

THE HYDROGRAPHY OF THE NORTH SEA AND ADJACENT WATERS.

THE fourth report of the North Sea Fisheries Investigation Committee contains a number of papers on hydrographical researches in the northern part of the North Sea and the Færøe-Shetland channel which are of special interest, inasmuch as they provide a *résumé* of the work done since the committee began its labours, and a statement of certain results and conclusions which may now be accepted as definitely established and used as standards for comparison with future observations. These papers are:—

(1) and (6) on hydrographical investigations in the North Sea and Færøe-Shetland channel during the years 1906-7-8, by Dr. A. J. Robertson; (2) on the temperature of the surface waters of the North Sea during the years 1906 and 1907, by Mr. Frank G. Young; (3) on the salinity of the North Sea, and (4) on surface-temperature observations between Hull and Hamburg during the years 1877-83, by Prof. D'Arcy Thompson; and (5) on the deep currents of the North Sea as ascertained by experiments with drift bottles, by Captain C. H. Brown. Dr. Robertson discusses the observations made during the periodic cruises executed by the SS. *Goldsecker* on lines laid down by the International Council. Mr. Young subjects to harmonic analysis temperature observations made by captains of passenger steamers and officers in charge of certain lightships and lighthouses. Prof. D'Arcy Thompson reviews in his first paper a long record of surface-temperature observations made between Hull and Hamburg by Captain W. Barron, and examines the relation of the sea temperature in the southern part of the North Sea to the air temperature of the adjacent coasts, and in his second paper gives an account of the mean values of salinity in the waters of the North Sea—the general distribution of salinity, its mean periodic variation, and the epochs of maximal and minimal salinity. Captain Brown reports upon experiments with the drift bottle devised by Mr. G. P. Bidder, which is so constructed as to float a few inches above the sea bottom, being carried along by the bottom current, and in the course of time scooped up by a trawl-net or found stranded on a beach.

In the summary which concludes his report on the observations of 1906, Dr. Robertson makes use of the results obtained by the other investigators, and lays down certain general rules. Tidal action is sufficiently active in the southern part of the North Sea to effect a thorough mixing of waters from surface to bottom; hence over this area, the northern boundary of which, by the way, seems somewhat uncertain in position, surface observations alone will henceforth be deemed sufficient. In the northern section the conditions are altogether different, and no uniformity exists in the surface to bottom distribution. Over the North Sea area the temperature decreases from the shore to the open sea in summer and increases in winter. In summer the warmest water (15° to 18° C.) occurs along the Belgian and Dutch coasts, and the coldest in the deep channel off Norway, while in winter the coldest water is, as a rule, along the Danish coast (2° to 3° C.), and the warmest between Scotland and Shetland (7° C.). The greatest annual variation at the surface occurs along the Belgian, Dutch, and German coasts, where it amounts to 13° , while between Scotland and Shetland it is some 9° less. In the deeper layers over the northern area of the North Sea the value is only 1° , while the smallest variation of all takes place in the deepest parts of the Skagerak, where it amounts to only 0.2° .

Mixing by tidal currents is so strong that water of less salinity than 33 per mille is rarely found more than a few miles from shore; over the North Sea area the variations in salinity are greatest at the surface, and the greatest mean deviation from the average occurs where salinity is lowest. In the northern area the variation seldom exceeds 0.2 per mille. The changes in salinity are thus too small to have any direct effect upon the occurrence or wanderings of food-fishes; they are mainly of interest as a guide in studying the movements of the waters.

Much information has been acquired with regard to the general circulation of the waters within the area, and the extent to which this undergoes changes of periodic and irregular kinds. Large volumes of Atlantic water are normally streaming northward as a surface current through

the Færøe-Shetland channel into the Norwegian Sea, comparatively little entering the Norwegian Sea between Færøe and Iceland, where the east Iceland current comes southwards. Under exceptional conditions Polar water extends far enough south to enter the regions of the channel. (Dr. Robertson cites 1908 as one in which this occurrence was very well marked, and it was observed in 1902, as appears from Dr. Wolfenden's observations [*Geographical Journal*, April, 1903] and Dr. Robertson's report to the North Sea Committee, 1902-3 [p. 11]. The conditions observed by H.M.S. *Jackal* in 1893 were also probably somewhat similar.) The deeper layer north of the Wyville Thomson ridge is normally flooded with cold water of salinity 34.9 per mille, which is in direct connection with the bottom area of the Norwegian Sea, but in the southern parts of the channel at least these bottom layers are occasionally displaced by warmer and saltier water, showing that marked changes may occur even at the greatest depths. (This also appears, from Dr. Wolfenden's observations, in the summer of 1900.)

