

Citation:

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with Ω^4 is therefore separated thrice, and as this section must be counted once more as part of the section with Δ^3 , Φ^{23} has degenerated into the surface Φ^7 found above and in the four times counted surface Ω^4 .

§ 12. On each of the straight lines PQ considered in § 1 lies an involution of associated points, of which the double points are situated on Δ^4 . If these are associated to each other an *involution on Δ^4* is obtained. It has been deduced in a different way by STURM (Die Lehre von den geometrischen Verwandtschaften, Vol. III, p. 409). He proves among others that in this way to each plane section c^4 of Δ^4 a twisted curve ρ^6 of order six and rank sixteen is associated.

Chemistry. — “*On the allotropy of the ammonium halides I.*”
By DR. F. E. C. SCHEFFER. (Communicated by Prof. A. F. HOLLEMAN).

(Communicated in the meeting of June 26, 1915).

1. *Introduction.* In the literature, in particular in the crystallographical literature, there are a number of papers to be found which lead us to the conclusion that ammonium chloride and ammonium bromide can occur in two different crystalline forms. Thus STAS¹⁾ found that the transparent crystalline mass which deposits from the vapour of subliming ammonium chloride, comes off from the wall when cooled, and becomes opaque; he also states that the specific weight of the transparent and the opaque ammonium chloride are different. Though STAS does not enter into further details about these phenomena, these experiments would already be sufficient to suggest dimorphy here. It is remarkable that STAS has evidently succeeded in cooling the transparent ammonium chloride, which according to the above is metastable at the ordinary temperature, to room temperature without the conversion taking place, the more so because in the papers that have appeared later no indications are to be found for this possibility. GOSSNER²⁾, who repeated STAS' sublimation experiment, says that generally conversion sets in already during the sublimation, and the clear crystals can only be preserved for a short time.

LEHMANN³⁾ was the first to conclude to dimorphy; he tried

¹⁾ STAS Untersuchungen über die Gesetze der chemischen Proportionen u. s. w. übersetzt von ARONSTEIN. S. 55 (1867).

²⁾ GOSSNER, Zeitschr. f. Kryst. 38 110 (1903).

³⁾ LEHMANN, Zeitschr. f. Kryst. 10 321 (1885).

to prove this by crystallisation experiments of a mixture of ammonium chloride, bromide, and iodide from aqueous solution. With a suitable choice of the concentrations he succeeded on cooling in obtaining a cubic kind of crystal, which is transformed on further cooling to the well-known skeletons, which the chloride and bromide of ammonium exhibit at the ordinary temperature. It is evident that only the appearance of a *transformation* can prove the dimorphy of the halogen salts, for ammonium chloride and bromide have the skeleton form at the ordinary temperature, whereas ammonium iodide crystallizes into cubi. From a solution which contains a mixture of the salts, both cubi and skeletons can deposit. According to LEHMANN the *transformation* must be explained in this way that mixed crystals of the skeleton type are converted to cubic mixed crystals, in which then at the same time interchange of substance with the solution will take place. That in mixtures of the three salts two kinds of mixed crystals occur, becomes also probable because of the very close crystallographic resemblance of NH_4Cl and NH_4Br , and from the limited miscibility of NH_4Cl and NH_4I , which GOSSNER¹⁾ observed.

According to KRICKMEYER²⁾ NH_4Cl and KCl show limited miscibility. GROTH³⁾ expressed the supposition in virtue of this isodimorphy that the crystalline form of the ammonium chloride, which can form at higher temperature, would be isomorphous with KCl . WALLACE⁴⁾ points out in his treatise that if this supposition is correct, this would lead to a very remarkable conclusion. As KCl belongs to the pentagonikositetrahedral class of symmetry, this would also have to be the case for the form of the ammonium chloride, which is metastable at the ordinary temperature, and which I shall call the β -form in what follows. As, however, α -ammonium chloride also belongs to the same class of symmetry, we should have two modifications with the same crystallographical symmetry. Then we should be obliged in my opinion to seek the difference between the two modifications in a different structure of the molecule. Ammonium chloride and bromide would then be very suitable examples for a test of Prof. SMITS' theory of the allotropy; according to this theory the phenomenon of allotropy is namely generally explained by the assumption of different kinds of molecules. If we consider that the above mentioned experiments of LEHMANN render it probable that NH_4Cl and NH_4Br can dissolve in NH_4I with formation of cubic mixed crystals, and

¹⁾ GOSSNER, Zeitschr. f. Kryst. **40**. 70 (1905).

