (Proc. Roy. Soc. 24, p. 397). Ved Beregning af Egenvægternes Værdi ved Havets Temperatur i Forhold til Vand af 4° er Forholdet mellem Volumet af rent Vand ved 4° og 17,5° sat = 0,998768.

<sup>2</sup> Pure water of 4° was chosen as the unit of reduction, J. Y. Buchanan having previously adopted it as such (Proc. of Roy. Soc. 24, p. 397). When computing the specific gravities at the temperature of the sea, as compared with water of 4°, the ratio existing between the volume of pure water at 4° and 17,5° was assumed to be 0,998768.

Tab. III.

No.	Stat. No.	Nordlig Bredd. (North Latitude)	Længde fra Greenw. (Longitude from Greenwich)	Dybde hvorfra Proben lerdet. (Depth from which the Specimens were collected)		Alteste Ege-vægt. (Sp. G. heaviest fossil)	Temperatur. (Temperature)		Ege-vægt. (Sp. G. heaviest)		Saltvægt. (Amount of Salt)	
				Egelske Favn. (Danish Fathoms)	Metre (Metres)		Under Altsammenhed (Below each)	I Havet. (In Sea)	Ved 17° 34' (At 17° 34')	Ved 17° 5' (At 17° 5')	Chlor. (Amount of Chlorine)	Etter Altsammenhed. (By the Amount of)
1	—	—	—	0	0	1.0151	14.8	—	—	1.01405	—	1.93
2	—	—	—	1	2	1.0234	13.7	—	—	1.0227	—	2.00
3	—	—	—	2	4	1.0257	12.5	—	—	1.0228	—	3.04
4	—	—	—	3	5	1.0244	13.0	—	—	1.0233	—	3.07
5	—	—	—	4	7	1.0242	13.8	—	—	1.0235	—	3.10
6	—	—	—	5	9	1.0240	17.3	—	—	1.02305	—	3.10
7	—	—	—	6	11	1.0245	17.0	—	—	1.0241	—	3.22
8	—	—	—	7	13	1.0240	20.0	—	—	1.02515	—	3.30
9	2	61° 0' 0"	31° 0'	672	1220	1.0270	16.7	6.7	—	1.0266	1.0274	3.54
10	—	—	—	0	0	1.0148	0.2	—	—	1.0107	—	1.44
11	—	—	—	0	0	1.0147	12.0	—	—	1.0130	—	1.40
12	—	—	—	1	2	1.0188	12.5	—	—	1.0180	—	2.37
13	3	61° 5' 2"	31° 15' 3"	618	1130	1.0280	11.0	6.0	—	1.0210	1.0274	3.51
14	—	—	—	0	0	1.0262	0.7	—	—	1.0240	—	3.24
15	—	—	—	0	0	1.0202	0.0	—	—	1.0245	—	3.25
16	—	—	—	0	0	1.0262	10.2	—	—	1.0247	—	3.26
17	—	—	—	6	11	1.0204	16.7	—	—	1.0245	—	3.25
18	—	—	—	6	11	1.0258	15.6	—	—	1.0252	—	3.32
19	—	—	—	0	0	1.0262	10.0	—	—	1.0248	—	3.27
20	—	61° 25' 3"	31° 11' E	0	0	1.0254	16.8	—	—	1.0250	—	3.30
21	16	61° 41' 3"	31° 08' 5"	0	0	1.0253	16.2	11.5	—	1.0248	1.0248	3.27
22	12	61° 53' 3"	31° 0'	0	0	1.0270	18.0	11.1	—	1.0260	1.0270	3.55
23	14	62° 4' 2"	31° 14' 5"	0	0	1.0265	19.9	9.9	—	1.0268	1.0274	3.53
24	11	62° 4' 2"	31° 14' 5"	220	413	1.0268	18.6	6.1	—	1.0268	1.0277	3.53
25	10	62° 23' 0"	31° 17'	0	0	1.0275	15.4	10.9	—	1.02685	1.0270	3.54
26	17	62° 33' 2"	31° 4'	0	0	1.0271	17.5	11.2	—	1.0260	1.0260	3.55
27	18	62° 44' 5"	31° 18'	0	0	1.0270	18.4	11.6	—	1.0270	1.02605	3.56
28	—	62° 39' 2"	31° 8'	0	0	1.0270	17.9	12.5	—	1.0260	1.0267	3.55
29	—	62° 29' 2"	31° 34'	0	0	1.0273	16.2	12.5	—	1.0268	1.0260	3.53
30	10	62° 23' 5"	31° 50'	0	0	1.0262	17.5	11.0	—	1.0260	1.02605	3.43
31	20	62° 40' 3"	31° 8'	0	0	1.0259	18.7	11.2	—	1.0250	1.0257	3.48
32	24	62° 44' 3"	31° 27' 5"	0	0	1.0251	17.8	13.4	—	1.02405	1.02455	3.29
33	22	62° 43' 2"	31° 40' 5"	0	0	1.0251	18.0	12.0	—	1.0253	1.02505	3.34
34	—	62° 52' 5"	31° 51' 5"	0	0	1.0252	19.5	12.4	—	1.0251	1.0253	3.35
35	—	62° 50' 0"	31° 16'	0	0	1.0253	18.4	12.8	—	1.0253	1.0250	3.34
36	—	—	—	0	0	1.0255	17.5	—	—	1.0253	—	3.34
37	—	63° 10' 0"	31° 30'	0	0	1.0260	16.2	10.0	—	1.0255	1.0257	3.36
38	24	63° 10' 5"	31° 57' 5"	0	0	1.0262	17.5	11.7	—	1.0260	1.0250	3.43
39	24	63° 10' 5"	31° 57' 5"	90	165	1.0262	17.5	6.0	—	1.0260	1.0267	3.43
40	—	63° 10' 5"	31° 19'	0	0	1.0260	17.2	11.2	—	1.0263	1.0264	3.47
41	26	63° 10' 5"	31° 10'	0	0	1.0264	17.6	11.8	—	1.0250	1.0258	3.41
42	—	63° 7' 4"	31° 17'	0	0	1.0264	18.0	11.7	—	1.0261	1.0264	3.38
43	—	63° 10' 4"	31° 50'	0	0	1.0264	17.5	14.0	—	1.0262	1.0264	3.46
44	32	63° 10' 4"	31° 51' 3"	430	780	1.0270	17.0	10.0	—	1.0267	1.0281	3.52
45	—	63° 9' 3"	31° 56'	0	0	1.0265	16.2	11.2	—	1.0260	1.0260	3.43
46	—	63° 6' 3"	31° 1'	0	0	1.0260	15.8	11.8	—	1.0251	1.02535	3.35
47	33	63° 5' 3"	31° 0'	525	960	1.0270	15.0	11.1	—	1.0272	1.0280	3.50
48	—	63° 5' 2"	31° 57'	0	0	1.0274	15.2	11.6	—	1.0264	1.0264	3.48
49	—	63° 4' 2"	31° 52'	0	0	1.0260	14.6	12.3	—	1.0264	1.0259	3.44
50	—	63° 3' 2"	31° 43'	0	0	1.0260	17.3	11.9	—	1.0263	1.0262	3.47
51	—	63° 3' 2"	31° 10'	0	0	1.0275	14.3	12.0	—	1.02665	1.0265	3.52
52	—	63° 5' 1"	31° 7'	0	0	1.0278	14.7	11.5	—	1.0270	1.0270	3.50
53	34	63° 5' 0"	31° 52' 5"	587	1073	1.0277	15.0	11.0	—	1.0270	1.0284	3.50
54	—	63° 3' 0"	31° 54'	0	0	1.0277	14.8	12.0	—	1.02695	1.0268	3.55
55	—	62° 48' 1"	31° 51'	0	0	1.0273	16.3	11.9	—	1.0268	1.0267	3.53
56	—	62° 44' 2"	31° 10'	0	0	1.0272	16.4	11.1	—	1.0267	1.0267	3.52

No.	Stat. No.	Nørdlig Bredd. (North Latitude)	Længde (Longitude)		Dybde hvorfra Proben høstes. (Depth from which the Samples were collected)	Fagelske Mønter. (English Fathoms)	Meter. (Metres)	Aftale Ege-vægter. (Specific Gravity read)	Temperatur. (Temperature)		Ege-vægter. (Specific Gravity)		Chlor-mængde. (Amount of Chlorine)	Saltmængde. (Amount of Salt measured)	
			Grøn-vædd. (Longitude from Greenwich)	Østlige. (East)					Inde. (When read)	I Havet. (In Situ)	Ved 17.5 (At 17.5)	Ved 4. (At 4)		Effet Aræo-metec. (By the Aræometer)	Effet Chlor-mængde. (By the Amount of Chlorine)
57	—	62° 37'	2° 37' E.	0	0	0	1.0277	13.1	11.5	1.0266	1.0266	—	3.54	—	
58	—	62 40.5	1 58	0	0	0	1.0276	13.7	11.4	1.0266	1.02665	—	3.54	—	
59	—	62 45	1 13	0	0	0	1.0277	14.6	11.4	1.0266	1.0266	—	3.55	—	
60	—	63 2	1 12 W.	0	0	0	1.0275	15.0	11.1	1.02665	1.0270	—	3.55	—	
61	—	63 3	1 14	0	0	0	1.0275	13.4	10.8	1.0265	1.0266	—	3.56	—	
62	—	63 4	1 19	0	0	0	1.0277	13.2	10.8	1.02665	1.1268	—	3.52	—	
63	—	63 6	1 24	0	0	0	1.0279	12.5	10.4	1.0267	1.0269	—	3.52	—	
64	—	63 8	1 20	0	0	0	1.0279	12.0	10.8	1.0268	1.0269	—	3.53	—	
65	—	63 12	1 26	0	0	0	1.0279	12.8	10.4	1.0268	1.0270	—	3.53	—	
66	—	63 14	1 27	0	0	0	1.0278	12.8	10.5	1.0267	1.02685	—	3.52	—	
67	—	63 17	1 28	0	0	0	1.0279	13.3	10.8	1.02685	1.0270	—	3.54	—	
68	—	63 18	1 23	0	0	0	1.0280	14.0	10.8	1.0267	1.02685	—	3.52	—	
69	—	63 15	0 57	0	0	0	1.0277	15.2	10.7	1.0270	1.0272	—	3.50	—	
70	—	63 19	1 0	0	0	0	1.0277	15.2	10.2	1.0270	1.02725	—	3.50	—	
71	—	63 20	1 28	0	0	0	1.0274	16.5	10.8	1.02665	1.0271	—	3.55	—	
72	—	63 18	1 38	0	0	0	1.0275	16.2	10.4	1.0270	1.0272	—	3.50	—	
73	—	63 8	1 58	0	0	0	1.0279	13.8	10.4	1.02665	1.02715	—	3.55	—	
74	—	62 58	2 8	0	0	0	1.0279	14.0	10.2	1.0270	1.0272	—	3.50	—	
75	—	62 40	3 34	0	0	0	1.0277	14.0	9.8	1.0268	1.0271	—	3.53	—	
76	—	62 34	4 28	0	0	0	1.0283	14.0	9.4	1.0270	1.0274	—	3.56	—	
77	—	62 20	5 28	0	0	0	1.0282	12.3	10.0	1.0270	1.02725	—	3.50	—	
78	—	62 5	6 22	0	0	0	1.0278	13.8	10.6	1.02685	1.0270	—	3.54	—	
79	—	Thorshavn.			0	0	1.0280	13.4	9.4	1.0270	1.02735	—	3.56	—	
80	—	Do.			0	0	1.0266	10.2	9.4	1.0251	1.0254	—	3.31	—	
81	—	Do.			0	0	1.0275	15.8	9.4	1.0266	1.0273	—	3.55	—	
82	—	Do.			0	0	1.0276	15.0	9.4	1.0266	1.02725	—	3.55	—	
83	—	Do.			0	0	1.0277	15.0	9.4	1.0270	1.02735	—	3.50	—	
84	37	62° 28' 3"	2° 29' W.	300	565	0	1.0270	15.3	9.1	1.0266	1.0283	—	3.55	—	
85	37	62 28.3	2 29	600	1262	0	1.0270	15.8	— 1.1	1.0270	1.0285	—	3.50	—	
86	—	62 15	4 32	0	0	0	1.0274	15.8	9.3	1.0268	1.0272	—	3.53	—	
87	—	62 23	3 26	0	0	0	1.0274	15.5	9.6	1.0268	1.0271	—	3.53	—	
88	—	62 28	2 29	0	0	0	1.0274	15.7	10.4	1.0268	1.0270	—	3.53	—	
89	—	62 37	2 52	0	0	0	1.0275	15.7	10.2	1.0269	1.0271	—	3.55	—	
90	—	62 50	3 30	0	0	0	1.0270	15.3	10.5	1.0269	1.0271	—	3.55	—	
91	—	62 57	3 47	0	0	0	1.0275	14.8	10.3	1.02675	1.0270	—	3.53	—	
92	—	63 12	4 39	0	0	0	1.0274	15.7	9.7	1.0268	1.0271	—	3.53	—	
93	—	63 22	5 20	0	0	0	1.0277	14.0	9.4	1.0268	1.0272	—	3.53	—	
94	40	63 22.5	5 20	515	942	0	1.0277	13.6	— 0.4	1.0267	1.0281	—	3.52	—	
95	40	63 22.5	5 20	0	0	0	1.0277	13.8	9.7	1.02675	1.0271	—	3.53	—	
96	40	63 22.5	5 20	0	0	0	1.0277	13.8	9.7	1.02675	1.0271	—	3.53	—	
97	40	63 22.5	5 20	0	0	0	1.0277	15.4	10.3	1.02705	1.0273	—	3.57	—	
98	—	Reikjavik.			0	0	1.0272	11.1	9.8	1.0258	1.0261	—	3.40	—	
99	—	Do.			0	0	1.0207	16.3	10.0	1.0202	1.0205	—	3.46	—	
100	—	63 49	22 52	0	0	0	1.0273	14.5	8.8	1.0205	1.0209	—	3.50	—	
101	—	63 37	21 58	0	0	0	1.0274	14.2	9.7	1.0265	1.0268	—	3.50	—	
102	—	63 42	22 25	0	0	0	1.0278	14.7	9.5	1.0265	1.0268	—	3.50	—	
103	—	63 25	21 0	0	0	0	1.0271	15.6	10.0	1.0265	1.02675	—	3.50	—	
104	—	63 13	19 54	0	0	0	1.0273	15.6	10.4	1.0267	1.0269	—	3.52	—	
105	—	63 6	18 43	0	0	0	1.0273	16.8	10.0	1.0266	1.0271	—	3.55	—	
106	—	63 7	17 34	0	0	0	1.0273	15.3	10.2	1.0266	1.02685	—	3.51	—	
107	—	63 7	16 20	0	0	0	1.0273	15.6	11.0	1.0267	1.0268	—	3.52	—	
108	—	63 8	15 9	0	0	0	1.0270	15.2	11.0	1.0269	1.0270	—	3.55	—	
109	—	63 8	13 59	0	0	0	1.0270	13.0	10.7	1.0268	1.02695	—	3.53	—	
110	—	63 20	13 22	0	0	0	1.0272	16.0	10.7	1.02665	1.0268	—	3.52	—	
111	45	63 28	12 58	0	0	0	1.0273	16.9	10.4	1.02695	1.02715	—	3.55	—	
112	—	63 38	12 35	0	0	0	1.0270	13.6	10.0	1.0269	1.0272	—	3.55	—	