Between the Færøes and Fair Isle the centre of the Atlantic stream is situated between 3° and 5° west longitude, where the mean annual temperature is 9.5° C. and salinity 35.29 per mille. Within the regions of the channel its direction of flow varies from north-east to east, and the speed of the surface waters apparently averages about fourteen miles in twenty-four hours. Branches are thrown off which enter the North Sea round the north and south of Shetland, and of these the latter is certainly subject to seasonal variation. A scanty winter salt-water distribution is normally followed by more vigorous inflow during early spring, increasing to a maximum in the beginning of summer, and gradually decreasing again on the approach of the following winter. As exceptional seasons, Dr. Robertson quotes (1) the winter 1905-6, when an unusually powerful Atlantic inflow took place; (2) the summer of 1907, when the maximum inflow was unduly delayed; and (3) the whole of 1908, when the inflow was very scanty.

The greater proportion of the Atlantic water entering the northern part of the North Sea area bends eastward before reaching the 57th parallel of latitude, and after throwing off a branch which enters the Skagerak as an undercurrent is carried back northwards. This rotational movement, due to the configuration of the bottom, gives rise to a cold, deep-water area, an area with a great temperature phase delay over which the maximum value in the bottom layers is not reached until near the close of the year. (This layer appears in the *Jackal* observations, 1893.) A fresh-water current continually streams northward along the Norwegian coast, being exclusively confined to the in-shore regions during the winter months, but extending in summer far out to sea as a thin surface layer; similar movements occur in summer off the Scottish coast.

From the above summary of Dr. Robertson's conclusions it appears that the normal distribution and circulation of the waters in the North Sea area may now be regarded as definitely known. The departures from the normal are, as was supposed, very considerable, but it would seem that the years 1905-6 and 1908 may be taken as representing the nature of the extreme variations which are likely to occur, and it is noteworthy that the older observations of H.M.S. *Jackal* and other vessels indicate conditions which, while showing some abnormal features for the years to which they refer, agree satisfactorily with the more recent and more adequate work as regards the type of distribution and general movement, and fall within the limits of departure from that type which they have themselves recorded.

H. N. DICKSON.

THE THOMSEN MEMORIAL LECTURE.¹

AMONG the Danes whose names are inscribed as men of science on the eternal bead-roll of fame, that of Julius Thomsen stands pre-eminent—linked indeed with that of Oersted. It is significant of the position which Thomsen acquired in physical science, and of the respect which that position secured for him in the eyes of his countrymen, that his statue should have been erected during his lifetime

¹ Delivered before the Chemical Society on February 17, by Sir Edward Thorpe, C.B., F.R.S., past-president of the Society.

and placed in the vicinity of that of Oersted in the courtyard of the Polytechnic High School of Copenhagen. Thomsen, in fact, played many parts in the intellectual, industrial, and social development of Denmark. To Europe in general he was mainly known as a distinguished man of science. By his fellow-citizens he was further recognised as an educationist of high ideals, actuated by a strong common sense and a stern devotion to duty; as an able and sagacious administrator; as a successful technologist and the creator of an important and lucrative industry based upon his own discoveries; and as a man of forceful character, who brought his authority, skill, and knowledge of men and affairs to the service of the communal life of Copenhagen.

Thomsen was a municipal councillor of that city for more than a third of a century. He occupied a commanding position on the Council, and was invariably listened to with respect. The gas, water, and sewage works of Copenhagen are among the monuments to his civic activity. From 1882 up to the time of his death he was a member of the Harbour Board of the port. In these respects Thomsen sought to realise Priestley's ideal of the perfect man—that he should be a good citizen first and a man of science afterwards.

Hans Peter Jürgen Julius Thomsen was born in Copenhagen on February 16, 1826. He was educated at the church school of St. Peter in that city, and subsequently at von Westens Institute. In 1843 he commenced his studies at the Polytechnic, and in 1846 graduated there in applied science, and became an assistant to Prof. E. A. Scharling. Of his earliest years comparatively little is known. Thomsen, always a reserved and taciturn man, talked little about himself even to his intimate friends—and least of all about the days of his youth. It was known to a few that these days had not been smooth. Those who were best informed were conscious that to these early struggles much of that dour and resolute nature which formed a distinguishing trait in his character was due. Thomsen, indeed, began life as a fighter, and a fighter he remained to the end of his four-score years.