²⁾ KRICKMEYER, Zeitschr. f. physik. Chemie. **21**. 72 (1896).

³⁾ GROTH, Chem. Kristall. I. 167.

⁴⁾ WALLACE, Centralblatt für Mineralogie u. s. w. 1910 S. 33.

that NH_4I probably crystallizes pentagonikositetrahedrally, we should arrive by the same train of reasoning as above at the conclusion that α - and β -ammonium chloride are both pentagonikositetrahedral.

An entirely different indication for the existence of two modifications has been found by Prof. ZEEMAN and HOOGENBOOM¹⁾. In the research of the birefringency of the ammonium chloride cloud in the electric field it appeared that this can have a different sign and that also the reversal of sign of the refraction can be demonstrated. These phenomena are explained by the assumption that the refraction of positive and negative sign must be due resp. to the two ammonium chloride modifications.

The above mentioned experiments prove that ammonium chloride occurs in two modifications, but whether we have to do here with enantiotropy or monotropy cannot be inferred from the above.

WALLACE²⁾, however, has shown of late that NH_4Cl and NH_4Br are enantiotropic. From cooling curves he found the points of transition resp. at 159° and 109° . By the aid of LEHMANN's Heating microscope he could directly observe the conversion; besides, dilatometric determinations furnished a confirmation of these results. For NH_4I no transition could be observed.

2. The question whether ammonium chloride shows allotropy is of importance in connection with JOHNSON's well-known experiment³⁾, according to which dry and somewhat moist ammonium chloride have the same vapour pressure, though in the first case the partial dissociation of the vapour in ammonia and hydrochloric acid does not take place. Prof. ABEGG, in whose laboratory these experiments were carried out, considered this fact as in contradiction with our views on chemical equilibrium phenomena⁴⁾. In the discussion of these experiments I proved before that JOHNSON's experiment leads to the conclusion that the thermodynamic potentials of the solid substance in dry and moist state are different⁵⁾; I did not venture, then, however, to give an explanation of this difference in thermodynamic potential; especially as the occurrence of allotropy for NH_4Cl was not known to me then, and even though NH_4Cl were allotropic, the connection with JOHNSON's experiment would require a separate proof. Besides the possibility did not seem excluded

¹⁾ ZEEMAN and HOOGENBOOM, These Proc. XIV, p. 558 and 786 XV, p. 178.

²⁾ WALLACE l. c.

³⁾ JOHNSON, Zeitschr. f. physik. Chemie 61. 457. (1908)

⁴⁾ ABEGG, Zeitschr. f. physik. Chemie 61. 455 (1908).

⁵⁾ SCHEFFER, Dissertatie Amsterdam 1909. Zeitschr. f. physik. Chem. 72. 451. (1910).

to me that the entropy would undergo a modification through the presence of some water as catalyst¹⁾. Before the publication of my thesis for the doctorate Prof. WEGSCHEIDER led by slightly different considerations, had pointed out that the explanation of JOHNSON'S experiment might among others be found by the assumption of two modifications of the ammonium chloride²⁾. When now WALLACE'S paper came under my notice, and I learned from it that ammonium chloride shows enantiotropy, I have come to the conclusion in connection with the above that I could investigate the possibility of the explanation which Prof. WEGSCHEIDER considered the most probable. First of all I have repeated WALLACE'S experiments for this purpose; it appeared to me already at the first thermal determination that really NH_4Cl is enantiotropic, but that the temperature of transition had to deviate appreciably from the value given by WALLACE. In what follows I will begin with a description of the experiments which I have carried out to define the point of transition of ammonium chloride as accurately as possible.

3. *Thermal determination of the point of transition of ammonium chloride.*

A test tube with ammonium chloride crystals was heated in an oil bath at about 200° , and then placed on cotton wool in a wider tube. Observation of the temperature every half minute showed the temperature to remain constant at about 174° . If I placed a tube at room temperature in the oilbath of 200° , again in an air jacket, then the temperature-time-curve appeared to exhibit a horizontal part about 187° . Repetition of these experiments at lower temperature of the oil bath and with use of a second oil bath for the cooling curves produced but little change in the temporary constancy of the temperature. We must therefore deduce from these observations that ammonium chloride possesses a point of transition between 174° and 187° , which is found too low on cooling and too high on heating, through the conversion of the modifications proceeding too slowly at the point of transition to consume the supplied heat immediately and to supply the removed heat immediately again. The point of transition could not be defined more accurately in consequence of this retardation of the conversion. These experiments, however, lead me to the conclusion that the temperature of 159° , which WALLACE gives for the point of transition, is indeed, considerably too low.