1. Støkk Regt. Hevst. Rædd.

No.	Stat. No.	Nordlig Breidde. (North Latitude)	Længde fra Greenwich. (Longitude from Greenwich)	Dybde hvorfra Proben hentet. (Depth from which the Samples were collected)		Alteste Egenvægt. (Specific Gravity read)	Temperatur. (Temperature)		Egenvægt. (Specific Gravity)		Saltmængde. (Amount of Salt measured)		
				Engelske Fæm. (English Fathoms)	Metre. (Metres)		Under Aftesningen. (When read)	I Havet. (In Sea)	Ved 17.5. 17.5	Ved 17. 17	Chlor- mængde. (Amount of Chlorine)	Etter Anom- meter. (By the Anometer)	Etter Chlor- mængde. (By the Amount of Chlorine)
113	—	63° 57'	11° 52' W.	0	0	1.0277	13.6	10.2	1.0267	1.0264	—	3.52	—
114	—	64 14	11 12	0	0	1.0277	14.0	9.5	1.0268	1.0271	—	3.53	—
115	48	64 36	10 21.5	0	0	1.0270	11.5	5.3	1.02655	1.0275	—	3.50	—
116	—	64 44	10 4	0	0	1.0270	17.5	7.0	1.0268	1.0275	—	3.53	—
117	—	65 0	9 24	0	0	1.0290	18.0	7.4	1.0268	1.0275	—	3.53	—
118	—	65 21	8 36	0	0	1.0271	16.8	7.8	1.0267	1.0273	—	3.52	—
119	—	65 39	7 53	0	0	1.0271	15.0	7.2	1.0264	1.02705	—	3.18	—
120	51	65 53	7 18	0	0	1.0272	15.0	8.0	1.0265	1.02705	—	3.50	—
121	51	65 53	7 18	515	942	1.0272	16.0	-0.6	1.02665	1.0281	—	3.52	—
122	51	65 53	7 18	1103	2127	1.0272	16.0	-1.1	1.02665	1.0281	—	3.52	—
123	—	65 51	5 36	0	0	1.0269	18.2	8.4	1.0268	1.02735	—	3.53	—
124	—	65 49	4 18	0	0	1.0270	17.6	9.3	1.0268	1.0272	—	3.53	—
125	52	65 47.5	3 7	0	0	1.0270	17.0	9.7	1.0268	1.0271	—	3.53	—
126	52	65 47.5	3 7	515	942	1.0270	17.4	-0.4	1.02675	1.0282	—	3.53	—
127	52	65 47.5	3 7	1861	3403	1.0280	12.0	-1.2	1.0267	1.0282	—	3.52	—
128	—	64 47	4 24 E.	0	0	1.0274	13.0	11.0	1.02645	1.02655	—	3.49	—
129	—	64 47	4 24	0	0	1.0264	14.5	11.0	1.0266	1.0267	—	3.51	—
130	—	64 49	4 46	0	0	1.0263	16.0	10.8	1.0264	1.0265	—	3.48	—
131	—	64 46	5 38	0	0	1.0270	18.0	11.2	1.0266	1.02695	—	3.55	—
132	—	64 42	9 47	0	0	1.0265	19.0	10.6	1.0266	1.0268	—	3.51	—
133	—	64 37	8 0	0	0	1.0265	16.0	10.8	1.0266	1.0267	—	3.51	—
134	—	64 27	8 36	0	0	1.0253	16.2	10.5	1.02545	1.0259	—	3.30	—
135	—	Mølleens System og Hølløben Mellem Støttemæl og Hølløben		0	0	1.0229	15.8	—	1.0217	—	—	2.86	—
136	63	64 41.3	0 0	0	0	1.0278	13.4	11.6	1.0268	1.02675	—	3.53	—
137	68	64 44.1	8 9	0	0	1.0277	13.0	11.6	1.0266	1.0266	—	3.51	—
138	73	64 46.5	7 28	0	0	1.0276	13.0	11.3	1.0265	1.0265	—	3.50	—
139	—	64 48	6 45	0	0	1.0277	13.0	11.5	1.0266	1.0266	—	3.51	—
140	—	64 48	6 26	0	0	1.0281	12.2	11.6	1.02685	1.0268	—	3.54	—
141	—	64 33	5 31	0	0	1.0278	14.2	11.8	1.0269	1.0269	—	3.55	—
142	—	64 4	5 35	0	0	1.0277	13.8	11.7	1.02675	1.0267	—	3.53	—
143	—	64 2	5 42	0	0	1.0277	13.8	12.0	1.02675	1.0267	—	3.53	—
144	89	64 1	6 7.5	0	0	1.0277	13.8	12.2	1.02675	1.0266	—	3.53	—
145	—	64 0	6 42	0	0	1.0270	12.0	11.4	1.0266	1.02665	—	3.51	—
146	—	63 48	6 42	0	0	1.0268	12.8	12.8	1.0257	1.0264	—	3.39	—
147	—	63 22	6 47	0	0	1.0259	12.8	—	1.0248	—	—	3.27	—
148	—	Stadt.		0	0	1.0250	14.2	—	1.02415	—	—	3.19	—
149	94	59 8.2	4 38'	0	0	1.0259	12.0	9.8	1.0245	1.0248	—	3.23	—
150	94	59 8.2	4 38	145	265	1.0263	12.0	5.0	1.0249	1.0258	—	3.28	—
151	95	60 42.5	4 13.7	0	0	1.0254	12.0	9.4	1.0242	1.0245	—	3.18	—
152	95	60 42.5	4 13.7	175	320	1.0278	11.0	5.5	1.0264	1.0272	—	3.45	—
153	—	64 47	2 50	0	0	1.0276	12.7	9.4	1.0263	1.0267	—	3.47	—
154	96	66 8.5	3 0	0	0	1.0278	13.5	8.2	1.0266	1.0272	—	3.51	—
155	96	66 8.5	3 0	805	1472	1.0275	13.0	-1.1	1.0266	1.0280	—	3.51	—
156	97	66 2	4 21	683	1249	1.0284	10.9	1.1	1.0268	1.0283	—	3.53	—
157	98	65 56	5 21	388	719	1.0278	13.0	-1.0	1.02655	1.0280	—	3.59	—
158	99	65 51.5	6 25	213	399	1.0277	13.5	6.1	1.0265	1.0274	—	3.50	—
159	101	65 36	8 32	0	0	1.0270	12.6	9.4	1.0263	1.02665	—	3.47	—
160	101	65 36	8 32	223	468	1.0283	10.3	6.0	1.0266	1.0275	—	3.51	—
161	104	65 28	9 56	162	299	1.0282	11.4	6.5	1.0267	1.0275	—	3.52	—
162	124	66 41	6 59	0	0	1.02735	14.5	8.4	1.0264	1.0269	—	3.48	—
163	125	67 52.5	5 12	0	0	1.0282	10.1	7.9	1.0265	1.0272	1.957	3.59	3.54
164	125	67 52.5	5 12	700	1289	1.0280	10.4	1.4	1.02635	1.0278	1.951	3.48	3.53
165	137	67 24	8 58	0	0	1.02745	9.9	8.2	1.0257	1.0263	—	3.30	—
166	137	67 24	8 58	400	732	1.0281	11.7	-1.0	1.0266	1.0281	—	3.51	—
167	143	66 58	10 33	0	0	1.0273	10.7	8.2	1.0257	1.0262	1.899	3.39	3.44
168	143	66 58	10 33	180	346	1.0279	12.0	6.2	1.0265	1.0273	1.956	3.59	3.54

No.	Stat. No.	Nordlig Breddo. <i>(North Latitude)</i>	Længde fra Greenwich. <i>(Longitude from Greenwich)</i>		Dybde-hvorfra Provent hentet. <i>(Depth from which the Samples were collected)</i>		Alteste Ege- vægter. <i>(Specific Gravity read)</i>	Temperatur. <i>(Temperature)</i>		Ege- vægter. <i>(Specific Gravity)</i>		Chlor- vægtdo. <i>(Amount of Chlorine)</i>	Saltmængde. <i>(Amount of Salt measured)</i>		
			Engelske Favne. <i>(English Fathoms)</i>	Meter. <i>(Meters)</i>	Under Atlans- mægen. <i>(Under sea)</i>	I Havet. <i>(In Sea)</i>		Ved 17,0° F. <i>(At 17,0° F.)</i>	Ved 17,5° F. <i>(At 17,5° F.)</i>	Efter Ar- cimeter. <i>(By the Arcometer)</i>	Efter Chlor- vægtdo. <i>(By the Amount of Chlorine)</i>				
160	—				0	0	1.00917	11.7	—	1.0083	—	—	1.00	—	
170	152	07° 18'	12° 40'	E.	0	0	1.0266	14.3	8.2	1.0256	1.0261	—	3.38	—	
171	152	07	18	12	40	70	1.0270	13.5	4.1	1.02585	1.0260	—	3.41	—	
172	152	07	18	12	40	125	220	1.0274	13.5	4.1	1.0262	1.0273	—	3.46	—
173	162	08	23	10	20	705	1454	1.0270	17.2	1.2	1.0200	1.0280	1.043	3.51	3.51
174	—				0	0	1.0260	14.5	8.8	1.0250	1.0261	—	3.41	—	
175	171	09° 18'	14° 20'		0	0	1.0272	11.0	0.0	1.0258	1.0262	—	3.40	—	
176	171	09	18	14	20	642	1174	1.0282	0.0	—1.0	1.0205	1.0270	—	3.50	—
177	170	09	18	14	32.7	0	0	1.0270	13.3	8.6	1.0258	1.0264	—	3.40	—
178	170	09	32	11	10	0	0	1.0280	10.0	8.8	1.0264	1.0269	1.045	3.48	3.52
179	170	09	32	11	10	1607	2930	1.0282	0.7	—1.2	1.0264	1.0270	1.035	3.48	3.50
180	183	09	50.5	0	15	0	0	1.0270	13.5	8.6	1.0207	1.0272	1.052	3.52	3.53
181	184	70	4	0	50	0	0	1.0280	12.0	7.0	1.0207	1.0273	1.043	3.52	3.51
182	184	70	4	0	50	600	1007	1.0270	12.8	0.0	1.0260	1.0280	1.028	3.51	3.40
183	184	70	4	0	50	1547	2820	1.02705	13.4	—1.3	1.0265	1.0270	1.035	3.50	3.50
184	187	69	51.5	14	41	1335	2441	1.0276	15.2	—1.1	1.02675	1.0282	1.033	3.53	3.50
185	188	69	43	15	29	0	0	1.0278	13.2	0.0	1.0260	1.0270	1.030	3.51	3.51
186	189	69	41	15	42	0	0	1.0275	13.2	0.0	1.0263	1.0260	1.023	3.47	3.48
187	189	69	41	15	42	860	1573	1.0270	12.0	—1.1	1.0260	1.0281	1.031	3.51	3.40
188	200	71	25	15	10.5	0	0	1.0282	0.0	7.8	1.0265	1.0271	—	3.50	—
189	200	71	25	15	40.5	620	1134	1.0285	0.4	—1.0	1.0267	1.0281	1.040	3.52	3.53
190	200	70	45	14	30	0	0	1.0282	0.5	8.2	1.0264	1.0270	1.045	3.48	3.52
191	200	70	45	14	30	700	1280	1.0285	8.7	—0.7	1.0266	1.0280	1.045	3.51	3.52
192	200	70	45	14	30	1248	2282	1.0283	0.2	—1.1	1.0265	1.0270	1.045	3.50	3.52
193	—				0	0	—	—	—	—	—	1.744	—	3.15	—
194	212	70° 12.5'	17° 41'		0	0	1.0255	21.7	7.2	1.0201	1.02675	1.895	3.44	3.43	
195	212	70	12.5	17	41	112	260	1.0272	17.6	5.8	1.02685	1.02775	1.040	3.54	3.51
196	213	70	23	2	30	0	0	1.0277	14.2	8.2	1.0267	1.0272	1.050	3.52	3.54
197	213	70	23	2	30	1760	3210	1.0274	15.5	—1.2	1.0260	1.02805	1.051	3.51	3.53
198	215	70	53	2	0	0	0	1.0276	14.0	8.0	1.0267	1.0273	1.045	3.52	3.52
199	215	70	53	2	0	200	366	1.02755	15.2	2.8	1.0267	1.0270	1.045	3.52	3.52
200	215	70	53	2	0	700	1280	1.0276	14.3	—0.6	1.0266	1.0280	1.035	3.51	3.50
201	215	70	53	2	0	1665	3045	1.0275	11.5	—1.2	1.0265	1.02705	1.030	3.50	3.51
202	217	71	0	5	8.5	0	0	1.0283	0.5	4.0	1.0262	1.0272	—	3.46	—
203	—				0	0	1.0280	4.0	3.0	1.02595	1.0268	—	3.38	—	
204	225	70° 58'	8° 4'		0	0	1.0278	0.2	3.4	1.0260	1.0271	—	3.43	—	
205	226	70	59	7	51	0	0	1.0277	10.5	3.0	1.0261	1.0272	1.893	3.44	3.42
206	226	70	59	7	51	340	622	1.0282	0.1	—0.6	1.02635	1.0278	1.030	3.48	3.50
207	—	69	20	11	18	0	0	1.0276	12.8	4.3	1.0263	1.02745	1.025	3.47	3.48
208	—	68	33	7	25	0	0	—	—	—	—	1.030	—	3.50	—
209	243	68	32.5	0	20	0	0	1.0280	12.8	7.8	1.0267	1.0273	1.045	3.52	3.52
210	243	68	32.5	6	26	600	1007	1.02715	16.7	—0.8	1.0266	1.0280	1.027	3.51	3.40
211	243	68	32.5	0	26	1385	2533	1.0280	5.7	—1.3	1.0264	1.0278	1.040	3.48	3.51
212	245	68	21	2	5	0	0	1.0280	13.4	0.0	1.0268	1.02725	—	4.53	—
213	247	68	5.5	2	24	0	0	1.0278	13.8	0.4	1.0267	1.0271	1.054	3.52	3.53
214	247	68	5.5	2	24	500	914	1.0278	13.1	0.4	1.0266	1.0280	1.027	3.51	3.40
215	247	68	5.5	2	24	1120	2048	1.0275	14.5	—1.2	1.0265	1.02705	1.026	3.50	3.40
216	249	68	12	0	35	1003	1944	1.0274	15.4	—1.3	1.0266	1.0280	1.037	3.51	3.50
217	251	68	6.5	0	44	0	0	1.0276	13.0	1.3	1.0265	1.0262	1.027	3.50	3.40
218	252				0	0	1.0254	10.2	14.0?	1.0254	1.0246	1.820	3.35	3.20	
219	253				0	0	1.0178	14.4	13.0	1.0173	1.0168	1.261	2.28	2.28	
220	253				263	481	1.02755	11.2	3.2	1.0260	1.02715	1.887	3.43	3.41	
221	254	67° 27'	13° 25'		0	0	1.0266	12.6	10.0	1.0253	1.0255	1.843	3.34	3.33	
222	254	67	27	13	25	70	128	1.0278	11.2	4.8	1.02625	1.0272	1.029	3.46	3.40
223	254	67	27	13	25	140	256	1.0281	12.1	5.8	1.0267	1.0276	1.031	3.52	3.40
224	—				0	0	1.0202	12.0	—	1.0248	—	1.822	3.27	3.20	