In 1847, he became assistant to Forchhammer, passing rich, like Goldsmith's pedagogue, on 40*l.* a year. Georg Forchhammer, whose earliest work dates back to the period when Berzelius was in his prime, was an active and industrious investigator of the old school, mainly in inorganic chemistry, and more particularly on problems of chemical geology and physiography. He was a frequent visitor to this country, and was well known to early members of the British Association. Although doubtless influenced, in common with all teachers in northern Europe, by the example and methods of Berzelius, such influence as he himself was able to exert died with him. Forchhammer attracted few pupils, and created no school, and Thomsen probably derived no inspiration or acquired any stimulus from this association. For a time Thomsen supplemented his scanty income by teaching agricultural chemistry at the Polytechnic. In 1853 he obtained a travelling scholarship, and spent a year in visiting German and French laboratories. He probably owed this scholarship in great measure to his first contribution to the literature of chemistry, namely, his memoir, "Bidrag til en Thermochemisk System" (contributions to a thermochemical system), communicated to the Royal Society of Sciences of Copenhagen in 1852, and for which he received the silver medal of the society and a sum of ten guineas to enable him to procure a more accurate apparatus. In this memoir he sought to develop the chemical side of the mechanical theory of heat, doubtless under the influence of Ludwig Augustus Colding, an engineer in the service of the Municipality of Copenhagen, and a pioneer, like Mayer, in the development of that theory. Indeed, the Danes now claim for Colding, who had made experiments on the relation between work and heat as far back as 1842, but whose labours were practically ignored by his contemporaries, the position which the Germans assign to Mayer (see Mach's "Development of the Theory of Heat"). In 1861 Thomsen further developed his ideas in a memoir on the "General Nature of Chemical Processes; and on a Theory of Affinity Based Thereon," published in the Transactions of the Danish Academy of Sciences. In this paper he laid the foundations of the chief scientific work of his life.

In 1853 Thomsen patented a method of obtaining soda from cryolite, so-called "Greenland," or ice-spar, a naturally occurring fluoride of sodium and aluminium, $\text{Al}_2\text{F}_6\cdot 6\text{NaF}$, found largely, indeed, almost exclusively, in Greenland, and particularly at Ivigtut. It derives its mineralogical name from its ice-like appearance and ready fusibility even in the flame of a candle. It seems to have been first brought to Europe in 1794, and to have been described by Schumacher in the following year. Klaproth first showed that it contained soda, and its composition was further established by Vauquelin, Berzelius, and Deville.

Thomsen's process consists in heating a finely divided mixture of cryolite and chalk in a reverberatory furnace, whereby carbon dioxide is expelled and calcium fluoride and sodium aluminate are formed. The roasted mass is lixiviated with water, so as to dissolve out the sodium aluminate, which is then treated with carbon dioxide. Alumina is precipitated, and sodium carbonate remains in solution. The alumina is either sold as such or converted into sulphate (so-called "concentrated alum" or "alum-cake"), and the sodium carbonate is separated by crystallisation. Both products are obtained in a remarkably pure condition, and the cryolite-soda yields excellent "caustic."

Thomsen's process, although simple enough in principle, requires considerable skill and pains in its practical execution, and most of the manufacturing details were worked out by him, or under his direction. Success largely depends upon the maintenance of a proper temperature; the decomposition begins below a red-heat, but requires to be finished at that temperature, and care must be taken to avoid fusion or even sintering of the mass. In 1854 Thomsen obtained the exclusive right of mining for cryolite and of working up the mineral in Denmark for soda and alumina. Actual manufacturing operations were begun on a small scale in 1857, and in the following year Thomsen planned the present large factory at Oeresund, near Copenhagen, which was opened on his thirty-fourth birthday. The importance of this industry to Denmark may be seen from the circumstance that during the fifty years of its existence the firm have paid the Danish Government nearly 300,000*l.* for the concession. Other factories were started in Germany, Bohemia, and Poland, but met with little success. The Pennsylvania Salt-manufacturing Company at Natrona, near Pittsburg, eventually obtained the right to work up two-thirds of all the cryolite mined in Greenland. From the start Thomsen took a large share in the management of the Oeresund works, and by his energy, foresight, and skill placed the undertaking on a sound commercial basis.