¹⁾ KOHNSTAMM and SCHEFFER, These Proc. XVII p. 789, (1910/11).

²⁾ WEGSCHEIDER, Zeitschr. f. physik. Chemie. 65. 97 (1908).

4. *Vapour pressure measurements.*

It follows from the observations of the vapour pressure of solid ammonium chloride through extrapolation that the detection of the transition temperature through observation of a discontinuity in the vapour pressure line would require an exceedingly accurate pressure measurement; the pressure at 180° only amounts to a few millimeters of mercury.

I have, therefore, tried to find a discontinuity in the three-phase line *SLG* of the system $\text{NH}_4\text{Cl}-\text{H}_2\text{O}$. For if we measure the vapour pressures of the saturate solutions, the transition temperature will remain unchanged, at least if the solid substance does not absorb water in appreciable quantities. The vapour pressure measurements, performed by means of Cailletet tube and air manometer according to the well-known method, yielded no break which could be demonstrated with certainty when the accuracy was about $\frac{1}{20}$ atm. As I however want these vapour pressure measurements for the determinations of § 5, I have inserted some of the found pressures in table 1.

TABLE 1.

Temperature	Pressure (in atmospheres)	Temperature	Pressure (in atmospheres)
160.0	3.25	185.7	5.4
164.9	3.6	189.1	5.8
171.2	4.1	194.5	6.4
176.9	4.6	198.9	6.9
182.5	5.1	199.6	7.0

5. *Determinations of the solubility of ammonium chloride in water at temperatures between 160° and 205°.*

Another method for the determination of the transition point is found in the determination of the discontinuity in the liquid branch of the above mentioned three phase line *SLG* in the system $\text{NH}_4\text{Cl}-\text{H}_2\text{O}$. It is known that the liquid points can only be determined by approximation directly by means of fused tubes. In a liquid point the system can namely exist entirely as liquid phase which is just saturate with solid substance, the pressure being exactly equal to that of the vapour which might coexist with the liquid phase. If we observe in a tube the vanishing point of the crystals, we determine the liquid point of a mixture indicated by the concentration of the liquid at the disappearance of the last crystals; we

must, therefore, then think the vapour as removed. It is clear that the weighed quantities must then be corrected for the quantity of substance which is found in the vapour phase at the vanishing point. For this, volume and pressure of the vapour must be known. In the observation of the vanishing point the position of the meniscus was for this purpose indicated on the tube by means of a writing-diamond. The volume of the vapour, which practically consists of water here, as the vapour pressure of NH_4Cl is negligible at all the observed temperatures, was then measured after the tube had been cut open, with water from a burette. The pressure could be read from table I and then the quantity of water in the vapour could be calculated by the aid of the laws of BOYLE and GAYLUSSAC. On account of the deviation from the gas-laws this calculation is of course not quite accurate, but the correction being small, this method of determination is, after all, accurate enough for this purpose. It is, of course, necessary to take the vapour space as small as possible.

First the tubes were filled with ammonium chloride and weighed; then from a burette, a definite quantity of distilled water was added and brought into the tube through the capillary connecting tube and stem by repeated heating and cooling. The tube (of combustion glass) was then fused to in the lighting gas oxygen flame, and weighed again. The determinations marked by crosses in table 2, were carried out in tubes of from 25 to 30 grams; these were weighed down to half milligrams. In later determinations the weight of the tubes of about 15 grams was determined down to tenths of milligrams. As the weighing of the tubes can easily give rise to errors on account of the large surface, I think that less value is to be attached to the determinations marked with crosses than to the others. In the second and third columns of table 2 the weighed quantity of substance is given; the fourth column gives the observed vanishing points, which were determined in an oilbath, electrically heated by 220 Volts of alternate current, which was regulated by the insertion of incandescent lamps. Uniformity of temperature in the oilbath was ensured by rapid stirring. The fifth column gives the quantities of water in the vapour at the vanishing point calculated according to the above given method; the sixth column contains the corrected quantity of water; the seventh the quantity of grams of NH_4Cl to 100 grams of water in the liquid saturate with gas and solid substance. Finally the eighth column gives the value for $-\log x$, in which x represents the number of molecules of NH_4Cl present in one mol. of the mixture. Hence x is given by:

$$x = \frac{\frac{g}{M_{NH_4Cl}}}{\frac{g}{M_{NH_4Cl}} + \frac{100}{M_{H_2O}}} = \frac{g}{g + 297.0},$$

in which g represents the values of the seventh column.

