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LXI. *Saturation of Salt-Solutions.* By W. W. J. NICOL, M.A., B.Sc., F.R.S.E., &c., Lecturer on Chemistry, Mason College, Birmingham*.

ACCORDING to the theory of solution brought forward in my paper on the Nature of Solution†, saturation of a solution of a salt results when the sum of the attractions of the salt-molecules present in the solution for any individual salt-molecule is equal to the sum of the attractions of the water-molecules for that particular salt-molecule—the attraction of the water-molecules for one another being disregarded, as a probably constant quantity. At that time I endeavoured to prove that the attraction of the dissimilar molecules of water and salt is one cause of the contraction attending the solution of a salt, while the attraction of the similar molecules of the salt has an opposite effect, and tends to produce an increase in the volume.

I wished at the time of publication of the above to show a connexion between the molecular volume of a salt in the solid state and its solubility. That such a connexion does exist, my early experiments soon convinced me. But as yet I am in a position only to indicate the nature of this relation; sufficient evidence is still wanting to give my conclusions a quantitative value.

The results‡ obtained by comparisons of the molecular volumes of dilute solutions of various salts, show that in such solutions the intermolecular spaces are practically coextensive whatever may be the salt, while this is clearly not the case in the solid state, except with isotomous salts. In solution the molecules of salt are so far apart that they are out of the sphere of one another's attraction; in the solid state, on the other hand, they are packed more or less closely together, according to the temperature § of crystallization and the attraction they have for one another. If, now, the above theory of saturation be the correct one, it is evident that, since loose packing of the molecules—that is, large molecular volume in the solid state—is due to weak attraction between the molecules of the salt, such a salt should be more easily dissolved than one which differs from it only in the attraction between its molecules being so great as to cause a smaller molecular volume. I hope to be able to show that this is the case.

As already shown by Gerlach and others, the rate of increase

* Communicated by the Author.

† Phil. Mag. 1883, xv. p. 91.

‡ Phil. Mag. 1883, xv. p. 121, and *Ber. d. deut. chem. Ges.*

§ Phil. Mag. Feb. 1883, p. 94.

of the specific gravity of a salt-solution is less than the rate at which it increases in concentration; consequently the molecular volume of each successive molecule of a salt added to a solution is a constantly increasing quantity. Tables I. and II. contain the results of experiments with NaCl.

Table I. gives the density (δ) and the molecular volume (M. V.) of solutions containing n molecules of NaCl in 100 molecules of water, at $t^\circ = 20^\circ$. The column headed Δ gives the difference in molecular volume produced by each successive molecule of salt added.

TABLE I.

$n \text{ NaCl} + 100 \text{ H}_2\text{O}.$				
$t^\circ.$	$n.$	$\delta.$	M. V.	$\Delta.$
20°	·5	1·01145	1808·54	17·08
„	1·0	1·02255	1817·52	17·96
„	2·0	1·04393	1836·29	18·77
„	3·0	1·06437	1856·03	19·74
„	4·0	1·08408	1876·23	20·20
„	5·0	1·10276	1897·42	21·19
„	6·0	1·12099	1918·84	21·42
„	7·0	1·13838	1940·92	22·08
„	8·0	1·15503	1963·59	22·67?
„	9·0	1·17140	1986·09	22·50
„	10·0	1·18707	2009·15	23·06
„	10·99	1·20191	2032·76	23·61

The molecular volume therefore increases from 17·08 up to 23·61 for the last ·99 molecule added. In Table II. the data are treated differently. The molecular volume of the water is assumed constant = 1800, and is subtracted from the molecular volume of the solution; the remainder (M. V. - 1800) = r is what Thomsen has called the "*Rest*"—it is the volume of the salt in the solution; and $\frac{r}{n}$ is the mean molecular volume of a molecule of the salt in a solution of strength n : this in the case of NaCl increases from 17·08 to 21·16 in the saturated solution. The molecular volume of the salt in the solid state $\frac{\text{Mol. wt}}{\delta}$ is given by Schröder = 27·1.