Although Thomsen died a rich man, mainly as the result of the industry he created, in the outset of his career as a teacher and a technologist his means were very straitened. He came of poor parents, of no social position or influence, and they were unable to further his inclinations towards an academical career. In 1854 he applied unsuccessfully for a position as teacher of chemistry at the Military High School in Copenhagen. During three years—from 1856 to 1859—while still engaged in developing his cryolite process, he acted as an adjuster of weights and measures to the Municipality of Copenhagen. It was a poorly paid position, but it kept the wolf from the door. At about this period he betook himself to literature, and published a popular book on general subjects connected with physics and chemistry—somewhat in the style of Helmholtz's well-known work—entitled "Travels in Scientific Regions," which had a considerable measure of success. He was, however, not altogether unknown even at this time as an author, since in 1853 he had collaborated with his friend Colding in producing a memoir on the causes of the spread of cholera and on the methods of prevention, which attracted much attention at the time of its appearance.

In 1859, whilst engaged in the Oeresund factory, he again applied to the authorities for a position as teacher at the Military High School, and succeeded in obtaining an appointment to a lectureship in physics, which he held until 1866. During his tenure of this office he devised his polarisation battery, which received many awards at international exhibitions and was used for a time in the Danish telegraph service.

In 1859–60 he was "vicarius" for Scharling at the University, and in 1865 became a teacher, and in the following year professor of chemistry and director of the

Chemical Laboratory, a position which he retained—active to the last—until 1901, when he retired in his seventy-fifth year of age.

Before his connection with the University, he founded and edited, from 1862 to 1878, in association with his brother, August Thomsen, the *Journal of Chemistry and Physics*, one of the principal organs of scientific literature in Denmark.

In 1863 he was elected a member of the Commission of Weights and Measures, and was instrumental in bringing about the adoption of the metric system and the assimilation of the Danish system to that of the Scandinavian Kingdom.

In 1883 Thomsen became Chancellor of the Polytechnic High School of Copenhagen—a position which he held for about nine years. During this period he entirely changed the character and spirit of the school, and stamped it with the impress of his earnestness and industry. Under his direction, new buildings were erected and arranged in accordance with the best Continental and American models. Thomsen's administration was in marked contrast to that of his somewhat easy-going predecessor, but it is doubtful if it brought him popularity in the school. The students respected and even feared him, but his cold and unsympathetic nature evoked no warmer feeling. It was said of him by one who knew him intimately that he never learned to draw the young to him, to create in them an interest for his work, to form a school. Thomsen was a homely man, but not even in his home, says the same authority, was it possible for him to change his active, earnest, strenuous disposition—what his friends called his fighting character. But if he was always the serious master of the house, he was also its obedient servant. In reality he was a man of deep feeling, and was not without power to give that feeling expression in words, sometimes in verse, and occasionally even in music.

It was while occupying the position of director of the chemical laboratory of the University that Thomsen executed the thermochemical investigations which constitute the experimental development of the ideas he had formulated in his memoir of 1861. The results of these inquiries were first made known in a series of papers published from 1869 to 1873 in the Transactions of the Royal Danish Society of Sciences, and from 1873 onwards by the *Journal für Praktische Chemie*. The papers were republished in collected form in four volumes (1882–1886) by a Leipzig house under the title of "Thermochemische Untersuchungen." A summary of this experimental labour, which extended over a third of a century, was subsequently prepared by Thomsen, and published in 1905 in Danish under the title of "Thermokem'ske Resultater."

In this work he reviewed the whole of the numerical and theoretical results, to the exclusion of the greater portion of the experimental details. A translation of this volume by Miss Katharine A. Burke, entitled "Thermochemistry," renders it readily accessible to English readers. Miss Burke has supplemented the original work by a short account, taken from the "Thermochemische Untersuchungen," of the experimental methods employed, thereby rendering the whole more intelligible to the student. Moreover, in the English edition a partial attempt has been made to translate Thomsen's deductions into the language of modern theory based on the conception of ionisation, which, of course, was not known to science at the time the "Thermochemische Untersuchungen" was published.

It is impossible within the limits of such a notice as this to deal in detail with the immense mass of experimental material which this work embodies, and I shall not attempt, therefore, to do more than to offer a generalised statement, based mainly upon the admirable account of Thomsen's work given by Prof. Brønsted to the Chemical Society of Copenhagen on the occasion of the meeting held on March 2, 1909, to commemorate Thomsen's services to science.