No.	Stat. No.	Nordlig Breddle.		Längde fra Greenwich.		Dybde hvortil Proven hentet.		Engelske Favne.	Meter.	Aftaste Egenvægt.	Temperatur.		Egenvægt.		Chlor- mængde.	Saltmængde.	
		(North Latitude.)	(Longtude from Greenwich.)	(Depth from which the Samples were collected.)	(Specific Gravity read.)	(Under Atmosphere.)	(In Sun.)				(Specific Gravity.)	(Amount of Chlorine.)	(Amount of Salt measured.)	(For the Amount of Chlorine.)			
225	255	68°	12.3	15°	40'	E.	0	0	1.0262	14.3	10.7	1.0252	1.0253			3.32	
226	255	68	12.3	15	40		300	540	1.0286	12.0	6.5	1.0207	1.0275			3.52	
227	256	70	8.5	23	4		0	0						1.118			2.02
228	256	70	8.5	23	4		225	411	1.0280	10.0	1.0	1.0201	1.0275	1.030		3.48	3.40
229	258	70	12.0	23	2.5		0	0	1.0276	8.3	11.6	1.0257	1.0250	1.805		3.30	3.37
230	258	70	12.0	23	2.5		230	421	1.0282	6.0	10.0	1.0201	1.0272	1.007		3.44	3.45
231	259	70	48.0	25	50		80	146	1.0286	6.7	4.1	1.02015	1.0275	1.012		3.49	3.51
232	261	70	47.5	28	30		0	0	1.0248	11.0	7.4	1.0231	1.0240	1.713		3.00	3.10
233	261	70	47.5	28	30		127	232	1.0280	10.0	2.8	1.0201	1.0270	1.020		3.48	3.47
234	262	70	36	32	35		0	0	1.0282	8.5	5.0	1.0203	1.0272	1.021		3.47	3.47
235	262	70	36	32	35		148	271	1.0284	8.0	1.0	1.0205	1.0278	1.032		3.50	3.40
236	263	70	44.5	34	14		121	221	1.1286	6.0	1.0	1.0205	1.02775	1.027		3.50	3.40
237	264	70	50	35	37		0	0	1.0270	11.3	5.2	1.0201	1.0273	1.020		3.48	3.40
238	264	70	50	35	37		80	157	1.0281	11.1	1.0	1.0200	1.02785	1.034		3.51	3.50
239	268	71	36.5	30	18		0	0	1.0284	8.7	4.4	1.0205	1.02755	1.025		3.50	2.48
240	268	71	36.5	30	18		130	238	1.0285	8.0	—1.0	1.0200	1.0281	1.038		3.51	1.51
241	270	72	27.5	35	1		0	0	1.0284	9.0	3.0	1.02055	1.0277	1.037		3.50	1.50
242	270	72	27.5	35	1		130	240	1.0280	8.0	0.0	1.0207	1.0281	1.037		3.52	3.50
243	272	73	10.8	33	3		113	207	1.0285	8.0	1.5	1.0206	1.0270	1.037		3.51	3.50
244	273	73	25	31	30		0	0	1.0285	8.7	1.0	1.0206	1.0276	1.038		3.51	3.51
245	273	73	25	31	30		107	360	1.0285	8.5	2.2	1.0206	1.0278	1.043		3.51	3.51
246	275	74	8	31	12		0	0	1.0287	5.0	2.0	1.0205	1.0277	1.035		3.50	3.50
247	275	74	8	31	12		147	260	1.0280	5.5	—0.4	1.02005	1.02805	1.030		3.52	3.50
248	278	74	1.5	22	27		0	0	1.0280	5.0	4.2	1.0201	1.02745			3.48	
249	278	74	1.5	22	27		230	421	1.0287	5.3	0.0	1.0204	1.0278			3.48	
250	280	74	10.5	18	51		0	0	1.0282	9.3	1.2	1.0204	1.0277			3.48	
251	280	74	10.5	18	51		35	64	1.0283	9.4	1.1	1.0205	1.0278			3.50	
252	281	74	3	17	18		0	0	1.0285	8.0	4.0	1.0200	1.02765	1.007		3.51	3.50
253	281	74	3	17	18		115	210	1.0287	8.8	2.2	1.0208	1.0281	1.030		3.53	3.51
254	283	73	47.5	14	21		0	0	1.0282	11.3	7.2	1.0207	1.0271	1.038		3.52	3.51
255	284	73	1	12	58		0	0	1.0283	11.2	6.8	1.02075	1.0275	1.040		3.53	3.51
256	286	72	57	14	32		447	817	1.0284	9.5	—0.8	1.0206	1.02805			3.51	
257	280	72	41.5	20	18		0	0	1.0282	11.1	7.0	1.02065	1.0273			3.52	
258	280	72	41.5	20	18		219	400	1.0282	11.1	2.0	1.02065	1.0270			3.52	
259	291	71	51	21	57		0	0	1.0280	12.0	7.4	1.0206	1.02725	1.030		3.51	3.50
260	291	71	51	21	57		104	355	1.0284	10.5	3.0	1.02075	1.02795	1.044		3.53	3.52
261	293	71	7	21	11		0	0	1.0272	5.0		1.02495		1.000?		3.29	3.45
262	293	71	7	21	11		95	174	1.0270	5.3		1.0254		1.043		3.35	3.51
263	294	71	35	15	11		0	0	1.0272	4.0		1.02495		1.048		3.49	3.47
264	294	71	35	15	11		637	1165	1.0284	7.1	—1.2	1.0203	1.02775	1.034		3.47	3.50
265	295	71	50	11	40		0	0	1.0278	13.5	7.0	1.02065	1.02735	1.042		3.52	3.51
266	295	71	55	11	30		100	183	1.0283	10.1	3.2	1.0209	1.0278	1.042		3.51	3.51
267	295	71	55	11	30		600	1097	1.0281	10.7	0.8	1.0205	1.0270	1.030		3.50	3.50
268	295	71	50	11	40		1110	2030	1.0278	13.3	—1.3	1.0200	1.02805	1.034		3.51	3.50
269	296	72	15.5	8	0		100	183	1.0286	7.1	3.1	1.0205	1.0277	1.044		3.50	3.52
270	296	72	15.5	8	0		600	1097	1.0287	7.1	—0.5	1.0200	1.0280	1.030		3.51	3.51
271	297	72	36.5	5	12		0	0	1.0284	5.0	4.8	1.0262	1.0272	1.028		3.40	3.40
272	297	72	36.5	5	12		1280	2341	1.0286	5.0	—1.4	1.0263	1.02775	1.026		3.47	3.48
273	298	72	52	1	50.5		0	0	1.0272	15.1	4.0	1.0203	1.0271	1.047		3.47	3.47
274	298	72	52	1	50.5		1500	2743	1.0274	16.8	1.5	1.0200	1.0280	1.045?		3.51	
275	299	73	10	2	14	W.	0	0	1.0269	13.7	3.6	1.0258	1.0299	1.888		3.49	3.42
276	300	73	10	3	22		0	0	1.0255	15.2	1.7	1.0247	1.0259	1.810		3.29	3.27
277	301	74	1	1	20		0	0	1.0203	14.3	2.2	1.0253	1.0295	1.837		3.34	3.32
278	302	75	16	0	54		0	0	1.0285	7.0	3.0	1.0205	1.0277	1.020		3.50	3.47
279	303	75	12	3	2	E.	0	0	1.0283	6.5	3.3	1.02015	1.0273	1.044		3.45	3.49
280	303	75	12	3	2		150	274	1.0288	4.4	—1.1	1.02015	1.0270	1.020		3.49	3.49

No.	Stat. No.	Nordlig Bredde. (North Latitude)		Længde fra Greenwich. (Longitude from Greenwich)		Dybde hvorfra Proben hentet. (Depth from which the Samples were collected)		Albæste Egenvægt. (Specific Gravity read.)	Temperatur. (Temperature)		Egenvægt. (Specific Gravity)		Chlor-mængde. (Amount of Chlorine)	Saltmængde. (Amount of Salt measured)		
						Engelske Favne. (English Fathoms)	Meter. (Metres.)		Under Aftensnoren. (When read.)	I Havet. (In Situ.)	Ved 17.05 At 17.05	Ved 4.0 At 4.0		Efter Aræometer. (By the Aræometer.)	Efter Chlor-mængde. (By the Amount of Chlorine.)	
281	304	75	3	4	51	E.	300	540	1.0273	14.0	-0.8	1.0264	1.0278	1.020	3.48	3.40
282	304	75	3	4	51		1735	3173	1.0273	14.5	-1.5	1.0263	1.02775	1.040	3.47	3.51
283	305	75	1.5	7	50		0	0	1.0272	14.8	5.3	1.0263	1.0272	1.047	3.47	3.52
284	306	75	0	10	27		0	0	1.0275	14.1	5.4	1.02645	1.0274	1.020	3.40	3.49
285	306	75	0	10	27		1334	2440	1.0272	14.9	-1.3	1.0263	1.0277	1.020	3.47	3.47
286	310	74	56	13	50		0	0	1.0274	14.7	5.5	1.02645	1.0274	1.036	3.40	3.50
287	310	74	50	13	50		1006	1840	1.0275	13.8	-1.4	1.0264	1.0278	1.032	3.48	3.49
288	316	74	50	10	20		0	0	1.0260	14.7	3.6	1.02505	1.02705	1.003	3.42	3.44
289	316	74	50	10	20		129	236	1.0275	14.6	1.0	1.02555	1.0278	1.030	3.50	3.40
290	321	74	56.5	10	30		25	46	1.0275	9.7	0.2	1.02575	1.0271	—	3.40	—
291	323	72	53.5	21	51		0	0	1.0283	9.7	7.8	1.02655	1.0272	1.047	3.50	3.52
292	323	72	53.5	21	51		223	408	1.0284	8.0	1.5	1.0265	1.0278	1.033	3.50	3.50
293	326	75	31.5	17	50		0	0	1.0276	8.9	4.8	1.02575	1.0267	1.004	3.40	3.44
294	326	75	31.5	17	50		123	225	1.0284	8.7	1.6	1.0265	1.0278	1.030	3.50	3.40
295	328	75	42	15	30		0	0	1.0270	0.9	4.7	1.0262	1.0272	1.008	3.46	3.45
296	328	75	42	15	30		200	366	1.0282	0.8	-1.3	1.02045	1.0270	1.042	3.40	3.51
297	331	75	51	13	5		0	0	—	—	—	—	—	1.035	—	3.50
298	332	75	50	11	36		1140	2101	1.0286	6.3	-1.5	1.0264	1.0270	—	3.48	—
299	333	76	12.5	14	0		0	0	1.0275	13.7	6.0	1.0264	1.0272	1.023	3.48	3.48
300	333	76	12.5	14	0		403	737	1.0277	13.7	1.0	1.0266	1.0270	1.035	3.51	3.50
301	335	76	10.5	14	30		0	0	1.0270	15.5	5.4	1.0262	1.0271	1.014	3.46	3.46
302	335	76	10.5	14	30		170	327	1.0276	13.4	1.0	1.0264	1.0277	1.040	3.48	3.51
303	339	76	30	15	30		0	0	1.0267	12.7	2.6	1.0254	1.0266	1.807	3.35	3.38
304	339	76	30	15	30		37	68	1.0273	13.6	0.0	1.02615	1.0275	1.024	3.45	3.48
305	342	76	33	13	18		0	0	1.0277	12.4	6.2	1.02035	1.0272	1.036	3.48	3.50
306	342	76	33	13	18		523	956	1.0277	12.2	-1.0	1.0263	1.0277	1.033	3.47	3.50
307	344	76	42	11	16		0	0	1.0283	6.2	5.2	1.0261	1.0271	—	3.44	—
308	347	76	40.5	7	47		0	0	1.0277	11.3	4.4	1.0262	1.0272	1.024	3.46	3.48
309	347	76	40.5	7	47		1420	2613	1.0278	11.0	-1.3	1.0263	1.02775	1.035	3.47	3.50
310	349	76	30	2	57		0	0	1.0274	11.2	3.8	1.02585	1.0266	1.808	3.41	3.43
311	349	76	30	2	57		1487	2710	1.0277	11.3	-1.5	1.0262	1.0270	1.046	3.46	3.52
312	350	76	26	0	20	W.	0	0	1.0270	10.0	3.0	1.0254	1.0266	1.872	3.35	3.39
313	350	76	26	0	20		300	540	1.0270	10.0	-1.1	1.0263	1.02775	1.022	3.47	3.48
314	350	76	26	0	20		1686	3083	1.0276	10.8	-1.5	1.0260	1.0274	1.016	3.43	3.47
315	352	77	56	3	20	E.	0	0	1.0272	12.8	3.9	1.0259	1.0270	1.008	3.41	3.45
316	352	77	50	3	20		300	540	1.0274	14.0	-0.8	1.0263	1.02775	1.028	3.47	3.49
317	355	78	0	8	32		0	0	1.0275	10.3	4.9	1.0258	1.0268	1.800	3.40	3.42
318	355	78	0	8	32		948	1734	1.0280	9.9	-1.3	1.0203	1.0277	1.027	3.47	3.49
319	357	78	3	11	18		0	0	1.0261	10.0	5.0	1.02455	1.02545	1.797	3.24	3.25
320	350	78	2	0	25		0	0	1.0280	5.3	4.3	1.02575	1.0268	—	3.40	—
321	350	78	2	0	25		416	761	1.0276	13.7	0.8	1.0265	1.0278	1.025	3.50	3.48
322	301	70	8.5	5	28		0	0	1.0278	11.5	4.2	1.0263	1.02735	1.006	3.47	3.45
323	301	70	8.5	5	28		995	1655	1.0272	12.0	-1.2	1.02505	1.02705	1.028	3.42	3.40
324	302	70	50	5	40		0	0	1.0274	13.0	5.2	1.02615	1.0271	1.017	3.45	3.47
325	302	70	50	5	40		450	839	1.0275	12.8	-1.0	1.0262	1.0276	1.022	3.46	3.48
326	303	80	0	8	15		0	0	1.0270	10.9	4.6	1.0260	1.0270	—	3.43	—
327	303	80	0	8	15		260	475	1.0284	7.7	1.1	1.0264	1.0277	1.045	3.48	3.52
328	—	—	—	—	—		0	0	1.0283	4.1	2.7	1.02505	1.0271	—	3.42	—
329	—	—	—	—	—		0	0	1.0268	12.3	2.2	1.02545	1.0266	—	3.36	—
330	368	78	43	8	20		0	0	1.0266	13.0	4.6	1.0254	1.02635	—	3.35	—
331	368	78	43	8	20		315	576	1.0286	8.5	1.6	1.0267	1.0280	1.036	3.52	3.50
332	—	78	34	0	22		0	0	1.0262	11.9	4.5	1.0248	1.0258	—	3.27	—
333	372	78	0	14	12		0	0	1.0258	5.0	4.1	1.0236	1.0246	—	3.11	—
334	373	78	0	14	26		0	0	1.0250	12.5	4.0	1.0237	1.0247	—	3.13	—
335	—	—	—	—	—		0	0	1.0250	5.3	4.7	1.02285	1.0237	—	3.01	—