TABLE II.

$n \text{ NaCl} + 100 \text{ H}_2\text{O}.$			
$t^\circ.$	$n.$	$r.$	$\frac{r}{n}.$
20	.5	8.54	17.08
"	1.0	17.54	17.54
"	2.0	36.29	18.14
"	3.0	56.03	18.68
"	4.0	76.23	19.06
"	5.0	97.42	19.48
"	6.0	118.84	19.81
"	7.0	140.92	20.13
"	8.0	163.59	20.45
"	9.0	186.08	20.68
"	10.0	209.15	20.92
"	10.9	232.76	21.16

We have therefore:—

- (1) M. V., NaCl solid = 27.1.
 (2) Mean M. V., NaCl saturated solution = 21.2.
 (3) M. V., NaCl .5 molecule solution = 17.1.

Now, $(1-3)=10.0$, and $(1-2)=5.9$; and

$$\frac{(1-2)}{(1-3)} = \frac{5.9}{10.0} = .59.$$

But (2) is the mean volume of each molecule in a saturated solution, when the attraction of similar molecules is equal to that of dissimilar molecules; (3), on the other hand, is when only dissimilar molecules act, and (1) only similar ones. Saturation has taken place therefore when the difference between the volume of a molecule of NaCl in the dissolved state and the volume in the solid state has reached .59 of that between the volume in the solid state and that when the molecules are entirely free from one another's attraction.

Again, in the case of potassium chloride:—

- (1) M. V., KCl solid = 37.4.
 (2) M. V., KCl in saturated solution = 30.9.
 (3) M. V., KCl in .5 molecule solution = 27.1.

Here $\frac{(1-2)}{(1-3)} = \frac{6.5}{10.3} = .631.$

Sodium Nitrate.

- (1) M. V., NaNO_3 solid = 37.6.
 (2) M. V., NaNO_3 in saturated solution = 34.2.
 (3) M. V., NaNO_3 in 1 molecule solution = 28.2.

$$\text{Here } \frac{(1-2)}{(1-3)} = \frac{3.4}{9.4} = .361.$$

Potassium Nitrate.

- (1) M. V., KNO_3 solid = 48.5.
 (2) M. V., KNO_3 in saturated solution = 41.4.
 (3) M. V., KNO_3 in .5 molecule solution = 38.1.

$$\text{Here } \frac{(1-2)}{(1-3)} = \frac{7.1}{10.4} = .682.$$

Now, to compare these results with the solubility, it must be kept in mind that the more nearly the fraction $\frac{(1-2)}{(1-3)}$ approaches to a whole number the greater the attraction of the salt-molecules for one another, and conversely.

TABLE III.

Salt.	$\frac{(1-2)}{(1-3)}$	Solubility.	$\frac{(1-2)}{(1-3)} \times \text{sol.} \times \text{Mol. wt.}$
KNO_3	.682	5.63	38.7
KCl	.631	8.38	39.4
NaCl	.590	10.99	38.0
NaNO_3 ...	.361	18.45	66.6

We find that the less the solubility the larger the fraction, holds good in all four cases; and I have added to the table, without intending to lay much stress on the result, the product of the fraction by the solubility by the molecular weight. In the three first cases the result is nearly a constant number; the mean difference is 2 per cent. only, which is little when the number of determinations involved is considered; but NaNO_3 is entirely exceptional. I have failed to find any error anywhere, and must leave it at present unexplained. It will be found that this is not the only instance in which NaNO_3 behaves differently from the majority of salts. My reason for introducing the molecular weight as a factor in the above calculation is that, other things being equal, the cohesion of the salt is evidently a function of its molecular weight.

I believe that further investigation will show the general truth of the following conclusions:—

That the more soluble a salt is in any liquid, the more nearly will its mean molecular volume in the saturated solution approach that in the solid state, and that in most cases the product of F by the solubility by the molecular weight will be found a constant, subject, however, to variations, due most likely to the influence of the at present unknown factor attraction of salt for water.