To set forth the discontinuity in the solubility line under vapour

TABLE 2.

Vanishing points of the solid substance in NH_4Cl-H_2O mixtures
 $M_{NH_4Cl} = 53.50$; $M_{H_2O} = 18.016$.

N ^o	Weight		t	Weight water in vapour	Weight water (corr.)	Grams of NH_4Cl to 100 grams of H_2O (g)	$-\log x$	$10^3 \frac{1}{T}$
	NH_4Cl	H_2O						
1	1942.8	1539.8	162.9	1.0	1538.8	126.2 ⁶	0.5253 ⁴	2.294 ¹
2 ×	1634.0	1271.0	165.65	3.5	1267.5	128.9 ¹	0.5190 ⁶	2.279 ⁷
3	2463.4	1853.7	169.5	0.9	1852.8	132.9 ⁵	0.5097 ³	2.259 ⁹
4	2293.8	1696.0	172.0	1.9	1694.1	135.4 ⁰	0.5042 ⁷	2.247 ²
5	2444.7	1748.0	176.1	1.7	1746.3	139.9 ⁹	0.4943 ⁷	2.226 ⁷
6 ×	1638.0	1163.5	177.2	4.0	1159.5	141.2 ⁷	0.4916 ⁹	2.221 ²
7	2087.1	1464.6	178.55	3.0	1461.6	142.7 ⁹	0.4885 ⁵	2.214 ⁶
8	2189.5	1533.6	178.95	3.1	1530.5	143.0 ⁶	0.4879 ⁹	2.212 ⁶
9 ×	1399.0	961.5	181.05	3.5	958.0	146.0 ³	0.4819 ⁹	2.202 ⁴
10 ×	1424.0	973.0	181.75	4.5	968.5	147.0 ³	0.4800 ⁰	2.199 ⁰
11	2479.5	1695.2	182.2	0.6	1694.6	146.3 ²	0.4814 ²	2.196 ⁸
12 ×	1838.0	1246.0	183.05	3.5	1242.5	147.9 ³	0.4782 ³	2.192 ⁸
13 ×	1917.5	1285.5	184.55	3.5	1282.0	149.5 ⁷	0.4750 ⁵	2.185 ⁵
14 ×	1621.5	1070.0	187.3	4.0	1066.0	152.1 ¹	0.4701 ⁹	2.172 ⁵
15	2309.9	1520.2	187.9	1.2	1519.0	152.0 ⁷	0.4702 ⁷	2.169 ⁷
16 ×	1525.0	998.5	189.1	5.0	993.5	153.5 ⁰	0.4675 ⁸	2.164 ⁰
17	2169.6	1409.5	190.15	2.0	1407.5	154.1 ⁵	0.4663 ⁸	2.159 ¹
18	2336.1	1505.8	191.7	1.7	1504.1	155.3 ¹	0.4642 ⁴	2.151 ⁹
19	2510.4	1592.4	194.7	2.7	1589.7	157.9 ¹	0.4595 ²	2.138 ¹
20	2421.1	1502.2	199.1	2.4	1499.8	161.4 ³	0.4532 ⁹	2.118 ²
21	2556.6	1574.0	200.5	2.1	1571.9	162.6 ⁴	0.4511 ⁹	2.111 ⁹
22	2246.2	1351.5	205.0	4.4	1347.1	166.7 ⁴	0.4442 ³	2.092 ⁰

pressure as clearly as possible I have not considered the solubility as function of the temperature, but led by the theoretical expression for the solubility curve in its simplest shape :

$$\bar{\log} x = \frac{a}{T} + b,$$

I have calculated the values of $\log x$ and $\frac{1}{T}$ (eighth and ninth columns of table 2), and drawn them as ordinate and abscissa in the graphical representation (fig. 1). The temperature range being small here I