Ved Nordlingen  
 (De Nord. Grønde)  
 Magdalenøey.  
 Mindringen af Almindelig  
 (Omtrent 60 Almindelig)



Af denne Tabel fremgaar det, at Differentserne mellem de ved Hjælp af Egenvægt og Chlormengde beregnede Saltmængder i Regelen ere meget smaa, kun de 3 samtidig udførte Bestemmelser i Vandproverne No. 261, 262 og 263 danne i saa Henseende en Undtagelse. De store her optrædende Differentser skyldes uden Tvivl en Feil ved Aflæsningen af Egenvægterne, som for disse Vandprovers Vedkommende ere fundne altfor lave, til at de kunne bringes i Harmoni med andre paa Steder i Nærheden udførte Observationer. Det er saaledes i høi Grad paafaldende for Vandproven No. 262, optagen fra et Dyb af 95 Favne (174 Meter) i ca. 8 Miles Afstand fra Land, at finde Egenvægten 1.0254, medens man i de indenfor liggende Fjorde, hvor Saltgehalten ellers overalt er mindre end paa Havet, i lignende Dyb finder en meget større Egenvægt. Selv i den indelukkede Skjærstadvand, hvor Overfladevandet er særdeles fattigt paa Salte, er dog Egenvægten paa Bunden funden at være 1.026, kort sagt, Egenvægter som de i de omtalte Tilfælde observerede staa paa dette Strøg af Kysten fuldstændig uden Sidestykke. Naturligst lade disse Urimeligheder sig forklare ved at antage Egenvægterne aflæste med 0.001 for højt, da de ved denne Antagelse paa det Nærmeste kan bringes i Overensstemmelse saavel med de i de samme Vandprover udførte Chlorbestemmelser som med de andre Observationer fra nærliggende Puncter.

Bortser man fra disse 3 nævnte Observationer og af de øvrige beregner den gjennemsnitlige halve Different mellem to paa samme Vandprobe ved Hjælp af Chlorititrering og Aræometer udførte Saltbestemmelser, resulterer som Udtryk for denne 0.00004, eller man erholder under Formindsættning af, at Feilene i lige høi Grad skyldes Chlor- som Egenvægtsbestemmelserne, for den gjennemsnitlige Feil af en Egenvægtsbestemmelse Værdien 0.000069 og af en Chlorbestemmelse 0.005. Differentserne falde, som man ser, snart til den ene snart til den anden Side, idet det dog maa bemærkes, at Chlormengden gjennemsnitlig giver lidt over 0.008 % mere Saltgehalt end Egenvægterne, hvad der næsten indelukkende skyldes de nordenfor den 75de Breddegrad udførte Observationer.

Førend jeg nu gaar over til at give en Oversigt over de Resultater, som af disse Observationer lader sig udlede, vil det være nødvendigt parenthetisk at indskyde nogle Bemærkninger om Dybde- og Temperaturforholdene i det norske Hav i sine groveste Træk. Hvad der til den Ende her meddeles, er hovedsagelig hentet fra en af Professor Dr. Mohr forfattet Afhandling, som findes trykt i C. F. Schiøtters "Væstlivet i Norge."

Dybden i det af den norske Expedition undersøgte Hav, forsaavidt det ligger vestenfor en Linie fra Spitzbergen til det nordlige Norge, er i større Afstand fra Land overalt over 1000 Favne (1829 Meter) og gaar i Regelen op til mellem 1500 og 2000 Favne (2743 og 3658 Meter) eller endog derover. Paa Strøget mellem Beeren Eiland og Jan Mayen hæver sig en Ryg, hvor Dybden ikke naar 1500 Favne (2743 Meter), medens der saavel søndenfor

This Table shows the differences in the amount of salt computed from specific gravity and the proportion of chlorine to be, as a rule, exceedingly small, the 3 determinations performed successively with samples Nos. 261, 262, and 263 constituting the sole exception. The great differences observed here must unquestionably arise from erroneous readings of the specific gravity, which, as found for these samples, is much too low when compared with that determined for others obtained from adjacent localities. Thus, for instance, the specific gravity of sample No. 262, drawn at a depth of 95 fathoms (174 metres), about 8 geographical miles from land, is stated to be 1.0254, whereas that determined for the water of the neighbouring fjords, in which the amount of salt at equal depths is invariably less than in the open sea, was much greater. Even for a frith locked in as is the Skjærstadvand, where the surface-water is remarkably deficient in salts, the specific gravity of bottom-samples was found to be 1.0260; in short, such exceptional specific gravities are without a parallel on this line of coast. The most natural explanation of these incongruities, is afforded by assuming the specific gravity in each case to have been read 0.001 too low; the results could then be made to agree pretty closely both with the chlorine-determinations performed with the same samples of water and with observations taken in adjacent localities.

Now, if we disregard the 3 exceptional observations, and for the others compute the average half-difference between two salt-determinations performed with the same sample of water by means of the aræometer and titrating with chlorine, this will be expressed by 0.00004 or, assuming the errors to be equally in the chlorine and the specific gravity determinations, the mean error of a specific gravity determination is 0.000069, and of a chlorine-determination 0.005. As will be seen, the differences between the 2 right-hand columns of the Table are sometimes positive, sometimes negative; but the amount of salt indicated by the proportion of chlorine exceeds on an average that denoted by the specific gravity by a trifle over 0.008 per cent, which must be referred almost exclusively to the observations taken north of the 75th parallel of latitude.

Before proceeding to review the results deducible from these observations, it will be necessary to interpolate a few general remarks on the depth and temperature of the Norwegian Sea. To this end, I shall merely recapitulate what Professor Mohr has stated on the subject in a Memoir printed in C. F. Schiøtters "Væstlivet i Norge."

The depth of the Sea investigated by the Norwegian North-Atlantic Expedition was found to be as follows. Throughout the tract extending west of an imaginary line drawn from Spitzbergen to the northern extremity of Norway, it is never less than 1000 fathoms (1829 metres) some considerable distance from land, and generally ranges from 1500 to 2000 fathoms (2743–3658 metres), nay, in some places it is even greater. Between Beeren Ei-

som nordenfor findes betydelig større Dyb paa indtil over 2000 Favnne (3658 Meter). Osthavet, det vil sige Havet østenfor en Linie fra Spitzbergen til det nordlige Norge, er overalt meget grundt, da Dybden der paa faa Steder overskrider 200 Favnne (366 Meter).

De talrige indhorte Temperaturobservationer vise, at Vandet i den af Expeditionen undersøgte Del af Osthavet med Følgelse af den østligste og nordligste Strækning holder Varmegrader lige fra Overfladen til Bunden, saaledes som dette ogsaa er Tilfælde med Vandet paa de norske Banker, som paa enkelte Steder strækker sig ud til en ikke ubetydelig Afstand fra Kysten. Helt anderledes er Forholdet i det vestenfor liggende dybere Hav, som med Hensyn paa Temperaturforholdene naturlig kan inddelles i 2 Hovedstrøg, den i den østlige Del nordover gaaende saakaldte Golfstrøm og den i den vestlige Del sydover gaaende østgrønlandske Polarstrøm. Grænsen mellem disse gaar nordenom Island op til Jan Mayen, hoier i en Bue søndenom og østenom denne og overskrider paa omkring 3 vestlig Længde med nordøstlig Retning den 71de Bredegrad. Herfra gaar den mod Øst til henimod 7 østlig Længde og fortsætter derfra i nordlig og lidt vestlig Retning til nordenom den 80de Bredegrad.

I den østenfor denne Grænse beliggende Del af Havet besidder Overfladevandet en forholdsvis høi Temperatur, der endog overskrider Luftens midt om Sommeren, hvorhos ogsaa Vandet i de nærmest under Overfladen liggende Lag holder Varmegrader, saaledes at 0° først forefindes i et Dyb af omkring 500 Favnne (914 Meter), hvorfra Temperaturen jævnt og langsomt synker til omkring 1, 3 ved Havbunden.

I den østgrønlandske Koldvandsstrøm er derimod Temperaturen i selve Overfladen meget lav men om Sommeren i ristret Vand dog overalt over 0°, medens den allerede fra faa Favnes Dyb og nedover lige til Bunden holder sig under 0°.

Med Hensyn paa Saltgehalten i Overfladevandet henvises til Kartet No. I, hvori findes indtegnet en større Del af de Tal, der fremgaa som Middelværdier af de efter Chlor- og Egenvegtstæstemmelserne beregnede Værdier for Saltmængden. Efter disse Observationer findes ogsaa optrukket Grænseløse for 3.55, 3.50, 3.45 og 3.40 ‰ Salt, saaledes som deres Form man antages at være i Sommermaanederne. Kartet viser, at den i Syd midt i det norske Hav strømmende Varmvandsstrøm fører Vand af temmelig stor Saltgehalt, som i de sydligste Egne paa begge Sider af Færoerne gaar op til 3.55 ‰ eller endog derover. Herfra gaar Strømmen videre i nordøstlig Retning med noget lavere Saltgehalt (omkring 3.525 ‰) indtil henimod Beeren Eiland, hvor den deler sig og sender en Arm mod Øst midt i Osthavet og en anden i nordlig og noget vestlig Retning

land og Jan Mayen there is a vast ridge, and here the depth does not reach 1500 fathoms (2743 metres); but south and north of that ridge it is much greater, in some localities more than 2000 fathoms (3658 metres). Barents' Sea, or, the tract of ocean stretching between Novaja Zemlja and an imaginary line drawn from Spitzbergen to the northern extremity of Norway, is everywhere exceedingly shallow, the depth in but few places reaching above 200 fathoms (366 metres).

The extensive series of observations shows that the temperature of the water throughout the part of Barents' Sea investigated by the Expedition, saving the most easterly and northerly tracts, exhibits everywhere a temperature above zero, from the surface to the bottom, as is also the case with the water on the great Norwegian banks, which, in certain localities, extend to a considerable distance from the coast. A very different relation rules in the deep western section, which, as regards temperature, may be divided into two principal tracts, an eastern, with the Gulf Stream, as it is called, flowing north, and a western, with the Arctic current, flowing south, along the shores of East Greenland. The boundary-line between these two currents extends north of Iceland to the island of Jan Mayen, where it makes a bend southward and eastward, crossing, in longitude about 5° W., with a north-easterly direction, the 71st parallel of latitude. From thence it runs east, and, when in longitude about 7° E., takes a northerly and somewhat westerly direction, continuing on past the 80th parallel of latitude.

In the tract of ocean stretching to the east of this boundary, the temperature of the surface-water is comparatively high, exceeding even that of the atmosphere in the middle of summer; the water, too, some distance below the surface exhibits a temperature above zero, the depth at which 0° is reached being about 500 fathoms (914 metres), from which the temperature sinks slowly and gradually to about -1.3, at the bottom.

In the cold East Greenland current, the temperature at the surface is on the other hand exceedingly low, though in summer above zero where the water is free from ice; 0° however is reached at the depth of a few fathoms.

As regards the amount of salt in the surface-water, the reader is referred to Plate I, in which will be found most of the figures representing the mean values, deduced from the chlorine and specific gravity-determinations, for the proportion of salt. In Pl. I, too, are laid down curves constructed from these results, to show the limits of distribution for the following percentages of salt: 3.55, 3.50, 3.45, and 3.40, as they may be assumed to extend in the summer months. The warm current, flowing from the south into the Norwegian Sea, brings with it, as shown by the Plate, an indraught of water containing a comparatively large amount of salt, the maximum percentage, upwards of 3.55, being reached in the most southerly tracts, along the eastern and western shores of the Færoe Islands. From thence, with a slightly reduced amount of salt (about 3.525), the

forbi Spitzbergens Vestkyst. I den mod Øst gaaende Gren synker Saltgehalten meget langsomt og jævnt, indtil den ved Grændsen af det af Expeditionen undersøgte Felt har naaet 3,50 ‰, medens den i den nordover flydende Arm meget hurtigt synker til endog under 3,45 ‰ for atter ved Spitzbergens Nordvestkyst at hæve sig til lidt over 3,45 ‰.