That the solubility of a salt is intimately connected with its molecular volume is also shown by the following:—

(1) Diminished molecular volume without change of composition is attended by diminished solubility: thus, in the case of sodium sulphate, the salt crystallized at different temperatures has a different molecular volume *.

t°	= 40°	110°	Melted.
M. V.	= 53.35	53.31	53.96
Solubility†	= 48.8	42.5	{ 230° 46.4

The solubility here is parts per 100 of water.

Under this head also come the instances given by me (*loc. cit.*), and also the determinations of the rate at which CaCO_3 dissolves in dilute acids in the different forms of calcspar and arragonite, where the former, with a lower specific gravity (*i. e.* larger molecular volume), was found to dissolve fastest.

(2) Diminished molecular volume with change of composition is attended by diminished solubility.

Sodium sulphate has its maximum of solubility at 32°·8, the temperature at which the decahydrated molecule is broken up. So with sodium carbonate at 32°·5 (Mulder).

Manganese sulphate has a maximum of solubility at 54° C., and the solid salt decomposes into a lower hydrate at 54° (Tilden).

Ferrous sulphate has its maximum at 63°·5, temperature of decomposition (Tilden). Other cases are given by Mulder‡. But enough has been said to show that here the solubility is connected with the hydration of the salt; but as increased or diminished hydration means increased or diminished molecular volume, the molecular volume is connected with the solubility. I do not intend by the above to imply that in solution the salt is combined with the water of crystallization. I formerly held this, the general view; but experiments, nearly completed,

* Phil. Mag. Feb. 1883, *loc. cit.*

† Tilden and Shenstone, Proc. Roy. Soc. xxxv. p. 345.

‡ Mulder, *Bijdragen tot de Geschiedenis van het scheikundig gebonden Water* (Rotterdam, 1864).

have raised grave doubts, and incline me to the opinion that water of crystallization is indistinguishable, when the salt is dissolved, from water of solution. This, however, does not affect the above: it is immaterial for the above argument whether the hydrate is ready formed in the solution, or the salt is forced by conditions of temperature &c. to carry with it that number of water-molecules—the effect on the molecular volume would be the same*.

I come now to the second part of the subject.

Saturation in Solutions of two Salts.

Hitherto we have considered saturation in the solution of a single salt. What laws govern the saturation of a solution with two or more salts? I shall confine my remarks for the present to solutions of only two salts; and this implies that they are salts containing the same metal or the same salt radical.

This is a subject which presents considerable experimental difficulties, and it has been attacked by but a few experimenters, the chief of whom are :—

KOPP (1840), Liebig's *Annalen*, xxxiv. pp. 260-271.

KARSTEN (1841), Liebig's *Annalen*, xl. pp. 197-206.

MULDER (1864), *loc. cit.* pp. 145-230.

RÜDORFF (1873), Poggen. *Annalen*, cxlviii. pp. 456 and 555.

Others who have touched upon it are :—

REGNAULT, *Journ. de Pharm. et de Chimie*, xliii. p. 187, xliv. p. 187.

PFAFF, *Ann. der Ch. u. Pharm.* xcix. p. 224.

LONGCHAMP, Otto-Graham, ii. 2, p. 188.

SCHAUFFELE, *Journ. de Pharm.* [3] xvii. p. 268.

TOBLER (double sulphates), *Ann. Ch. u. Pharm.* xcv. p. 198.

Before considering the results obtained by former observers, I shall describe my own experiments and state their results.

Four salts were taken for examination—the chlorides of sodium and potassium, and the corresponding nitrates; and their solubility and density at 20° C. were carefully determined in the following way. A large bath, fitted up as

* It is curious that the temperatures 32°-33° and 64°-66° should be marked out so definitely as those at which decomposition of hydrated salts takes place. Thus, 32°-33°, as above, is the t° at which sodium carbonate and sulphate decompose; $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ melts at 33°. The solubility of $\text{Sr}(\text{NO}_3)_2$ increases much less rapidly after 32° is reached, while the same is the case at 66° with SrCl_2 . The solubility of MnSO_4 , which drops suddenly at 54°, remains constant from 64° for more than 20°; FeSO_4 , maximum at 63°·5. The melting-point determinations of Wiedemann give critical points at 32°, at 63°, and 92° (*Wied. Annal.* xvii. p. 561).