The conception of affinity as a cause and determining condition of chemical change is traceable in some of the earliest efforts to coordinate and explain chemical phenomena. It certainly existed long prior to the time of Boyle, and was at the basis of every philosophical system after his period. We need only mention the names of Bergman, Wenzel, and Berthollet to indicate this fact. But to Thomsen belongs the credit of being the first to make the attempt to measure the relative value or strength

of affinity quantitatively, and to express it numerically in definite terms which admitted of exact comparison. Thomsen's theory of affinity, as enunciated by him in his 1851 paper, was based upon his conviction that affinity could be measured quantitatively by estimating the amount of heat evolved in the chemical process. We are not immediately concerned to show whether the theory is right or wrong, or in what respect it fails. The point is that the enunciation of this principle upwards of half a century ago constituted an important step forward, inasmuch as it sought to estimate affinity in relation to a quantity which can be fixed by experiment, and is capable of expression by numbers. In this and in the subsequent paper of which mention has been made already, he thus defines his conception of thermochemistry, and discusses, for the first time, its laws.

"The force which unites the component parts of a chemical compound is called affinity. If a compound is split up, whether by the influence of electricity, heat, or light, or by the addition of another substance, this affinity must be overcome. A certain force is required the amount of which depends on the strength of the affinity.

"If we imagine, on the one side, a compound split up into its component parts, and on the other side these parts again united to form the original compound, then we have two opposite processes the beginning and end of which are alike. It is therefore evident that the amount of the force required to split up a certain compound must be the same as that which is evolved if the compound in question is again formed from its component parts.

"The amount of force evolved by the formation of a compound can be measured in absolute terms; it is equal to the amount of heat evolved by the formation of the compound.

"Every simple or complex action of a purely chemical nature is accompanied by evolution of heat.

"By considering the amount of heat evolved by the formation of a chemical compound as a measure of the affinity, as a measure of the work required to again resolve the compound into its component parts, it must be possible to deduce general laws for the chemical processes, and to exchange the old theory of affinity, resting on an uncertain foundation, for a new one, resting on the sure foundation of numerical values."

As has been proved by later theoretical and experimental investigations, the theory of thermochemical affinity is not absolutely correct at ordinary temperatures. But, on the other hand, it has been shown that a comparatively large number of processes are approximately in unison with it. Not only do they agree qualitatively, that is to say, that heat is evolved during the process, but also in the fact that the results which newer and more exact methods for estimating affinity have produced agree numerically with what would be required by the thermochemical theory. We meet here with a fundamental phenomenon which Thomsen deserves great credit for having first pointed out, but the explanation of which could not be given at the time he indicated it. It can be demonstrated theoretically that the lower we reduce the temperature and the nearer we get to the absolute zero, the more nearly is the condition for the theory fulfilled, so that at the absolute zero the theory would be found to be an exact law of nature. If it were possible to work at such low temperatures it would be found that the evolution of heat, or the evolution of energy by the chemical process, would be an exact measure of the affinity of the process and that under this condition the theory of Thomsen would be the accurate expression of a natural law.

But under ordinary conditions this is not so, for in reality an ever-increasing number of endothermic processes are found to occur, that is, processes which proceed with the absorption of heat. Thomsen tried at first to explain these phenomena in such a way as to keep them within his system, and he drew a distinction between a purely chemical process running conformably to his theory and a physico-chemical process which did not fall within the law. But he was gradually convinced that his theory could not be maintained in its entirety. It is to his credit that he did not seek to uphold an untenable principle, or try to defend it as did Berthelot, who almost to his dying day maintained the validity of the principle in spite of all facts.

These ideas have, in the words of Ostwald, been the scientific confession of faith of chemists throughout half a century. They have had the greatest influence on scientific thought in every branch of chemistry. It is on the basis of them that we have arrived at a theory of affinity which at the present moment is being developed into one of the most perfect chemical theories. Lastly, it is due to these ideas that the experimental material has been produced which during all time will place the name of Julius Thomsen in the first rank of men of science.

To go through this material in detail is, as I have said, impossible here. It may be stated generally that practically every simple inorganic process has been investigated calorimetrically by Thomsen, or can be calculated by means of the calorimetric data furnished by him. In the case of organic substances, data have been given for estimating the heat of combustion of a large number of compounds. All these estimations were made by Thomsen personally, according to a pre-arranged plan, and in systematic succession during a period of more than thirty years. They comprise more than 3500 calorimetric estimations. It has been truly said that this work is unique in the chemical history of any country.