Denne i Vest for Spitzbergen forefundne ringe Salt-holdighed i Overfladen er dog sandsynligvis kun enblom-melig for den varmere Aarstid, da der fra Spitzbergens mægtige Is- og Snebrøer flyder store Mængder Ferskvand ned i det tilstøende Hav.

Indflydelsen af saadant fra Kysterne ndgaaende Fersk-vand indskrænker sig dog hovedsagelig kun til meget smaa Dyb, da det saavel af disse som tidligere publicerede Un-derøgelser af samme Art fremgaaer, at et over saltere Vand flydende ferskere Overfladelag besidder en mærkelig Evne til meget længe at holde sig forholdsvis ublandt, saaledes at den fra Kysterne hidrørende Fortynding i Overfladen ofte kan spores 30 til 40 Mile tilhavs, medens man ved Bunden i Nærheden af Land ja endog i Fjærdene kan finde meget saltholdigt Vand. Denne Eenblommelighed træder meget skarpt frem i Observationsrækken No. 1 til 8,<sup>1</sup> da Saltgehalten her fra Overfladen til 1 Favns (2 Meters) Dyb tiltager med over 1 ‰, medens den siden temmelig jævnt voxer med kun 0,06 ‰ for hver Favns Tilvæxt af Dybden. De paa Spitzbergens Banker tagne Observationer viser da ogsaa ganske rigtigt, at Vindet der paa Bunden i nogen Afstand fra Land besidder en Saltstyrke, som paa sine Steder endog gaar op til over 3,50 ‰.

Paa lægge Sider at den midt efter det norske Hav flydende salte Overfladestrom synker Saltgehalten paa den ene Side mod den norske Kyst og paa den anden Side mod den østgrønlandske Polarstrom, en Synkning, som paa Grund af de herskende Stromforholde hverken er jevn eller regelmæssig. Saaledes flyder der fra Nordsoen langs Norges Vestkyst i nordlig Retning en lidt saltholdig Overfladestrom, som ved den 62de Brejdegrad, hvor Kysten bøier nordøstover, forlader denne, og fortsætter fremdeles i nordlig Retning, indtil dens Virkninger i omtrent 40 Miles Afstand fra Land efterhaanden taber sig. En mindre mæ-jøretet lignende Kyststrom gaar fra Vestfjorden mløver i sydvestlig Retning og naar ligeledes temmelig langt tilhavs, førend dens Indflydelse paa Saltgehalten i Overfladevandet fuldstændig forsvinder. Mellem disse Kyststrømme kaster der sig en smaa Arm af det saltere Atlanterhavsvand for-holdsviis nær ind under Land, hvor den meget skarpt

current flows in a north-easterly direction, as far north almost as Beeren Eiland, where it divides into two arms, one running east into Barents' Sea, and the other in a north-westerly direction past the west coast of Spitzbergen. In the branch flowing east, the amount of salt diminishes very slowly and gradually down to 3,50 per cent, at the limit of the region explored by the Expedition, whereas in that running north it rapidly sinks even below 3,45 per cent, rising, however, on the north-western coast of Spitz-bergen a little above 3,45 per cent.

This low percentage of salt in the surface-water west of Spitzbergen is, however, in all probability the result of summer heat, vast quantities of freshwater pouring down to the sea at that season of the year from the immense glaciers and snow-fields of that group of islands.

The effect of such an influx of fresh water from the coast is, however, mostly confined to a very trifling depth, the result of the observations taken on the Expedition, and of others in connexion with the same subject previously published, being to show, *inter alia*, that freshwater possesses the remarkable property of floating on salt water for some considerable time in a comparatively unmixed state, so that its influence may be frequently traced at a distance of from 30 to 40 geographical miles off shore, whereas the bottom-water close in shore, nay that of friths and estu-aries even, often contains a very large proportion of salt. This peculiar feature was strikingly instanced in the series of observations from No. 1 to 8,<sup>1</sup> the amount of salt at the depth of 1 fathom (2 metres) exceeding that at the surface by 1 per cent, whereas the subsequent increase with the depth did not amount to more than 0,06 per cent for every fathom. The observations taken on the banks of Spitzbergen show that the maximum percentage of salt in the bottom-water some distance from land, in certain localities, reaches 3,50.

On either side of the salt surface-current flowing through the medial portion of the Norwegian Sea, the amount of salt diminishes, eastward in the direction of the Norwegian coast and westward in the direction of the Arctic current off East Greenland, but this diminution, owing to the effect of ocean currents, is however anything but regular and gradual. Thus, for instance, a surface-current, with a low percentage of salt, flows from the North Sea in a north-erly direction along the west coast of Norway, from which it diverges near the 62nd parallel of latitude, continuing on, still in a northerly direction, till, about 40 geographi-cal miles from land, its influence gradually ceases to be felt. Another coastal current, more limited in extent, flows from the Vestfjord in a south-westerly direction, its influence on the amount of salt in the surface-water being likewise perceptible comparatively far out at sea. Between these coastal currents runs a narrow arm

<sup>1</sup> Disse Observationer kunne desuden ogsaa tjene som Bevis for Fortæiligheden af den af Ekman angivne Vandbøien, som ved denne Leilighed benyttedes.

<sup>1</sup> These observations likewise attest the excellence of Ekman's apparatus for collecting seawater, which was used on this occasion.

afgrænses sig med det indentor flydende meget forskere Vand. Forøvrigt ligger Grænsen for det saltere Overfladevand sig meget langt tillægs med Indtagelse af, at den ved den 70de Breddegrad paa en ganske kort Strækning koster sig tæt ned under Kysten.

Denne Fortynding af Overfladevandet, som overalt viter sig ved den norske Kyst, er intetsteds ledsaget af nogen væsentlig Forrykkelse af Overfladetemperatur. Saltgehaltens Forændelse skyldes her adenkent det fra Kysterne indstrømmende Flodvand, der om Sommeren besidder en ikke ringe Varmegrad, saaledes at man i den mest fremtrædende Kyststrøm langs Norges Vestkyst endog finder en meget højere Overfladetemperatur end paa nærliggende Puncter. Ganske anderledes stiller Sagen sig paa den mod den østgrønlandske Polarstrøm vendende Side, hvor Overfladevandet fortyndes ikke ved Flodvand men ved det ved Havens Smeltning dannede, stærkt afkølede Ferskvand, og det viser sig derved, at en Synken i Saltgehaltens her beständig er ledsaget af en tilsvarende Forændelse af Overfladetemperatur. Grænsen for det saltere Vand i Overfladen følger derfor paa denne Side ofte Polarstrømmens Grænse, og selv der, hvor den forholder denne, optræder der dog samtidig med Overgangen fra saltere til ferskere Vand altid meget tydelige Variationer i Temperaturen, der gaa i samme Retning som Saltgehaltens. At Overfladetemperaturen synker, naar man enten nærmer sig eller overskrider Grænsen for 3.50 % Salt, vise Observationerne No. 115 til 120 og No. 207 til 209.

I selve Polarstrømmen er Saltgehaltens i Overfladen i nogen Aftand fra Grænsen oftest fundet meget lav, kun paa et Sted optræder i sin Henseende en Indtagelse fra den almindelige Regel, idet der omtrent paa den 70de Breddegrad skyder sig en smaa Tange med Vand af højere Salthstyrke ind over Polarstrømmen, uden at der dog derved bevirkes nogen væsentlig Forhøelse af Overfladetemperatur. En Mærkelighed, som fortjener at omtales, er den, at Professor Dr. G. O. Sars, som paa Expeditionens Tugter jævnlig undersøgte Dyrelivet i Overfladen, netop paa dette Punct langt inde i Polarstrømmen har gjenfundet de for det varmere Atlanterhavsvand endommege Dyreformer, der forresten intetsteds ellers ere fundne i den østgrønlandske Koldvandsstrøm.

Med Hensyn paa Saltmængderne i de større Dyle henvises til Kartet No. II, hvor paa samme Maade som ovenfor findes indtegnet Saltgehaltens ved Havbunden samt i de intermediate Dyle, forsaavidt Observationerne refererer sig til Puncter saa dybt under Overfladen, at Temperaturen der ligger under 0°. Hvor en Observation indrører fra et intermediate Dyle, er Tallet i Kartet understrøget.

Naar man løfter fra enkelte i Nærheden af Kysterne og paa grundt Vand optagne Vandprøver, varierer Saltgehaltens paa de store Dyle mellem 3.50 og 3.45 %.

of the salt ocean-water of the Atlantic, distant but a few miles from land, its boundary being distinctly marked by the limits of the brackish water flowing along the shore. Except in this region, and a locality bordering the 70th parallel of latitude, where, for a short distance, it runs close to the coast, the boundary of the salt surface-water lies far out at sea.

This dilution of the surface-water on all parts of the Norwegian coast is not anywhere found to exert a material influence on the surface-temperature. The decrease in the amount of salt must be obviously ascribed to the influx of river-water, the temperature of which during the summer months is relatively high, — so high indeed, that the principal coastal current, flowing along the western shores of Norway, has a somewhat higher surface-temperature than that observed in its immediate vicinity. Phenomena the reverse of these prevail in the tract of ocean exposed to the influence of the Arctic, or East Greenland, current. There, the surface-water is not diluted by an influx of river-water, but with freshwater of a low temperature, produced by the melting of drift-ice; and hence a decrease in the percentage of salt is invariably attended with a corresponding reduction of the surface-temperature. The salt surface-water borders, therefore, not infrequently the Arctic current; and even where its boundary diverges from it, the transition from salt to comparatively fresh water is always accompanied by a very considerable variation in temperature, proportionate to the variation in the amount of salt. That the surface-temperature becomes gradually lower on approaching the limits of the section in which the proportion of salt is 3.50 per cent, will be seen from the series of observations Nos. 115–120 and Nos. 207–209.

In the Arctic current, some distance from its extreme boundary, the proportion of salt at the surface was found to be very small, except in one locality, near the 75th parallel of latitude, where a narrow strip of saltier water flows into the current, without, however, causing an appreciable rise in the surface-temperature. It is a remarkable fact, which must not be passed by unnoticed, that Professor G. O. Sars, naturalist to the Expedition, found here in the surface-water, which he examined from day to day, forms of animal life peculiar to the warm area of the Atlantic water, which he never met with in any other part of the cold East Greenland current.

As regards the amount of salt observed at great depths, the reader is referred to Pl. II, in which, as in Pl. I, will be found the percentage both at the bottom and at intermediate depths, provided the observations were taken with samples of water the temperature of which *in situ* was below 0°. Observations with water from intermediate depths are denoted by underlining the figures expressing their results.

Disregarding a few samples of water collected near the coast and in shallow spots, the proportion of salt, where the depth is great, ranges from 3.50 to 3.45 per

og Differentserne ere saaledes ogsaa her vel paaviselige om end mindre end i Overfladen. For tydeligt at kunne markere disse optraedende Differentser paa en let overskuelig Maade, har jeg benyttet forskjellige Farver. Saaledes ere de Strog, hvor Saltgehalten beløber sig til 3.50 ‰ eller derunder, betegnede med Blaa Farve, de Strog, hvor Saltgehalten ligger mellem 3.50 og 3.55 ‰ med rød Farve, medens de Vandmasser, der ifølge Observationerne besidde en Saltmængde af over 3.55 ‰, ere tegnede med en noget kraftigere rød Farve. I Nærheden af Kysterne er Kartet overalt ufarvet uden Hensyn til, om Vandet der henhører under den ene eller den anden af de tre Hovedgrupper.

Den uregelmæssige Fordeling af Saltgehalten i de større Dyb, som det saaledes tegnede Kart ndviser, maa megetlig betegnes som meget paafaldende. At Saltmængderne paa Bankerne og i den sydlige Del af Osthavet paa det Nærmeste findes at svare til den, som det i Overfladen svømmende varme Atlanterhavsvand besidder, kan ikke synes overraskende. Havet er her meget grundt, og det deri flydende Vand besidder overalt en Temperatur af over 0° og maa saaledes nærmest henføres til den nørnlaver flydende Atlanterhavsstrøm, med hvilken det da ogsaa helt naturligt har Saltgehalt tilfelles. Ligeoverfor de store Dyle maatte man derimod paa Forhaand vente et andet Resultat. Temperaturen ligger her uden Undtagelse under 0° ja paa de fleste Steder endog under  $-1^{\circ}$ , og det kunde derfor synes rimeligst at tilskrive det der flydende Vand polar Oprindelse. Det fremgaar imidlertid med Bestemthed af alle mig bekjendte Undersøgelser over Saltmængderne i de forskjellige Have, at de fra arktiske Egne udgaende Strømme uden Undtagelse føre Vand af lavere Saltgehalt end de fra de mere tempererede Himmelstrøg udgaende Varmvandsstrømme, og man skulde derfor i de dybere og koldere Lag af det her undersøgte Hav vente at finde en Vandmasse med adskilligt lavere Saltgehalt end den, der er funden i det i Overfladen og nærmest under den flydende Vand, som anhenbart skrives sig fra varmere Egne. Hvad der virkelig finder Sted er desuagtet dette, at det i de dybere liggende Lag flydende, iskolde Vand paa store Strækninger viser sig at have en Saltgehalt, der temmelig nøjagtigt svarer til den, der er funden i den atlantiske Overfladestrom.

Saa vel af denne Grund som ogsaa af andre Grunde, som jeg senere skal fremføre, finder jeg det rimeligt at gjøre den Antagelse, at Vandet paa de større Dyle paa de Steder, som i Kartet findes aflagte med rød Farve, enten indelukkende skrives sig fra varmere Egne eller under enhver Omstændighed er saa opdaandet med sandt Vand, at det Hele derved antager en tydelig atlantisk Karakter, medens Vandet i de med blaa Farve betegnede Strækninger mere eller mindre skarpt udpræger sig som hidrørende fra polar Oprindelse.