described in a previous paper*, was provided with a cover pierced with holes to hold test-tubes 180 millim. by 30 millim. Round the top of the bath ran a tube with stopcocks at intervals, corresponding to the holes in the cover; this tube was connected with the air-blower. The course of experiment was as follows :—Two test-tubes with 50 cubic centim. of water in each were taken, and an excess of the same salt placed in each. The contents of one of the tubes were heated till solution was complete, and after partial cooling both tubes were placed in the bath at, say, 12 noon. By means of wide tubes attached to the stopcocks at the side of the bath, a slow stream of air saturated with water vapour was allowed to bubble up through the solutions in the test-tubes, which were loosely covered. The whole was left till 10 A.M. the next day, when the air-current was turned off, and the solutions were left at rest till 12 o'clock. In this way saturation had gone on in one of the tubes, and crystallization in the other for 24 hours. By means of a cork fitted with two tubes, one wide and sufficiently long to reach nearly to the bottom of the test-tube, and covered at the lower end with two-ply of cambric, a portion of the liquid was forced by air-pressure into a Sprengel tube placed in the bath, and another portion collected in a weighed dish. In this way the specific gravity and percentage composition of the solution saturated at 20° C. were found.

The results were as follows :—

TABLE IV.

t° .	Salt.	δ .	M. V.	n .	$\frac{r}{n}$.
20	NaCl	1.20191	2032.76	10.99	21.2
"	KCl	1.17777	2058.79	8.377	30.9
"	NaNO ₃	1.38608	2430.15	18.45	34.2
"	KNO ₃	1.16500	2032.96	5.63	41.4

The last column $\frac{r}{n}$ is the mean molecular volume of each molecule of the salt in a saturated solution.

Similar experiments were made with the following pairs of salts :—

(1) NaCl + KCl ;	(2) NaNO ₃ + NaCl ;
(3) KCl + KNO ₃ ;	(4) KNO ₃ + NaNO ₃ .

The results are given in full to show the amount of accuracy attained.

* Phil. Mag. 1883, p. 389.

$$\begin{array}{l} (1) \ 31.39 \text{ per cent.} \\ (2) \ 31.39 \text{ ,,} \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} 45.6/100^*. \text{ Mol. wt.} = 2623.3.$$

$$\begin{array}{l} (1) \ \delta = 1.23689 \\ (2) \ \delta = 1.23697 \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} \text{ Mol. vol.} = 2120.8.$$

The potassium and sodium estimated as sulphates gave :—

$$\text{Ratio } KCl : NaCl \left\{ \begin{array}{l} (1) \ R = 1 : 1.706, \\ (2) \ R = 1 : 1.613. \end{array} \right.$$

$$\text{Mean ratio} = 1 : 1.66.$$

And a number of compound molecules ($KCl \ 1.66 \ NaCl$) = 4.795.

$$\begin{array}{l} (1) \ 43.67 \text{ per cent.} \\ (2) \ 43.28 \text{ ,,} \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} 76.93/100. \text{ Mol. wt.} = 3184.7.$$

$$\begin{array}{l} (1) \ \delta = 1.36133 \\ (2) \ \delta = 1.36172 \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} \text{ Mol. vol.} = 2339.1.$$

Chlorine determined as $AgCl$:—

$$NaCl : NaNO_3. \text{ Ratio} = \left\{ \begin{array}{l} (1) \ 1 : 1.465, \\ (2) \ 1 : 1.422. \end{array} \right.$$

$$\text{Mean ratio} = 1 : 1.444.$$

Number of compound molecules = 7.64.

$$\begin{array}{l} (1) \ 34.45 \text{ per cent.} \\ (2) \ 34.55 \text{ ,,} \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} 52.67/100. \text{ Mol. wt.} = 2748.1.$$

$$\begin{array}{l} (1) \ \delta = 1.2484 \\ (2) \ \delta = 1.24878 \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} \text{ Mol. vol.} = 2200.9.$$