Among the results of Thomsen's thermochemical inquiries which have special value for physical chemistry is his investigation of the phenomena of neutralisation, in which he shows that the basicity of acids can be estimated thermochemically, and that it can in this way be proved whether or not a point of neutrality exists. His observation that the heat of neutralisation is the same for a long series of inorganic acids, such as hydrochloric acid, hydrobromic acid, hydriodic acid, chloric acid, nitric acid, &c., supports the theory of electrical dissociation, inasmuch as this requires that the heat of neutralisation of the strong acids must in all cases be independent of the nature of the acid, because the process of neutralisation for all of them is the combination of the ion of hydrogen in the acid with the ion of hydroxyl of the base to form water. These investigations also led to the important thermochemical result that the heat of neutralisation of acids (or the heat of their dissociation) cannot be considered as a measure of the strength of the acids.

Another important result is the proof by experiment of the connection which exists between the changes of the heat-effect with the temperature and the specific heat of the reacting substances. The first law of thermodynamics requires the relation indicated by Kirchhoff: $dU/dT = C_1 - C_2$, where U is the heat-effect, T the temperature, and C_1 and C_2 are the heat capacities of the two systems before and after the reaction, and Thomsen showed by investigation of the heat of neutralisation, the heat of solution, and the heat of dilution, that this relation was satisfied. For the purpose of his inquiry, the specific heats of a large number of solutions of salts were estimated by an ingenious method, and with an exactness hitherto unattained.

Of no less importance are Thomsen's thermochemical investigations on the influence of mass. In the year 1867 Guldberg and Waage published their theory of the chemical effect of mass. But they had only verified the theory to a small extent and in particularly simple cases. They had not investigated the complete homogeneous equilibrium, because at that time no method existed for experimental investigation of such homogeneous equilibrium. Thomsen showed that the estimation could be made thermochemically. By allowing, for instance, an acid to act on a salt of another acid in an aqueous solution, the latter acid will be partly replaced by the first, which will form a salt. By mixing, for instance, a solution of sodium sulphate and nitric acid, there is formed sodium nitrate and sulphuric acid, but the process will not proceed to completion. If we have estimated the heat of neutralisation of the two acids with sodium hydroxide, the difference between these two heat-phenomena will give the amount of heat corresponding to the total decomposition of the sodium sulphate, and the heat found experimentally by mixing the two solutions will therefore show to what degree the transformation has taken place. It would be possible to estimate thermochemically the amount of the four substances in solution, and thereby, by varying the concentration or the proportion between the initial quantities of substances, to calculate whether the

Guldberg-Waage theory on the effect of mass was confirmed in this case.

Thomsen applied this method to a large number of different acids and bases, and was enabled thereby to prove the agreement with the law of the influence of mass in all the cases which he examined. He found particularly that the proportion of the one acid which remained combined with the base was constant with mixtures of constant proportion. On this basis he propounded the term *avidity*, which he defined as the tendency of the acid to unite with the base, and he showed that the avidity was independent of the concentration, and only to a small extent varied with the temperature. The term avidity has since acquired great importance, particularly since other and more exact methods for its estimation have been found. Concurrently with this, its meaning has been made clear by the theory of electrolytic dissociation.

On the basis of these estimations, Thomsen drew up the first table, based on experiments, of the relative strength of the acids, and the numbers in this table have been found to agree with the results obtained by examining the electrical conductivity of the acids.

It is worth noting that Thomsen not only produced the experimental proof of the correctness of the Guldberg-Waage theory of the effect of mass soon after the appearance of this theory, but also that he was the first to acknowledge and adopt it. It is remarkable that this work of Thomsen received so little attention, although it appeared in a widely circulated German journal, and it was not until ten years later that the law of the effect of mass was generally recognised, as the result of the work of Ostwald and van 't Hoff.