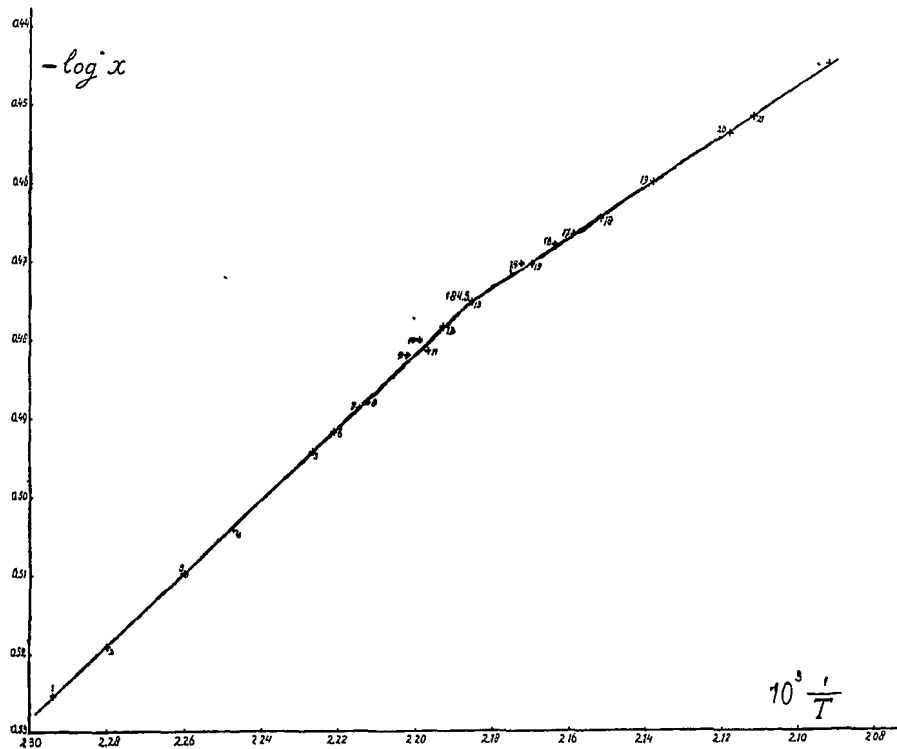


Fig. 1.

expected the above expression to account satisfactorily for the observations; the observations below and those above the transition point will present a straight line in this case. It appears from the graphical representation that really two straight lines can be drawn through the observed points so that the deviations occur irregularly on either side of these lines; at the same time in the tracing of these lines the probably smaller accuracy of the first determinations has been taken into account. I have calculated the values of a and b for both lines from the graphical representation; the equations of the lines drawn are :

$$- \log x = \frac{464.5}{T} - 0.5400 \text{ (below the transition point) and}$$

$$- \log x = \frac{327.8}{T} - 0.2412 \text{ (above the transition point).}$$

To get an idea of the extent of the experimental errors I have compared the values of g calculated according to the above expressions in table 3 with the values of the seventh column of table 2. It will be clear from the last column of table 3 that the agreement

TABLE 3.

No.	t	Number of grams of NH_4Cl to 100 grams of H_2O .		Error
		calculated	found	
1	162.9	126.1 ⁵	126.2 ⁶	+0.1 ¹
2 ×	165.65	128.9 ⁵	128.9 ¹	-0.0 ⁴
3	169.5	132.9 ⁵	132.9 ⁵	0.0
4	172.0	135.6 ¹	135.4 ⁰	-0.2 ¹
5	176.1	140.0 ³	139.9 ⁹	-0.0 ⁴
6 ×	177.2	141.2 ⁴	141.2 ⁷	+0.0 ³
7	178.55	142.7 ³	142.7 ⁹	+0.0 ⁶
8	178.95	143.1 ⁷	143.0 ⁶	-0.1 ¹
9 ×	181.05	145.5 ²	146.0 ³	+0.5 ¹
10 ×	181.75	146.3 ¹	147.0 ³	+0.7 ²
11	182.2	146.8 ²	146.3 ²	-0.5 ⁰
12 ×	183.05	147.7 ⁸	147.9 ³	+0.1 ⁵
13 ×	184.55	149.4 ⁸	149.5 ⁷	+0.0 ⁹
14 ×	187.3	151.7 ²	152.1 ¹	+0.3 ⁹
15	187.9	152.2 ¹	152.0 ⁷	-0.1 ⁴
16 ×	189.1	153.1 ⁹	153.5 ⁰	+0.3 ¹
17	190.15	154.0 ⁶	154.1 ⁵	+0.0 ⁹
18	191.7	155.3 ³	155.3 ¹	-0.0 ²
19	194.7	157.8 ²	157.9 ¹	+0.0 ⁹
20	199.1	161.5 ²	161.4 ³	-0.0 ⁹
21	200.5	162.7 ⁰	162.6 ⁴	-0.0 ⁶
22	205.0	166.5 ⁴	166.7 ⁴	+0.2 ⁰

is satisfactory; the maximum error in the value of g amounts to 5% ; for 14 of the 22 observations the deviation is even smaller than 1% .