Chlorine as $AgCl$:—

$$KNO_3 : KCl. \text{ Ratio} = 1 : 2.36.$$

Number of compound molecules = 3.42.

$$\begin{array}{l} (1) \ 57.49 \\ (2) \ 57.52 \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} 135.29. \text{ Mol. wt.} = 4235.2.$$

$$\begin{array}{l} (1) \ \delta = 1.49608 \\ (2) \ \delta = 1.49624 \end{array} \left. \vphantom{\begin{array}{l} (1) \\ (2) \end{array}} \right\} \text{ Mol. vol.} = 2830.6.$$

Sodium and potassium as sulphates :—

$$KNO_3 : NaNO_3. \text{ Ratio} = \left\{ \begin{array}{l} (1) \ 1 : 2.46, \\ (2) \ 1 : 2.44. \end{array} \right.$$

$$\text{Mean ratio} = 1 : 2.45.$$

Number of compound molecules = 7.87.

In Table V. the leading results of the above experiments are given with those of calculations based on them. In column B are given the number of salt-molecules of each salt

* $x/100$ = parts of salt per 100 of water.

TABLE V.

Salts.	R.	Compound molecules.	A.	B.	A × B.	(A × B) + 1800.	Mol. vol.	Diff.
KCl	1	4.795	30.9	4.795	148.2	2117.0	2120.8	+3.8
NaCl	1.66		21.2	7.96	168.8			
NaCl	1	7.64	21.2	7.64	161.2	2338.5	2339.1	+.6
NaNO ₃ ...	1.444		34.2	11.03	377.2			
KNO ₃ ...	1	3.42	41.4	3.42	141.6	2191.0	2200.9	+9.9
KCl	2.36		30.9	8.07	249.4			
KNO ₃ ...	1	7.87	41.4	7.87	325.8	2785.5	2830.6	+45.1
NaNO ₃ ...	2.45		34.2	19.29	659.7			

A = mean mol. vol. in saturated solution of the salt alone.

B = number of salt-molecules present in the saturated solution of both salts.

present in a saturated solution per 100 H₂O. Comparing these numbers with those in Table IV., we find that in Case (1) the solubility has increased for :—

NaCl from 10.99 to 15.92
KCl „ 8.38 „ 9.59

Case (2),

NaCl „ 10.99 „ 15.28
NaNO₃ „ 18.45 „ 22.06

Case (3),

KNO₃ „ 5.68 „ 6.84
KCl „ 8.38 „ 16.14

Case (4),

KNO₃ „ 5.68 „ 15.74
NaNO₃ „ 18.45 „ 38.58

This is on the assumption that each salt takes one half of the water present in the solution. The solubility has therefore increased in every case.

Again the ratio together and separate is :—

KCl	together	$\frac{1}{1.66}$	separate	$\frac{1}{1.31}$
NaCl				
NaNO ₃	„	$\frac{1}{1.444}$	„	$\frac{1}{1.679}$
KNO ₃				
KCl	„	$\frac{1}{2.36}$	„	$\frac{1}{1.488}$
KNO ₃				
NaNO ₃	„	$\frac{1}{2.45}$	„	$\frac{1}{3.277}$

Here the more soluble salt has its solubility increased more than that of the less soluble, with the exception of NaNO_3 , since R together < R separate.

The more important part of Table V. is in the last four columns, where I have compared the actual molecular volume of the salt-solution with the volume calculated on the supposition that each salt-molecule is present in the solution with the volume it possesses in its own saturated solution. In the three first cases the agreement is satisfactory; but $\text{KNO}_3 + \text{NaNO}_3$ is exceptional, the actual volume of the salts being about 10 per cent. higher than the calculated. I may venture to suggest that a possible explanation of this is to be found in the fact that KNO_3 is dimorphous, and in one of its forms (that of rhombohedra) is isomorphous with NaNO_3 . It may be that the presence of this last salt may influence the form in which the KNO_3 would crystallize out; and inasmuch as the isomorphous form is the unstable one under usual conditions, it is probable that its molecular volume in the solid state would be greater, and hence its solubility and molecular volume in a saturated solution would also be greater than that of the usual form.