Hvor det gjælder at besvare Spørgsmaalet om, hvorledes de øvre Lag finder Vej ned til Bunden, da synes dette ikke at kunne besvares paa anden Maade, end at det atlantiske Vand under stadig Aftjøling maa synke gennem det iskolde og fordrive dette, under enhver Omstæn-

cent; and there too, accordingly, the differences are appreciable, though smaller than at the surface. For the better apprehension of these differences, the sections in which they occur have been differently coloured in the Plate: blue indicates a percentage of 3.50, and under; red, a percentage ranging from 3.50 to 3.55; and a somewhat deeper red, a higher percentage than 3.55. Along the coasts, the Plate is left uncoloured, no matter to which of the three principal groups the water there belongs.

This irregular distribution of the amount of salt at great depths, as shown in the Plate, is certainly a most remarkable phenomenon. That the proportion of salt on the banks and in the southern portion of Barents' Sea should agree pretty closely with that contained in the warm surface-water of the Atlantic, is not indeed surprising: the depth is in both localities comparatively trifling, and the water, having everywhere a temperature above 0°, must be referred to the warm Atlantic current; its percentage of salt is therefore naturally the same as that of the Gulf Stream. For the great depths, on the other hand, there was reason to expect a very different result. Here, the temperature is without exception below 0°, may in most places below  $-1^{\circ}$ ; and hence, as regards the origin of such water, there seems much to urge in favour of an indraught from the Polar Sea. Of the observations undertaken to determine the amount of salt in sea-water, all with which I am acquainted furnish incontrovertible proof that the water of the currents flowing from the Arctic Ocean has a lower percentage of salt than that of the warm currents flowing from more temperate regions, and the proportion of salt in the deeper and colder strata of the tract of ocean explored by the Expedition was expected, therefore, to prove considerably lower than that observed at the surface or a short distance beneath it, where the water is obviously an influx from warmer climes. But such was not the case, for the amount of salt found in the water of the cold area, where the temperature is below zero, agrees, in some localities, pretty closely with that in the water of the Atlantic surface-current.

This phenomenon, in conjunction with reasons that will afterwards be explained, has led me to assume, that the water met with at great depths in the sections coloured red in the Plate, is either exclusively the result of an influx from warmer regions, or is, at least, so mixed with such water as to have distinctly acquired Atlantic characteristics; whereas the water in the blue-coloured sections would seem to indicate more or less determinately a Polar origin.

As to the question involved in the descent of the upper strata to the bottom, the only way in which this can take place seems to be by the Atlantic surface-water, as it parts with its excess of heat, gradually sinking through the water of the cold area, and displacing it; at all events,

dighed synes det sikkert, at man for det afgrænsede østfor Jan Mayen beliggende Strøg ikke kan antage nogen anden Væ. Men at den varmere Vandmasse saaledes skulde synke gennem den koldere, kunde jo ved første Øekast synes stridende mod vel kjendte Naturlove, da man nærmest maatte tro, at det i Nærheden af Overfladen flydende atlantiske Vand paa Grund af sin højere Temperatur skulde være specifisk lettere end det ifølge sin lave Temperatur stærkt fortættede Bumlvand. Nærmest for at ljerne enhver Tvivl i saa Henseende, er det i den forhen gjenævnte Tabel indført en Rubrik for Vandprovernes Egenvegte ved den i Havet observerede Temperatur i Forhold til rent Vand af 4°. Ved Hjælp af de der beregnede Tal kan man med Lethed studere den specifikke Vægts Variation med Dybden, saaledes som den finder Sted i Havet, bortset fra den ved Vindets Sammentrykkelighed forårsagede Fortæthning i de større Dyb.

Den Region, som i denne Henseende mest interesserer os, er den, hvori der i Overfladen og nærmest under den findes en bestemt udpræget atlantisk Varmvandsstrøm, en Region, som paa det Nærmeste falder sammen med den sønderst for en Linie fra Island til Bæren Eiland liggende Del af Havet, dog saaledes at det nærmest Norge liggende Part paa Grund af den fra Kysterne udgaaende Fortynding maa bortskjæres. Grupperer man de i denne Egntagne Observationer over Saltgehalt og den specifikke Vægt reduceret til Havets Temperatur og en Atmospheres Tryk efter Dybden, fremgaar som Resultat heraf Følgende.

Dybdeintervall.		Middl. Dybde.		Middl. Saltgehalt.	Middl. Egenvægt ved Havets Temperatur.
Engelske Fath.	Metres.	Engelske Fath.	Metres.		
0	0	0	0	3.526	1.02688
0—300	0—549	167	305	3.514	1.02782
300—600	549—1097	502	1118	3.521	1.02812
600—1000	1097—1820	681	1245	3.513	1.02802
1000—1500	1820—2743	1203	2200	3.506	1.02800
under 1500	under 2743	1688	3087	3.507	1.02800

Det i denne Tabel erholdte Tal for Saltgehalten paa Strøget mellem 0 og 300 Fathnes (0 og 549 Meters) Dyb er indført uden Tvivl for Lavt, da en uforholdsmæssig stor Del af Observationerne i dette Dyb hidrøre fra Østhavet, hvor Saltgehalten overalt er mindre end i de centrale og sydlige Dele af Fødet. De Observationer, som skrives sig fra dette Dyb i større Afstand fra Kysten, tyde her paa, at Saltgehalten der meget nær svarer til den, der er funden i Overfladen paa de samme Steder. Denne Mislighed ved den geografiske Fordeling af Observationerne fra de mindre Dyb faar derimod ingen væsentlig Indflydelse paa det som Middelt af de specifikke Vægter erholdte Tal, da den i de nordligere Egne ved Saltgehaltens Synkning forårsagede Formindskelse af Egenvegteerne paa det Nær-

it is certain that no other plausible explanation can be given of the phenomenon for the region east of Jan Mayen. But, that water of a higher temperature should sink in this manner through water of a lower, appears at first sight to be at variance with well-known physical laws; for the water from the Atlantic current having a higher temperature, one would imagine it to be specifically lighter than the cold and dense bottom-water. With the object of dispelling every doubt that might arise in connexion with this subject, a column has been added to the Table given above for the specific gravity of the samples of water at their temperature *in situ*, as compared with that of pure water of 4°. By means of the figures set down in the column, the variation of the specific gravity with the depth, as it occurs in the sea irrespective of increased density from the compressibility of water at great depths, may be readily investigated.

The tract of ocean which in this respect it will be most desirable to investigate, is that through which flows, on or near the surface, a warm current, setting from the Atlantic, — a tract which nearly coincides with the region stretching south of an imaginary line drawn from Iceland to Bæren Eiland, but from which, owing to the influx of freshwater, must be cut off the section extending along the Norwegian coast. Now, if we group together the observations taken in this part of the North-Atlantic to determine the percentage of salt and the specific gravity reduced to the temperature of the sea and a pressure of one atmosphere, the result will be as follows: —

Intervals of Depth.		Mean Depth.		Mean Amount of Salt per cent.	Mean Sp. Gr. at the Temp. of the Sea.
English Fathoms.	Metres.	English Fathoms.	Metres.		
0	0	0	0	3.526	1.02688
0—300	0—549	167	305	3.514	1.02782
300—600	549—1097	502	1118	3.521	1.02812
600—1000	1097—1820	681	1245	3.513	1.02802
1000—1500	1820—2743	1203	2200	3.506	1.02800
below 1500	below 2743	1688	3087	3.507	1.02800

The figures in this Table expressing the amount of salt at depths ranging from 0 to 300 fathoms (0—549 metres) are, however, unquestionably too low, seeing that a disproportionate number of the observations at this depth were taken in Barents' Sea, where the amount of salt is everywhere smaller than in the central and southern sections of the tract investigated. The observations referring to this depth at a considerable distance from land, show that the percentage of salt is very nearly the same as that at the surface. The said defect in the geographical distribution of the observations taken at a comparatively trifling depth, does not however materially affect the correctness of the figures expressing the mean specific gravity; for the fall in specific gravity occasioned in northern regions

meste opveies af den Forøgelse af samme, der skyldes de der herskende lavere Temperaturer.

Det fremgaar altsaa, at Differentserne mellem Saltgehaltten i de atlantiske Overfladelag og de paa Bunden hvilende iskolde Vandmasser gjennemsnitlig kun ere meget smaa, om de end paa de Puneter, hvor Vandet i de dybere Lag besidder en overveieude polar Karakter, turde være adskilligt mere fremtrædende. Disse Differentser af henimod 0,02% ere dog mere end tilstrækkelig store til i de nederste mere afkølede Lag af det atlantiske Vand at fremkalde et, som det vil sees af Tabellen, meget tydeligt om end svagt Maximum af den specifikke Vægt, hvad der nærmest bevirkes derved, at Sovandet ved Afkøling under 0° nærmer sig sit Tæthedsmaximum og derfor i Nærheden af dette for mindre Temperaturvariationer kan forandrer sit Volumen med næsten mærkelig smaa Værdier, saaledes at en selv meget ringe Forøgelse af Saltgehaltten under disse Omstændigheder faar en overveieude Indflydelse ligeoverfor en Grads Forandring af Temperaturen.

Det er saaledes saa langt fra Tilfælde, at der i de specifikke Vægter af de forskjellige Vandlag ligger nogen Hindring for Antagelsen af, at det atlantiske Vand skulde synke gennem det koldere Polarvand, at man tyvtom af disse maa slutte, at saa maa være Tilfælde, dersom ikke andre i Havet herskende Strømme virke hemmende paa en saadan Bevægelse. Man tenke sig t. Ex. ved Siden af landenden i Havet to Vandsøiler af 2000 Fathoms (3658 Meters) Dybde, hvori Temperaturens Variation med Dybden for Simpeltheds Skyld kan antages at være den samme, hvorimod Saltgehaltten i den 1ste helt igjennem settes til 3,52‰ medens den i den 2den paa Stroget fra Overfladen til 500 Fathoms (914 Meters) Dyb gives Værdien 3,52‰ og fra 500 til 2000 (914 til 3658) Værdien 3,50‰, saaledes som Forbuddet ifølge Observationerne virkelig synes at stille sig paa enkelte Steder i det undersøgte Hav. Det er da umiddelbart indlysende, at en saadan Fordeling af Saltgehaltten vil have en Synkning i den 1ste Soile til Følge, saaledes at Vandet i denne vil søge at udhvide sig langs Bunden og fordrive det omliggende specifik lettere Vand. Den Hastighed, hvormed en saadan Bevægelse foregaar, vil naturligvis rette sig efter Differentien mellem Trykkene i samme Niveau i begge Soiler, en Different, som ved Bunden i 2000 Fathoms (3658 Meters) Dyb efter Beregning beløber sig til henimod 32<sup>mm</sup> Kviksølvsøile.

For nærmere at begrunde den forhen fremsatte Hypothese, om at det paa Bunden hvilende iskolde Vand paa de i Kartet med rød Farve betegnede Steder skulde have atlantisk Oprindelse, vil jeg benytte mig af de i en tidligere Afhandling<sup>1</sup> beskrevne Observationer over de i Sovandet indeholdte Kvalstofmængder, hvis Anvendelse i saadant Oiemed allerede paa det Sted løselig er bleven antydet.

Som bekjendt herskede der i ældre Tider den Anskuelse, at de i Sovandet i de større Dyb indeholdte Luftmængder paa Grund af det der herskende Tryk maatte

by a decrease in the amount of salt, is almost compensated by the rise resulting from the low temperatures prevailing there.

It appears, therefore, that the differences between the amount of salt in the warm upper strata and that in the cold water at the bottom, are, on an average, exceedingly small, though more striking perhaps in localities where the water of the deeper strata to a very great extent is Polar in origin. These differences — about 0,02 per cent — are, however, as will be seen from the Table, more than sufficient in the deepest and coldest strata of Atlantic water to occasion an appreciable, though a low, maximum of specific gravity, which is explained by the fact, that sea-water below 0° has very nearly reached its maximum of density, and the increase in volume then resulting from trifling variations in temperature, is a well nigh unappreciable magnitude; hence, under such circumstances, the influence of a very slight addition to the amount of salt with but one degree's difference in temperature will be exceedingly great.

Such being the case, there is nothing in the specific gravities observed in the different strata of water to disfavor the assumption that the comparatively warm Atlantic water should sink through the cold water of Polar origin; nay, from these specific gravities we may infer its correctness, provided only that such descending motion be not counteracted by the effect of ocean currents. To give an illustration. Let us imagine two columns of water, 2000 fathoms (3658 metres) deep, in both of which, for convenience' sake, the variation in temperature with the depth is assumed to be equal; the amount of salt on the other hand, being put at 3,52 per cent throughout the whole of the first, but in the second, at 3,52 per cent from the surface to a depth of 500 fathoms (914 metres), at 3,50 per cent from 500 to 2000 fathoms (914—3658 metres). — a ratio of distribution actually observed in some localities. Thus given, it is obvious that such a distribution must cause the water in the first column to sink, and spread itself over the bottom, displacing as it does so the specifically lighter. The rapidity of this downward motion will of course be proportionate with the difference in pressure at the same level in the two columns, a difference which, at the depth of 2000 fathoms (3658 metres), has been computed equal to that of a column of mercury 32<sup>mm</sup> in height.

With a view to furnish additional confirmation of the hypothesis brought forward above, which assumes the cold bottom-water in the red-coloured sections of the Plate to be of Atlantic origin, I shall have recourse to my observations on the amount of nitrogen in sea-water, published in a former paper,<sup>1</sup> where their application to such a purpose was briefly alluded to.

The opinion formerly entertained, that the quantity of air contained in sea-water at great depths must be exceedingly great, by reason of the immense pressure pre-

<sup>1</sup> "Om Luften i Sovandet."

<sup>1</sup> "On the Air in Sea-Water."

være i forholdsmæssig store, en Anskuelse, som ved de senere Undersøgelser fuldstændig er bleven modbevist. Rigtig nok er det paa den engelske Challenger-Expedition iagttaget, at de i den høje Zone fra Havbunden optagne Vandprøver ved at henstaa nogen Tid vise Overmætningsphænomener, men dette vil jo ikke være vanskeligt at forklare, naar man erindrer, at Vandet i de store Dyle selv i Ækvatorregionene er meget mer iskoldt. Det følger nemlig af sig selv, at de til en saa lav Temperatur svarende Luftmængder ikke kunne holdes opløst, naar Vandprøverne ved længere Tids Henstaael antager de tropiske Egnes høje Lufttemperatur. Stærkest taler de paa den norske Expedition indtøtte Luftbestemmelser for, at Tryktilvæxten med Dybden ikke kan have nogen Indflydelse paa Mængden af den i Søvandet opløste Luft. Tager man nemlig Middelstet af Dybder, Temperaturer og Kvælstofmængder for alle de fra Puneter under Overfladen stammende Vandprøver, hvori der paa denne Expedition er foretaget Luftbestemmelser, erholder man til et Middeldyb 693 Fathne (1267 Meter) en Middeltemperatur = 0,05 og en midlere Kvælstofgehalt 13,99 CC. per Litre, det vil sige, Vandet i Dybset indeholder gjennemsnitlig næsten 0,5 CC. Kvælstof *under*, end det ved sin Temperatur vilde kunne holde opløst under en Atmosphæres Tryk.