When we calculate the point of intersection of the two lines, we find 184.5° for the transition temperature. In my opinion this value can only depart a few tenths of degrees from the real point of transition.

In these experiments the transition point could not directly be determined optically; I have thought only a few times that I could detect a difference in the appearance of the crystals above and below the transition point.

6. *Thermic determination of the transition point of ammonium chloride by means of catalysts.*

After the determination of the transition point from the solubilities in water I have resumed the original thermic determinations, and I have tried to find catalysts which can annul the retardation in the conversion at the point of transition. For this purpose I have looked for substances which are liquid at the transition point, and of which it could be expected that they react only little, if at all, to ammonium chloride. The number of available substances is not large; glycerine is very suitable for this purpose. A quantity of ammonium chloride was uniformly moistened in a mortar with a few drops of glycerine, and conveyed to a test tube. By placing this in an oilbath above the point of transition and then in a bath

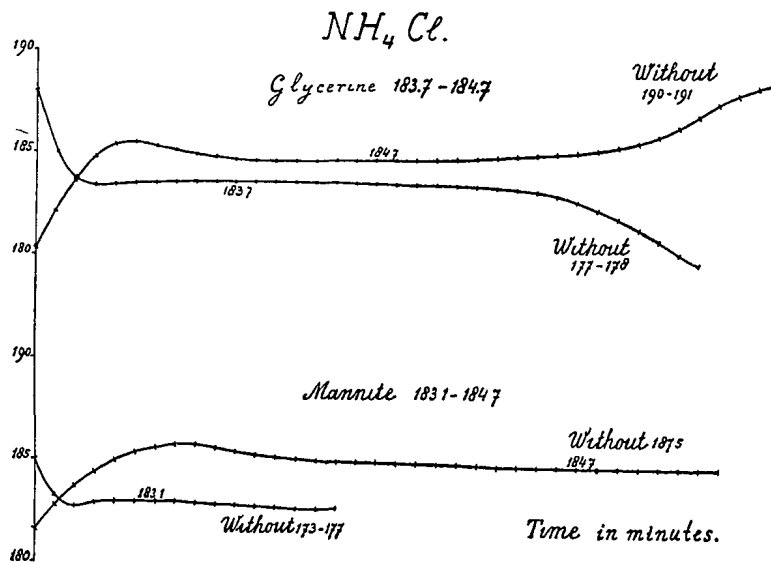


Fig. 2.

below this point I have determined a series of heating and cooling curves, the best examples of which are represented in the graphical representation (fig. 2). Descending we found $183^{\circ}.7$, rising $184^{\circ}.7$. At the same time it will appear from the graphical representation that the curves exhibit resp. a minimum and a maximum, which points to this that the conversion at first proceeds only slowly, but soon becomes constant so that the supplied resp. discharged heat and the thermal effect of the conversion compensate each other.

A second couple of curves, for which mannite acts as catalyst, presents only little more diverging values. Also the results of a few more substances used are reported in table 4.

TABLE 4.

Catalyst	Descending (max.)	Rising (min).
Glycerine	183.7	184.7
Mannite	183.1	184.7
Resorcin	183.3	185.4
Paraffin	179.9	185.75
Diphenylamine	179.95	186.3

It is clear that the catalysts counteract the retardation in the conversion of the solid substance in a more or less degree, and that this is particularly the case for glycerine and mannite, where the limits for the point of transition from 13° (see § 3) to 1° , resp. $1^{\circ}.6$ have contracted. Moreover it appears that the retardation in the conversion without catalysts is much smaller in case of heating than in case of cooling. If, however, we imagine that also when catalysts are used this difference in retardation continues relatively to exist, then the point of transition would be calculated at 184.5° in the experiment with glycerine, at 184.4° in that with mannite, in perfect harmony with the experiments of § 5.