I have examined this point in another way: by preparing a solution of one of the above salts, and then adding to it, after determination of the molecular volume, a number of molecules of another salt: for example, a 7 NaCl 100 H_2O solution had 2 KCl, 3 KCl, and 4 KCl added.

The results are given in Table VI., and compared with the molecular volume calculated on the supposition that the more

TABLE VI.

	M'. V'.	n.	M. V.	M'. V'. $\times n$ + 1800.	Diff.
NaCl ...		7	1941.5	2006.7	+ .8
NaCl ...	20.7	7	2007.5		
KCl ...	30.9	2			
NaCl ...	20.9	7	2040.5	2039.0	+1.5
KCl ...	30.9	3			
NaCl ...	21.2	7	2074.1	2072.0	+2.1
KCl ...	30.9	4			
KCl ...		7	2010.9	2099.1	- .5
KCl ...	30.9	7	2098.6		
KNO ₃ ...	41.4	2			
M'. V'. = mean molecular volume of the salt in a solution as described above.					

soluble salt possesses a molecular volume the same as it would if all the salt-molecules present were the same, and that the less soluble salt possesses the molecular volume it has in a saturated solution. There is here very complete agreement between the two sets of figures.

Enough has been said to show that in the majority of the cases examined the molecular volume of the saturated solution is equal to the sum of the molecular volumes of the salts present, calculated on the hypothesis that each salt has the volume it would possess in its own saturated solution.

The results of previous experimenters on this subject are given in Table VII. I shall at present content myself with pointing out the general conclusions to be derived from it, reserving for future discussion the special points of difficulty. I do so with the less hesitation, since the data here given are liable to the same charges of inaccuracy that are made with so much truth against ordinary solubility determinations.

Out of forty-two determinations (including duplicates) there are thirty instances in which the more soluble salt has its solubility increased by the presence of another salt to a greater extent than that of the less soluble one.

In no instance is the solubility of the more soluble salt less than if it were alone in the solution, while in several instances it is doubled. In twelve cases the less soluble salt suffers a diminution of solubility; in all the others the reverse is the case.

The general rule appears to be that the solubility of two salts together is greater than that when separate. The probable explanation of this appears to me to be as follows:—

Each salt dissolves independently of the other. This is shown by the molecular volume of the solution. Each salt, however, increases in most cases the solubility of the other by what may be called mechanical means: thus, molecules of different salts do not, as a rule, attract one another; there is therefore no tendency to form a system containing two salts. At the same time, however, the formation of groups of similar salt-molecules is prevented to a certain extent by the interposition or collision with a molecule of the other salt: thus the number of similar salt-molecules must be increased before, in unit time, the number of encounters of similar molecules becomes as great as in a saturated solution of that salt alone.

The increased solubility of the more soluble salt at the expense, so to speak, of the less soluble salt is in all probability due to the greater attraction for water possessed by that particular salt. This is specially noticeable in the case of CaCl_2 .

In conclusion, I am fully aware that it is only by numerous and careful experiments that it is possible to decide whether the above results are merely fortuitous, or are part of a wider generalization; and I hope, at no distant date, to be able to bring forward further evidence in this direction.

TABLE VII.

Same Metal.