Naar man erindrer, at Trykket i Havdybene ikke dreier sig om Atmosphærer men om Hundreder af Atmosphærer, saa maatte man dog vente, at dets Indflydelse (om det havde nogen) vilde give sig tilkjende ved Uregelmæssigheder af paavelsig Størrelse, og man er, da dette ikke i mindste Maade er Tilfældet, berettiget til den Slutning, at Trykket ikke besidder nogen Evne til i mærkbar Grad at opløse Luftmængderne i de store Dyle. Paa den anden Side maa det fornødtvis antages, at Vandet i de dybere liggende Lag ikke kan afgive noget af sin Luft, da det jo paa Grund af det der herskende Tryk vil kunne holde opløst overværende større Mængder end de, der nogenstede ere forebundne.

Den rimeligste Slutning af de senere Tidens Observationer over disse Gjenstande vil saaledes være den, at en Vandprøve, saalænge den løbder sig under Overfladen, uforandret vil beholde den samme Luftmængde eller rigtigere Kvælstofmængde<sup>1</sup>, som den havde absorberet, da den sidste Gang befandt sig i Overfladen udsat for Luftens frie Indvirkning.

Nu er den Luftmængde, som Søvandet absorberer af Atmosphæren, hovedsagelig afhængig af Vandets Temperatur, idet Barometerstankens Variationer ligesoverfor større Temperaturforskelle kun har en underordnet Betydning. Heraf følger, at de Vandmasser, der have absorberet sin Luftmængde under varmere Himmelstrøg, maa være forholdsvis

voilende there, has been wholly refuted by the results of later observations. True, the samples of water obtained at great depths within the tropics on the 'Challenger' Expedition were found to exhibit the phenomena of supersaturation when allowed to stand over some time; this, however, is easily explained, if we call to mind that the water at great depths, even in equatorial regions, has a temperature but little above zero. Hence it naturally follows, that the quantity of air corresponding to so low a temperature cannot be retained on the samples of water having stood over sufficiently long to acquire the high temperature of the atmosphere in tropical climates. The air-determinations performed on the Norwegian Expedition afford the strongest proof of the fact, that the increase of pressure with the depth does not exert any appreciable influence on the proportion of air in sea-water. Now, if we compute the mean depth, temperature, and amount of nitrogen for all the samples of water from below the surface examined for air-determinations, the result will be as follows: mean depth 693 fathoms (1267 metres); mean temperature = 0,05; mean amount of nitrogen 13,99 per litre, which shows that in the depths of the ocean the proportion of nitrogen averages 0,5% less than could be absorbed by sea-water of the temperature prevailing there with the pressure of one atmosphere.

If we call to mind that the pressure in the depths of the sea is not computed even by tens, but by hundreds of atmospheres, its influence, if any, must surely, one would imagine, occasion irregularities of appreciable magnitude; and we may therefore safely conclude, since no such disturbance can be detected, that pressure does not perceptibly increase the amount of air at great depths. On the other hand, there is every reason to infer, that the water in the lower strata, owing to the immense pressure, cannot part with any of its air, the quantity actually absorbed never being even approximately so great as such a pressure would enable it to retain.

From the latest observations throwing light on this question, we may therefore reasonably infer, that all sea-water below the surface retains undiminished the quantity of air, or rather of nitrogen,<sup>2</sup> which it absorbed when last at the surface, in direct contact with the atmosphere.

Now, the quantity of air absorbed by sea-water is mainly dependent on the temperature of the latter, the rise or fall of the barometer, as compared with considerable differences in temperature, being in this case of but little moment. Hence it follows, that the proportion of air absorbed by sea-water in warm climates is small compared

<sup>1</sup> Den absorberede Surstofmængde er nemlig i nogen Grad afhængig af Dybde og andre Tilfældigheder, saaledes at det her lige som i den tidligere Afhandling vil være det Rigtigste at anvende Kvælstofmængden som Måad for den saaledes Luftmængde.

<sup>2</sup> The amount of oxygen absorbed by sea-water depending to a certain extent on the presence of animal life and other accidental causes, the amount of nitrogen may, with greater precision, be assumed to represent the total amount of air — a standard of measurement adopted in the preceding Memoir.



lidet luftholdige, medens de, der have absorberet sin Luftmængde i de arktiske Ægne, man indeholde meget større Mængder, og man vil derfor netop i de paa Expeditionen udførte Gasanalyser have et fortrinligt Middel til at kontrollere den forhen opstillede Hypothese, ifølge hvilken enkelte Regioner af det iskolde Dyb skulde være opfyldt af Vandmasser, der ialfald delvis havde atlantisk Oprindelse.

Førtat vise Udfaldet af en saadan Control har jeg tegnet Kartet No. III, hvorpaa efter samme Princip som det ved Tegning af Kartet No. II befulgte findes afsat de i Dybet fundne Kvælstofmængder udtrykte i CC. je. Litre reducerede til 0° og 760<sup>mm</sup> Tryk, ligesom der ogsaa ved Siden af disse Tal findes opført den Temperatur, hvorved Søvandet absorberer denne Kvælstofmængde, beregnet til nærmeste hel Grad efter den af de tidligere beskrevne Forsøg afledede Formel

$$N = 14.4 - 0.23t.$$

Det siger sig selv, at disse Temperaturer ikke kunne gjøre Fordring paa nogen stor Grad af Nøjagtighed, da en forholdsvis liden Feil i Kvælstofbestemmelsen bevirker en meget stor Feil i den dernæst beregnede Temperatur. Der findes saaledes flere Observationer, der give Temperaturen  $-4^{\circ}$ , en Temperatur, der mig bekjendt ikke er observeret i Havet. Dette vil dog ikke forekomme saa rimeligt, naar man tager Hensyn til, at Søvand af  $-2^{\circ}$  ved 780<sup>mm</sup> Barometerstand absorberer en Kvælstofmængde, der paa det Nærmeste gaar op til, hvad der i Ydertilfældene er fundet.

Farvelægningen er her foretagen saaledes, at de Strog, hvor Kvælstofmængden er funden at være 14.4 CC. eller derover, ere betegnede med blaa Farve, de Strog, hvor Kvælstofmængden ligger mellem 14.4 og 12.5 CC., med en svag rød Farve, medens et mindre Parti, hvor Kvælstofmængden er funden at ligge under 12.5 CC., er betegnet med en noget kraftigere rød Farve. Betydningen af disse Farver bliver ligesom i Kartet No. II den, at de røde Farver bedække de Strækninger, hvor Vandet i mere eller mindre Grad besidder atlantisk Karakter, medens den blaa Farve tilhører de Vandmasser, der have absorberet sin Kvælstofmængde ved en Temperatur af under 0°, og som altsaa nærmest synes at hidrøre fra de arktiske Ægne.

Ved at sammenligne Kartene No. II og III vil man strax se, at Farvelægningen i disse i alt Væsentligt viser en særdeles stor Overensstemmelse, som paa mange Puncter endog nærmer sig til Congruents, om man end ved nærmere Betragtning vil finde, at disse Ligheder ikke gaar igjen i alle Detailler, hvad man heller ikke paa nogen Maade kunde vente. Grændserne bliver nemlig paa Kartet No. III paa Grund af Observationernes Faatallighed meget vanskelige at bestemme, ja der findes endog her paa omkring den 64de Breddegrad et større Strog, hvorom man intet med Bestemthed kan slutte, da der under Analysen tabtes en mindre Del af de Luftprøver, der vare bestemt til at udfylde dette Hnl. saaledes at den samlede Luftmængde desværre ikke kunde maales. Desuden ere ogsaa Observationsfeilene både for Salt- og Kvælstofbestemmel-

with that absorbed in the Arctic regions, wherefore the analyses of gas performed on the Expedition furnish an excellent means of testing the value of the hypothesis according to which certain sections of the cold area are assumed to be made up of water part of which at least would seem to be of Atlantic origin.

To show the result of such a test, I have annexed a third Plate (drawn on the same principle as Pl. II), in which are given the different amounts of nitrogen present in deep water, expressed in centium per litre, reduced to 0° and a pressure of 760<sup>mm</sup>. Along with these figures will be found, too, the temperature at which sea-water absorbs such an amount of nitrogen, computed, in whole degrees, by means of the formula deduced from the observations previously described, viz: —

$$N = 14.4 - 0.23t.$$

These temperatures cannot of course pretend to any high degree of accuracy, a comparatively small error in a nitrogen-determination involving a very considerable error in the temperature. Thus, for instance, several of the observations indicate  $-4^{\circ}$ , a temperature which, so far as I am aware, was not anywhere observed in the sea. This, however, will not appear so strange, if regard be had to the fact, that sea-water of  $-2^{\circ}$  at a pressure corresponding to 780<sup>mm</sup>, absorbs an amount of nitrogen which agrees very closely with the highest found on the Expedition.

The sections in this Plate are coloured as follows: those in which the amount of nitrogen was found to equal or to exceed 14.4, blue; those in which it ranged from 14.4 to 12.5, light red; a somewhat deeper red serves to indicate a small tract in which the amount of nitrogen did not reach 12.5. Moreover, as in Plate II, the red colour indicates water more or less distinguished by Atlantic characteristics; the blue, water in which the nitrogen was absorbed at a temperature below 0°, and which, therefore, would seem to have derived its origin from some part of the Polar Seas.

A comparison of Plates II and III will at once show considerable agreement in the distribution of colour, many of the sections almost coinciding; though, on closer inspection this approach to congruity is not found to characterise all details, which indeed there was no reason to expect. In Pl. III, the limits proved exceedingly difficult to define, owing to the limited number of observations; nay, respecting an extensive tract near the 65th parallel of latitude nothing definite can be inferred, part of several samples of air, the analysis of which would have served to fill up the blank, having been unfortunately lost, and the total amount of air could not, therefore, be measured. Besides, the errors of observation both in the salt and the nitrogen determinations, are so considerable, when compared with the minute differences in amount, that, in some

sernes Vedkommende af saadan Størrelse, at de i Sammenligning med de smaa Differentser, som det her gjælder at paavise, lettelig paa sine Steder kunne gjøre sig gjældende og frembringe Føveensstemmelser, hvor de i Tilfælde af absolut miagtige Observationer ikke vilde findes.

Hvilken Vægt man nu end vil tillægge disse for Forskjelligheder mellem de to Kartter, saa meget er dog sikkert, at de kun optræde som Undtagelsen, medens den langt stærkere fremtrædende Regel er Overensstemmelser af saadan Art, at de ikke uden videre kunne tilskrives Tilfældigheder. Der eksisterer nemlig en paa mange Puncter næsten til Proportionalitet grændsende lovmæssig Forholdelse mellem Saltehalten og Kvælstofmængderne, som muligens ikke turde lade sig forklare paa anden Maade end netop gennem den her omtalte Hypothese, som saaledes man anses for at indeholde ialt en stor Del Sandhed, idet den samtidig bestrækkes af to af hinanden fuldstændig uafhængige, nensartede Observationsrækker, der i alt Væsentligt give det samme Resultat.

Den, som det synes, største Vanskelighed ved denne Hypothese består i at forklare, hvorledes det i de store Dyb flydende atlantiske Vand skulde have antaget en saa lav Temperatur, som det ifølge Observationerne viser sig at besidde. Dette turde dog maaske ikke synes saa urimeligt, naar man betænker, at den varme, søndenfra kommende Atlanterhavsstrøm vel at flyde henover det underliggende meget kolde Vand paa de nærmest til dette grændsende Læg man blive udsat for en meget stærk Afkøling indenfra, og at det først gennem en saadan Afkøling til omkring 0° opnaar den høje specifikke Vægt, der er den nødvendige Betingelse for, at det skal kunne synke tilbunds. Det atlantiske Vand har altsaa, allerede førend det begynder at synke, antaget en meget lav Temperatur og vil derfor under selve Synken, idet det da kanske i et meget langt Tidsrum befinder sig paa alle Sider omgivet af pudert Vand, end yderligere blive Gjenstand for Afkøling, førend det naar Bunden. Det fremgaar forøvrigt ogsaa af de endnu ikke offentliggjorte Temperaturobservationer, som jeg desuagtet ved Velvillie af Professor Mohr har faaet Anledning, til at gjøre mig bekendt med, at Temperaturen i de store Dyb paa de med rød Farve betegnede Partier er noget lavere end der, hvor Kartet er farvet blaåt, saaledes at i Virkeligheden ogsaa Temperaturforholdene tale for den opstillede Hypothese.

Det vilde dog være paa urette Sted paa dette Stadium at, forsøge at udrøide alle Vanskeligheder, saalænge de paa Expeditionen udførte talrige Temperaturbestemmelser endnu ikke ere forelagte Offentligheden, da man alene ved at tage tilbørligt Hensyn til det hele foreliggende Materiale af Observationer vil kunne vente at faa det ledst mulige Indblik i de mere udviklede Spørgsmaal om Strømføholdene. Det er dog meget sandsynligt, at man senerehen ved at combinere alle Data vil kunne kaste Lys over meget, som nu man synes dunkelt.

Uheldigvis var det ved Expeditionens Udreise ikke muligt at forudsæ, at de kemiske Observationer skulde kunne føre, til Slutninger af saadan Art som de her paa-

of the computations, they might easily affect the result, and give rise to discrepancies which, with perfectly accurate observations, there would be no fear of.

Whatever weight may be attached to these differences, they must unquestionably be regarded as exceptional; the rule is agreement, and of a character precluding the possibility of ascribing it to chance. Many of the observations prove incontestably the existence of a definite, well nigh proportional connexion between the amount of salt and that of nitrogen, a connexion difficult, perhaps, to explain without having recourse to the aforesaid hypothesis, which cannot but come near the truth, confirmed as it is by two widely different series of observations, leading, each independently of the other, in all essential points, to the same result.