7. Accordingly the experiments of § 5 and 6 yield the result that the point of transition of ammonium chloride has been fixed at 184.5° with a possible error of a few tenths of a degree. The value given by WALLACE (see § 1) is therefore more than 25° too low.

8. *Demonstration of the allotropy of ammonium chloride.* The transition from the β - into the α -form cannot be demonstrated by crystallisation of an aqueous solution under atmospheric pressure,

as the transition point lies too far above the boiling point, so that the β -crystals cannot be obtained metastable from these solutions either. I have, therefore, tried to make the transition suitable for demonstration by crystallisation from another solvent. The experiments of § 6 led me to surmise that glycerine would be suitable for this. If on an object glass we evaporise a solution saturated at the ordinary temperature to initial crystallisation, and if then we place the object glass under the microscope, we can clearly observe the cubi deposited in the heat. After some time a transformation then takes place, which propagates through the solid mass, and at the same time we see crystal skeletons of the known shape appear from the cubi. I have been able to demonstrate this transition by means of microscopic projection at the latest Physical and Medical Congress. The demonstration is still easier to carry out with ammonium bromide, as the point of transition lies at still lower temperature here, which I shall show in a following paper. The phenomena are entirely the same for ammonium chloride and bromide.

9. *Allotropy or isomery.* The phenomena which are explained by the assumption of more kinds of molecules, are expressed by a great number of names in the literature. Among these phenomena the occurrence of a substance in several solid phases will also often, if not always, have to be reckoned. In organic chemistry we have, namely, many examples of substances which can occur in two or more solid states, to which different molecular structure is assigned (tautomery, desmotropy). In § 1 I discussed an indication for the occurrence of two kinds of molecules also for ammonium chloride.

A rational collective name for the occurrence of more than one kind of molecules and more than one solid phase has however not yet been adopted, and yet this seems very desirable. The advantage lies in this that general thermodynamical relations (for homogeneous and heterogeneous equilibria) hold for both phenomena, which equations are therefore independent of the more subtle differences in structure of the molecules. Thermodynamically desmotropy, tautomery, isomery, metamery, allelotropy, pseudomery etc. etc. are namely perfectly equivalent, at least for so far as they refer resp. to homogeneous or heterogeneous states. If we consider which of the available denominations is suitable as a collective name, only allotropy and isomery present themselves for consideration in my opinion. The word isomery, however, is pretty generally current for the occurrence of molecules of equal molecular weight, which differ only in way of binding. There is no objection in my opinion to the use of allotropy as a

collective name. This word is generally only used when elements occur in more than one solid state; that this word should also be used for compounds is only an advantage, for there is no reason whatever to assume an essential difference for the phenomenon for elements and compounds. Besides we find allotropy used already several times for compounds; moreover we find it already applied to non-solid states; thus oxygen is often called allotropic, when the occurrence of oxygen as ozone and ordinary oxygen is referred to.

Why then should not we generally indicate the occurrence of different kinds of molecules by allotropy? In this sense it was already used by Prof. SMITS in his theoretical considerations. Rationally the occurrence of two or more solid states is then to be called *phase-allotropy*, the occurrence of more kinds of molecules *molecular-allotropy*. Phase allotropy will then in virtue of the above often, if not always, find its ground in molecular allotropy¹).

Nothing is known of structure and size of the molecules in solid state for ammonium chloride. In connection with the above this sufficiently justifies the choice of the title of this paper in my opinion.

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the University of Amsterdam.*

Physics. — “*Isothermals of di-atomic substances and their binary mixtures. XVII. Preliminary measurements concerning the isothermal of hydrogen at 20° C. from 60 to 90 atmospheres*”.
By H. KAMERLINGH ONNES, C. DORSMAN and G. HOLST. (Comm. 146a from the Physical Laboratory at Leiden).

(Communicated in the meeting of June 26, 1915)

1. *Introduction.* For a long time it has been the intention to extend the determination of isothermals of gases at low temperatures to pressures beyond the limit of 60 atmospheres, which had been fixed in the first stage of the Leiden investigations. In Communication 106 (April 1908) mention was made of a first step taken towards the realisation of that project.

On the basis of the data concerning the tensile strength of glass, published on that occasion, (about) fifteen manometer-tubes had been constructed, by which the divided open manometer (Comm. 44) could be extended in such a manner, that the entire height of mercury would correspond to a pressure of 120 atmospheres. These

¹) SMITS Zeitschr. f. physik. Chemie. 89 257 (1915).