Salts.	t° .	Solubility separ.	Solubility together.	Mol. separ.	Mol. tog.	R. separ.	R. tog.	Authority.
KCl	12.9	32.8	28.5	4.4	3.82	1.86	2.06	} Kopp.
KNO ₃	"	23.9	18.8	2.36	1.86			
KCl	15	33.5	28.8	4.49	3.86	1.73	2.07	} Kopp.
KNO ₃	"	26.3	18.9	2.6	18.7			
KCl	20	34.7	35.2	4.65	4.72	1.51	2.5	} Rüdorff.
KNO ₃	"	31.2	19.1	3.09	1.89			
KI	14.5	139.8	137.6	8.42	8.28	7.19	72.0	} Mulder.
$\frac{K_2SO_4}{2}$	"	10.2	1.0	1.17	.12			
KI	21.5	146.2	133.2	8.8	8.02	1.87	5.74	} R.
KCl	"	35.2	10.4	4.7	1.39			
KNO ₃	18.7	29.9	29.42	2.96	2.91	2.38	6.33	} Karsten.
$\frac{K_2SO_4}{2}$	"	10.8	4.00	1.24	.46			
KNO ₃	20	31.2	26.9	3.08	2.66	2.47	3.51	} Kopp.
$\frac{K_2SO_4}{2}$	"	10.9	6.6	1.25	.76			
KNO ₃	40	64.0	59.3	6.33	5.87	3.94	8.81	} Kopp.
$\frac{K_2SO_4}{2}$	"	14.0	5.8	1.6	.67			
NaNO ₃	18.7	86.6	52.85	10.19	6.22	1.66	1.45	
NaCl	"	36.0	25.04	6.15	4.28			
NaNO ₃	20	87.5	56.8	10.3	6.68	1.67	1.48	} R.
NaCl	"	36.0	24.6	6.15	4.51			
NH ₄ NO ₃ ...	19.5	183.0	173.8	22.9	21.7	3.31	3.99	} R.
NH ₄ Cl	"	37.0	29.1	6.9	5.44			
$\frac{(NH_4)_2SO_4}{2}$...	21.5	75.6	46.5	11.5	7.05	1.62	1.4	} R.
NH ₄ Cl	"	37.8	26.8	7.07	5.01			

Same Salt-Radical.

Salts.	t°.	Solu- bility separ.	Solu- bility together.	Mol. separ.	Mol. tog.	R. separ.	R. tog.	Authority.
KCl.....	16.6	33.8	27.2	4.53	7.3			} Kopp.
$\frac{\text{BaCl}_2}{2}$	"	34.9	18.2	3.36	3.5	1.35	2.1	
NaCl.....	10	35.8	30.0	6.12	5.13	.983	1.4	} M.
NH_4Cl	"	33.3	19.5	6.22	3.64			
NaCl.....	18.7	36.0	26.38	6.15	4.51	.897	1.09	
NH_4Cl	"	36.7	22.06	6.86	4.12			
NaCl.....	boiling	40.4	22.3	6.91	3.81	2.36	3.85	} M.
NH_4Cl	"	87.3	78.5	16.32	14.57			
NaCl.....	17	35.9	4.1	6.14	.7	?	?	} Kopp.
$\frac{\text{BaCl}_2}{2}$	"	35.0	34.5	3.37	3.32			
NaCl.....	boiling	40.4	35.3	6.91	6.03	1.19	3.24	} M.
$\frac{\text{BaCl}_2}{2}$	"	60.3	19.4	5.8	1.87			
NaCl.....	18.8	36.0	29.9	6.15	5.11	1.34	2.43	} R.
KCl.....	"	34.3	15.7	4.6	2.11			
NH_4Cl	20.5	37.4	22.9	6.99	4.28	1.13	1.05	} R.
NaCl.....	"	36.0	23.9	5.15	4.09			
NH_4Cl	15	35.2	28.9	6.58	5.4	1.47	2.36	} R.
KCl.....	"	33.4	17.1	4.48	2.29			
NH_4Cl	18.7	36.7	29.83	6.86	5.57	1.49	2.55	} Kopp.
KCl.....	"	34.4	16.27	4.61	2.19			
NH_4Cl	22	38.0	30.4	7.1	5.68	1.5	2.22	} R.
KCl.....	"	35.3	19.1	4.73	2.56			
NH_4Cl	boiling	87.3	67.7	16.32	12.65	2.08	4.31	} M.
KCl.....	"	58.5	21.9	7.84	2.94			
NH_4Cl	20	37.2	33.8	6.95	6.32	2.02	5.66	} M.
$\frac{\text{BaCl}_2}{2}$	"	35.7	11.6	3.43	1.11			
$\frac{\text{CaCl}_2}{2}$	7	56.0	63.5	10.09	11.44	2.43	17.4	} M.
KCl.....	"	31.0	4.9	4.16	.66			
$\frac{\text{CaCl}_2}{2}$	7	56.0	39.5	10.09	7.12	1.65	9.05	} M.
NaCl.....	"	35.7	4.6	6.1	.79			
$\frac{\text{CaCl}_2}{2}$	4	53.0	57.6	9.55	10.38	1.56	25.3	} ? M.
NaCl.....	"	35.7	2.4	6.1	.41			