The greatest apparent difficulty involved in this hypothesis consists in explaining the low temperature of the Atlantic water in the deeper strata. We must, however, bear in mind that the warm Atlantic current, in flowing over the cold water of the lower strata, is necessarily made to part with a very considerable amount of heat; and that the high specific gravity, without which it could not sink to the bottom, involves a temperature of about 0°. Hence, the Atlantic water will have required a very low temperature before beginning to sink, and moreover, being surrounded during its downward passage, possibly for a considerable period, by Polar water, give off a further amount of heat ere it reaches the bottom. For the rest, it appears from the independent series of temperature observations, not yet in print, with which Professor Mohr has kindly made me acquainted, that the temperature at great depths in the sections coloured red in the Plate, is somewhat higher than in those coloured blue; and hence the hypothesis adopted here derives additional support from the variation in temperature.

Meanwhile, it would be premature to attempt disposing of all difficulties, till the numerous temperature determinations performed on the Expedition shall have been made public, since to elucidate fully the more intricate questions connected with ocean currents, the whole stock of materials must be dealt with. We may however venture to hope, that, at a later stage of this interesting inquiry, a general combination of data will throw light upon much that is at present involved in obscurity.

Unfortunately, it was not possible to foresee on the departure of the Expedition, that such inferences as those here pointed out would be drawn from the chemical ob-

jegede, og det er derfor helt naturligt, naar Undersøgelserne ikke i Henseende til Studiet af tidligere ukjendte Eiendommeligheder ved Havet kunde føre til saa fylde Resultater, som ønskeligt kunde være. Men om end disse Undersøgelser paa Grund heraf nærmest fin Karakteren af forberedende Arbejder, saa vil det dog, som jeg laaber, indrømmes, at de desnagtet kunne have sine maaske ikke uvigtige Følger, idet de vise, at man gennem de kemiske Observationer, der tidligere i Sammenligning med Temperatur- og Dybdelestemmelser har spillet en mindre fremtrædende Rolle ved Studiet af Havets Physik, vil kunne skaffe Oplysninger om mærkelige Forhold i Havet, som man ad anden Vei vanskelig skulde falde paa at søge opklarede. Man vil ved Hjælp af de her erholdte Resultater med Lethed i Fremtiden kunne ndkaste en detailleret Plan for en fornyet Undersøgelse af det norske Hav, der i mine Øine stiller sig som særdeles ønskelig, da man ved at gjøre et lidindtil ukjendt Hav til Gjenstand for Bearbejdelse vanskelig turde gjøre Regning paa at træffe et, der i Henseende til Studiet af Strømførholdene er saa mstruktivt som det norske Hav.

Ved saadanne fremtidige Undersøgelser kunne de paa den norske Expedition benyttede Arbejdsmetoder ikke i alle Retninger blive optagne i ubændret Form, og det vil derfor ikke være uløbet til Slutning med sin Ord at paapege de Mangler, der kkebe ved disse.

De til Saltlestemmelserne tidligere benyttede Metoder, ifølge hvilke alle herhen lærende Observationer anstilles ombord, tør utvivlsomt for Fremtiden ikke komme til Anvendelse, da man ad den Vei tiltrøds for al anvendt Møie ikke vil kunne opnaa den Nødgatighed, som tiltrænges for med ønskelig Sikkerhed at kunne paaise de i Havet forekommende ofte meget smaa Differentser. Paa den norske Expedition blev denne Fremgangsmaade benyttet, fordi man med ældre Ingttageres Udtalelser for Ole maatte belygte, at Sovand ikke lod sig opbevare i længere Tidsrum uden at undergaa forskjellige Forandringer, en Frygt, der imidlertid efter min Erfaring kun forsaavidt er begrundet, som man til Opbevaring af Vandet benytter Kar, der ere forsynede med Korkprop. Jeg har nemlig undersøgt flere Vandprover, der have været opbevarede paa denne Maade i omkring 2 Aar og fundet, at de alle uden Uvtagelse have undergaaet Forandringer af saadan Art, at man turde være berettiget til at anse dem uskikkede til Egenvægtslestemmelse, hvorimod jeg hos Vandprover, der i lignende Tidsrum havde henstaaet paa Flasker forsynede med isleben Glasprop, ikke kunde opslage nogen- somhelst Eiendommeligheder, der kunde adskille dem fra friskt oste Vandprover. Ved denne Opbevaringsmaade risikerer man dog ganske sikkert Pardonstning af en Del af Vandet, og man maa derfor beskytte sig mod denne Føikilde ved at hjemføre det til Saltlestemmelser læstente Vand paa tilsmedede Glasrør.

I de saaledes conserverede Vandprover vil man senerehen efter Hjemkomsten kunne bestemme Egenvægten ved Sprengels Pyknometer og Chlorgehalten ved Hjælp af Veiningsanalyser med saadan Skarphed, som man ved Arbeide

servations, and hence the results of the work done, embracing as it did the investigation of phenomena unknown before, were naturally less comprehensive than might otherwise have been attained. But, though such labours must to a certain extent, be regarded as preliminary, they will, I trust, prove of considerable importance, showing as they do, that chemical observations, which, as compared with determinations of temperature and depth, previously held quite a subordinate rank among the means employed for studying the physical conditions of the ocean, will serve to throw light upon many remarkable phenomena, that without such data would be extremely difficult to explain. On the basis of the results here set forth, a detailed plan might be easily laid down for the further exploration of the Norwegian Sea, — in my opinion a most desirable undertaking, since of ocean tracts as yet unknown, there are probably few that, in regard to the study of ocean currents, would so well repay investigation as that section of the North-Atlantic.

As several of the methods of investigation practised on the Norwegian Expedition, will not admit of being adopted on future occasions in a wholly unmodified form, it will not be out of place in conclusion briefly to point out their defects.

The methods previously devised for determining the amount of salt in sea-water, by which all observations with this object in view were taken on board, should unquestionably cease to be adopted, since they will not suffice, with the greatest care even, to attain the high degree of accuracy requisite for detecting such minute differences as are frequently found to occur. These defective modes of operation were, however, adopted on the Norwegian Expedition, there being reason to believe from the statements of earlier observers, that sea-water could not be preserved for any length of time without undergoing chemical change, a supposition which, so far as my experience goes, is confirmed only in the event of its being kept in corked vessels. I have examined, for instance, various samples of sea-water that had been preserved for about 2 years in corked bottles, and found all without exception to have undergone a change sufficient to render them unfit for specific gravity determinations; whereas, on the other hand, sea-water which had been allowed to stand over for the same space of time in bottles furnished with ground glass stoppers, was not to be distinguished from freshly drawn samples. There is, however, a risk of loss from evaporation, the stoppers being seldom, if ever, tight-fitting; and to guard against this source of error, the water for salt-determinations must be brought home in hermetically sealed glass tubes.

With water thus preserved, the specific gravity may be determined by means of Sprengel's pycnometer, and the amount of chlorine by weighing, on the return of the Expedition, far more accurately than would be possible on

ombord ikke i fjerneste Maade vil kunne gjøre Regning paa ad opnaa, hvorhos man tillige vil have den Fordel at kunne benytte directe Saltbestemmelser som Controlmiddel.

Med de paa Expeditionen udtørte Luftbestemmelser vil ikke kunne gjøres nogen væsentlig Indvending, med mindre man skulde sige over, at de benyttede Vandprover ere optagne ved Hjælp af Apparater, der ikke vare omgivne med slette Varmeledere, saaledes at de ved Ankomsten til Overfladen vilde have havt Anledning til at antage ere i Forhold til sin Luftmængde noget før høj Temperatur. Denne Feilkilde kan dog ikke antages at have haft nogen væsentlig Indflydelse i et Hav som det her undersøgte, hvor kun et meget tyndt Lag nærmest Overfladen besidder en Temperatur af over 5°, især da Vand, der kun er svagt oversættet med Luft, meget langsomt giver Slip paa den overskydende Del.

Det ved Udkøgnngen benyttede, af Jacobsen beskrevne Apparat er i alt væsentligt imidlertid særdeles bekvemt, kun vilde det måske være hensigtsmæssigt at give Luftopsamlingsrøret en noget forandret Form, hvorved man lettelig vilde undgå den Vanskelighed, hvormed det nu er forønden at overtale Luftmængden i Endometret uden Tab.

Ovenstaaende Afhandlinger ere indsendte til Redaktionscomiteen for den norske Nordhavs-Expeditions Generalberetning, No. I og II i April 1879 og No. III i December samme Aar.

De i disse 3 Afhandlinger beskrevne Observationer ere, forsaavidt de ikke ere udførte ombord, anstillede i Professor Waages Afdeling af Universitetets chemiske Laboratorium i Christiania.

Sluttelig benytter jeg Anledningen til at udtale min Tak til D.Hr. Professorerne Waage og Mohr for den Bistand, de under mit Arbeide med disse Gjenstande paa flere Puneter har ydet mig.

board; moreover, there is the additional advantage of being able to test the results by direct salt-determinations.

As regards the air-determinations performed on the Expedition, their general accuracy can hardly be impugned. True, the apparatus with which the samples of water were collected not having been surrounded by a non-conducting medium, they may possibly in their passage to the surface have assumed a temperature somewhat too high as compared with the amount of air contained in them; but the error arising from this source cannot have exerted any material influence, since the tract of ocean investigated has but a thin stratum of water in which the temperature rises above 5°; besides, water slightly surcharged with air is found to part very slowly with the surplus portion.

The holding-apparatus devised by Jacobsen proved very convenient; possibly, however, the tube for collecting air might be given a somewhat different form, to obviate the difficulty now experienced in transferring the air to the eudiometer without loss.

These Memoirs were sent in to the Editorial Committee for the Norwegian North-Atlantic Expedition as follows: — Nos. I and II in April 1879 and No. III in December.

The observations set forth in the foregoing Memoirs were, when not taken on board, instituted in Professor Waage's department of the Chemical Laboratory of the University of Christiania.

In conclusion, I must not omit to thank Professors Waage and Mohr for the assistance they kindly rendered me, in certain respects, when engaged on the investigation of the subjects treated of in these papers.

#### Errata.

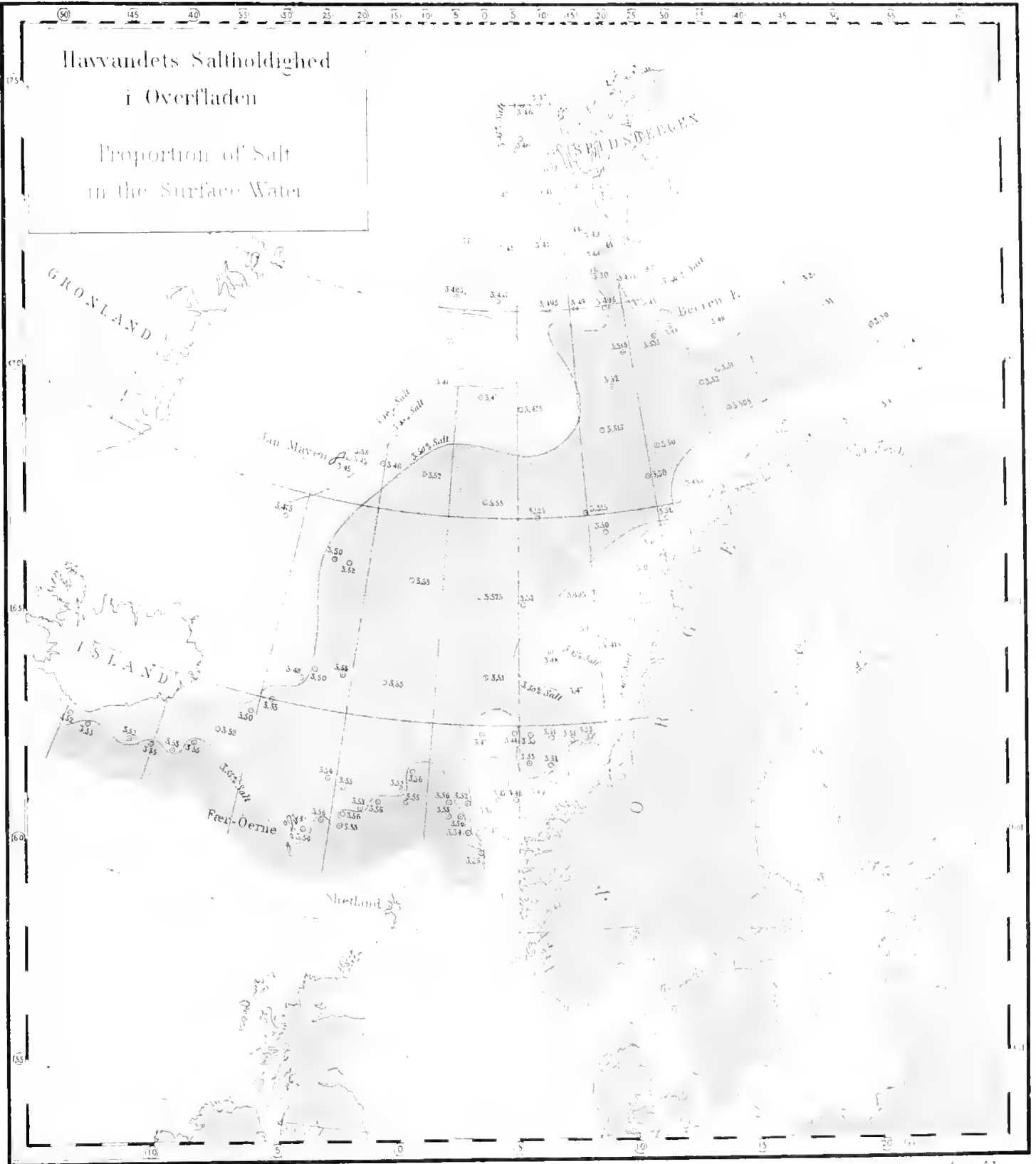
Page 3, line 26, from top of page, *for* 35.4 to 32.4 — 33.6 per cent, being *read* 35.4 to 32.4, 33.6 per cent being.

9, line 20, from top of page, *for* the extent to which the results based on that hypothesis, etc. *read* the slight extent to which Jacobsen's results, etc.

28, line 22, from top of page, *for* 'soda' was added, and the whole compound *read* 'carbonate of soda' was added, and the whole mixture.

38, line 3, from foot of page, *for* 'soda' *read* 'carbonate of soda.'

— 39, line 13, from foot of page, *for* 'soda' *read* 'carbonate of soda.'





















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