Although Thomsen's title to scientific fame rests mainly upon his thermochemical work, his interests extended beyond this particular department of physical chemistry. He worked on chloral hydrate, selenic acid, on ammoniacal platinum compounds, and on glucinum platinum chloride, on iodic acid and periodic acid, on hydrogen peroxide, hypophosphorous acid, and hydrogenium. He early recognised the importance of Mendelëeff's great generalisation, and contributed to the abundant literature it produced. His paper of 1895, "On the Probability of the Existence of a Group of Inactive Elements," may be said to have foreshadowed the discovery of the congeners of argon. He pointed out that in periodic functions the change from negative to positive value, or the reverse, can only take place by a passage through zero or through infinity; in the first case, the change is gradual, and in the second case it is sudden. The first case corresponds with the gradual change in electrical character with rising atomic weight in the separate series of the periodic system, and the second case corresponds with a passage from one series to the next. It therefore appears that the passage from one series to the next in the periodic system should take place through an element which is electrically indifferent. The valency of such an element would be zero, and therefore in this respect also it would represent a transitional stage in the passage from the univalent electronegative elements of the seventh to the univalent electropositive elements of the first group. This indicates the possible existence of a group of inactive elements with the atomic weights 4, 20, 36, 84, 132, the first five numbers corresponding fairly closely with the atomic weights respectively of helium, neon, argon, krypton, and xenon (*Zeitsch. anorg. Chem.*, 1895, ix., 283; *Journ. Chem. Soc.*, 1896, lxx., ii., 16). He subsequently made known the existence of helium in the red fluorite from Ivigtut.

As evidence of Thomsen's manipulative ability and his power of accurate work may be mentioned his determination of the atomic weights of oxygen and hydrogen, and incidentally of aluminium. For the atomic weight of hydrogen he obtained the value 1.00825 when $O=16$, which is practically identical with that of Morley and Noyes. He further made most accurate estimations of the relative densities of these gases, and of the volumetric ratios in which they enter into the composition of water. His value for the atomic weight of aluminium is nearly identical with that adopted in the last Report of the International Committee on Atomic Weights.

Thomsen maintained his interest in thermochemical problems up to the end, and was a keen and clear-sighted critic of the work which appeared from time to time during

the later years of his life. This interest occasionally gave rise to controversy, and some of his latest papers were wholly polemical.

Thomsen was a pronounced atomist, and to him a chemical process was a change in the internal structure of a molecule, and the chief aim of chemistry was to investigate the laws which control the union of atoms and molecules during the chemical process. He considered that chemistry should be treated mathematically as a branch of rational mechanics. But no one insisted more strongly than he how little we really know of these questions. In summarising his theoretical ideas in the *Thermokemische Resultater*, he says, "An almost impenetrable darkness hides from us the inner structure of molecules and the true nature of atoms. We know only the relative number of atoms within the molecule, their mass, and the existence of certain groups of atoms or radicles in the molecule, but with regard to the forces acting within the molecules and causing their formation or destruction our knowledge is still exceedingly limited." He fully realised that his own work was only the foundation on which the future elucidation of these questions must rest. "He worked," says Brönsted, "in the conviction that what we somewhat vaguely call the affinity of the atoms—their interaction, their attraction, and varying effect, &c.—follows the general laws of mechanics, and that, as he worded it, the principle that 'might is right,' holds good in chemistry as in mechanics. On this foundation he hoped to be able to evolve the laws for the statics and dynamics of chemical phenomena, even although the true nature of the action is unknown."

Thomsen's merits as an investigator received formal recognition from nearly every country in the civilised world. So far back as 1860 he was elected one of the thirty-five members of the Danish Royal Society of Sciences of Copenhagen, and from 1888 until his death he was its president. In 1876 he became an honorary foreign member of the Chemical Society of London. On the occasion of the fourth centenary of the foundation of the University of Upsala (created in 1477), he received the degree of Doctor of Philosophy *honoris causa*. In 1879 he was made an honorary M.D. of the University of Copenhagen. Two years later he was made a foreign member of the Physiological Society of Lund, and in 1888 he was elected a member of the Society of Science and Literature of Gothenburg. In 1885 he became a member of the Royal Society of Sciences of Upsala, and in 1886 of the Stockholm Academy of Sciences.

In 1883 he and Berthelot were together awarded the Davy Medal of the Royal Society—a fitting and impartial recognition on the part of the society of the manner in which the two investigators, whose work not infrequently brought them into active opposition, had jointly and severally contributed to lay the foundations of thermochemistry.

In the same year Thomsen was made a member of the Accademia dei Lincei of Rome, and in the following year he was elected into the American Academy of Arts and Sciences in Boston, and of the Royal Academy of Sciences of Turin. In 1887 he was made a member of the Royal Belgian Academy.

In 1886–7, and again in 1891–2, he was rector of the University of Copenhagen. In 1888 he became Commander of the Dannebrog, and in 1896, and on his seventieth birthday, he was made Grand Commander of the same order. On the same occasion the Danish chemists caused a gold medal to be struck in his honour. In 1902 he became a Privy Councillor (*Geheime Konferenz raad*). In the same year he was elected a foreign member of the Royal Society of London.