Salts.	t°.	Solu- bility separ.	Solu- bility together.	Mol. separ.	Mol. tog.	R. separ.	R. tog.	Authority.
$\frac{\text{SrCl}_2}{2}$	14.5	50.7	48.6	6.39	6.13	1.44	4.08	} M.
KCl	"	33.2	11.2	4.45	1.5			
KNO_3	18.5	29.7	28.8	2.94	2.85			} M.
$\frac{\text{Ba}(\text{NO}_3)_2}{2}$...	"	8.9	5.4	.68	.41	4.3	6.88	
NaNO_3	18.7	86.6	88.14	10.19	10.27			} Karsten.
$\frac{\text{Ba}(\text{NO}_3)_2}{2}$...	"	8.9	3.77	.68	.29	15.3	35.9	
NaNO_3	15.6	84.4	84.3	9.93	9.92			} Kopp.
$\frac{\text{Pb}(\text{NO}_3)_2}{2}$...	"	48.7	33.6	2.94	2.03	3.37	4.88	
NaNO_3	18.7	86.6	87.75	10.19	10.33			} Karsten.
$\frac{\text{Pb}(\text{NO}_3)_2}{2}$...	"	51.3	34.26	3.1	2.07	3.29	4.98	
NaNO_3	20	87.5	84.6	10.3	9.96			} Kopp.
$\frac{\text{Pb}(\text{NO}_3)_2}{2}$...	"	52.3	38.4	3.16	2.32	3.26	4.29	
NaNO_3	14.5	83.7	66.4	9.85	7.81			} M.
$\frac{\text{Sr}(\text{NO}_3)_2}{2}$	"	62.0	51.0	5.86	4.82	1.68	1.62	
NH_4NO_3 ...	11	143.0	88.8	17.9	11.1			} M.
KNO_3	"	20.2	40.6	2.0	4.0	8.95	3.75	
NH_4NO_3 ...	15	161.0	130.4	20.13	16.3			} M.
KNO_3	"	26.0	46.2	2.57	4.57	7.82	3.57	
NH_4NO_3 ...	16	166.0	162.9	20.75	20.36			} R.
NaNO_3	"	84.7	77.1	9.96	9.07	2.08	2.24	
NH_4NO_3 ...	10	143.0	119.9	17.9	13.95			} M.
$\frac{\text{Pb}(\text{NO}_3)_2}{2}$...	"	43.6	67.5	2.63	4.08	6.79	3.43	
NH_4NO_3	10	143.0	101.3	17.9	12.67			} M.
$\frac{\text{Ba}(\text{NO}_3)_2}{2}$...	"	6.8	6.2	.52	.48	34.3	26.6	
$\frac{\text{Pb}(\text{NO}_3)_2}{2}$...	21.2	53.3	119.6	3.22	7.23			} R.
KNO_3	"	32.6	67.1	3.23	6.32	1.0	1.09	
$\frac{(\text{NH}_4)_2\text{SO}_4}{2}$...	10	73.0	50.6	11.06	7.67			} M.
$\frac{\text{K}_2\text{SO}_4}{2}$	"	9.8	7.2	1.13	.83	9.83	9.28	

The solubility is expressed in parts per 100 of water, and is taken from Mulder (*loc. cit.*). The solubility in molecules is referred to 1000 parts of water, and is calculated from the above.