He died on February 13, 1908, full of years as of honours, and was buried on the eighty-third anniversary of his birth and on the jubilee of the opening of the Oeresund factory. His wife, Elmine Hansen—the daughter of a farmer on Langeland—predeceased him in 1890.

I desire to express my acknowledgments to Director G. A. Hagemann, of Copenhagen, and to Prof. Arrhenius, of Stockholm, for their assistance in obtaining information concerning Thomsen's personal history. I am also much indebted to our fellow, Mr. Harald Faber, for his kindness in making for me a translation of Prof. Brönsted's account of Thomsen's scientific work, on which my own *résumé* is mainly based.

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UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Sir J. J. Thomson has been nominated to represent the University at the celebration next October of the centenary of the University of Berlin.

Mr. S. Brodetsky, bracketed senior wrangler in 1908, has been elected to the Isaac Newton studentship, tenable for three years.

The adjudicators of the Smith's prizes and Rayleigh prizes are of opinion that the following essay sent in by a candidate is of distinction, "Discontinuous Motion in Gases," by Mr. G. I. Taylor. A Smith's prize is awarded to Mr. Taylor for this essay. The second Smith's prize is not awarded.

In response to an appeal for funds for the purpose of purchasing a site and for building, equipping, and conducting a field laboratory on the outskirts of Cambridge, mainly for the study of protozoal and parasitic diseases, donations amounting to 988*l.* 17*s.* have been received. A donation of 1000*l.* has been promised, anonymously, when the fund has reached 6000*l.* In addition to the foregoing, the Government of Cape Colony has placed the sum of 500*l.* at the disposal of Prof. Nuttall for the purpose of investigating East Coast fever. By permission of the Government, a part of this sum will be utilised for the construction of the laboratory.

OXFORD.—The fact that Halley occupied the Savilian chair of astronomy at Oxford gives this University a special interest in Halley's comet. This interest the University proposes to mark by conferring the honorary degree of Doctor of Science on Mr. P. H. Cowell, F.R.S., chief assistant, and Mr. A. C. D. Crommelin, assistant, at the Royal Observatory, Greenwich, by whose joint calculations the exact determination of the re-appearance of Halley's comet was successfully accomplished. The actual ceremony of conferring the degree will probably take place in May, at the time when the comet is expected to be at its brightest. It has further been arranged that the first discourse given on the new foundation of the Halley lecture shall be delivered by the founder himself, Dr. Henry Wilde, F.R.S., and it is hoped that this may take place at the same time as the conferring of degrees on the two Greenwich astronomers.

ST. ANDREWS.—Besides the munificent gifts to the chemical department of the University already noted, Dr. Purdie recently handed 2000*l.* to the University Court to aid in paying a chemical assistant.

Prof. Percy Herring (physiology) has been appointed dean of the faculty of science, and he enters on his duties at the end of the winter session, the pro-dean (Prof. Butler) meanwhile officiating during the enforced retirement of Prof. Musgrove from illness.

The spacious new Pettigrew Museum of Natural History (the gift of Mrs. Pettigrew) is approaching completion, and the hothouses and conservatories in connection with the botanical department, to which Mrs. Pettigrew also liberally contributed, are well advanced.

A JOINT conference of members of the Geographical Association and of the Federated Associations of London Non-primary Teachers will be held at 3 p.m. on Saturday, March 12, at the Polytechnic, Regent Street, W., when an address will be given by Mr. H. J. Mackinder on "The Regional Method in Geography." Tickets may be obtained from the honorary secretary of the Federated Associations, Miss R. F. Shove, 26 Blessington Road, Lee, S.E.

EDUCATIONAL and charitable institutions, says *Science*, have received 32,400*l.* by the will of the late Mrs. Frances E. Curtiss, of Chicago. Among the institutions which have benefited is Williams College, Williamstown, Mass., 5000*l.* Cooper Medical College, San Francisco, has received a bequest of 1000*l.* by the will of the late Mrs. Myrick. In connection with these bequests to higher education, it is interesting to note that our contemporary reports President Schurman, of Cornell University, as having said in a recent address: "I should like most to see at Cornell a score of research professorships with salaries, say 1500*l.* each, which would call for a capital of some 600,000*l.* or 800,000*l.*, a really small amount in this age of American multi-millionaires."