XXXVIII. *Supplementary Observations on the Diffusion of Liquids.*

By Thomas Graham, *F.R.S.*, *F.C.S.*

Received May 2,—Read June 20, 1850.

THE experiments of my former paper furnished strong grounds for believing that isomorphous salts possess a similar diffusibility. All the salts of potash and ammonia, which were compared, appeared to be equi-diffusive; so also were the salts of certain magnesian bases. A single preliminary observation on the nitrates of lead and baryta, however, opposed the general conclusion, and demanded further inquiry. It is scarcely necessary to say that any new means of recognizing the existence of the isomorphous relation between different substances, must prove highly valuable. Let us inquire therefore how far liquid diffusion is available for that purpose.

The salts were still diffused from weak solutions, that is from solutions containing from 1 to 8 per cent. of salt; but now a measure of the solution, equal to 100 grs. of water, was made to contain 1 grain of the salt, to form what is called the 1 per cent. solution; instead of 1 grain of salt being added to 100 grs. of water, as before, without reference to the condensation which generally occurs. The quantities 1, 2, 4 and 8 per cent. thus indicate the parts of salt present in a constant volume of liquid,—as 10, 20, 40 and 80 grs. of the salt in 1000 water grain-measures of the solution. The same phials for the solution and jars for the external water-atmosphere continued to be used, and the manipulations were similar. It is believed, however, that the temperature of the liquids was maintained more uniform in the new experiments than the old, partly by the better regulation of the temperature of the apartment, and partly by placing the jars close together upon a table with upright ledges, and covering the whole over with sheets of paper during the continuance of an experiment. The mass of fluid in 80 or 100 jars, which were employed at once and placed together, made the small oscillations of temperature, which might still occur, slow and less injurious.

The investigation is also extended to several new substances, such as hydrocyanic acid, acetic acid, sulphurous acid, alcohol, ammonia and salts of organic bases, without reference to isomorphous relations. It is very necessary to have data which are minute and accurate respecting the diffusion of a considerable variety of substances. This it is my present object to endeavour to supply, leaving speculative deductions in general respecting the nature and laws of liquid diffusion for a future occasion.

The density of all the solutions was observed at a constant temperature, namely, 60° Fahr.

1. *Hydrochloric Acid.*

The period of diffusion arbitrarily chosen for this acid was five days. The diffusate, or quantity of acid diffused, was determined by precipitating the liquid of the external reservoirs with nitrate of silver, and weighing the chloride of silver formed. In the 1 and 2 per cent. solutions, the liquids of two jars were generally mixed and precipitated together.

(1.) Hydrochloric acid, 0·99 per cent.; density 1·0043. Diffused at 53°·5, in six cells, 7·52, 7·52, 7·42; mean 7·49 grs. for two cells. Calculated for 1 per cent., 7·56 grs. at 53°·5 for two cells, or 7·41 grs. at 51°, when corrected for that temperature.

(2.) Hydrochloric acid, 1·92 per cent.; density 1·009. Diffused at 51°, in eight cells, 14·71, 14·05, 14·54, 14·47; mean 14·44 grs. for two cells. Calculated for 2 per cent., 15·04 grs. at 51° for two cells.

(3.) Hydrochloric acid, 1·993 per cent.; density 1·0094. Diffused at 62°·8, in six cells, two experiments on one-sixth part of the mixed jars gave 8·203, 8·198; mean 8·20 grs. for one cell, or 16·40 grs. for two cells. Calculated for 2 per cent., 16·46 grs. at 62°·8 for two cells.

(4.) Hydrochloric acid, 3·90 per cent.; density 1·0190. Diffused at 51°, in eight cells, 29·18, 30·70, 30·70, 29·26; mean 29·96 grs. for two cells. Calculated for 4 per cent., 30·72 grs. at 51° for two cells.

(5.) Hydrochloric acid, 7·90 per cent.; density 1·0380. Diffused at 51°, in four cells, 32·71, 33·64, 33·64, 33·74; mean 33·43 grs. for one cell. Calculated for 8 per cent., 33·84 grs. at 51° for one cell.

Comparing the diffusibilities of the 2 per cent. solutions (2 and 3) at 51° and 62°·8, an increase is observed from 15·04 to 16·40 grs., or from 100 to 109·1, which gives an increase of 0·77 per cent. for 1°. This method of estimating the effect of temperature is not exact, as the times only in which an equal diffusion at the different temperatures takes place are truly comparable. We may deduce from it, however, the effect of the small difference of temperature of 2°·5 of the 1 per cent. solution from the others, as has been done, without sensible error. The diffusates at the same temperature would then be as follows:—

Diffusion of Hydrochloric Acid in five days at 51° Fahr.; two cells.

	Grs.	Ratio.
From 1 per cent. solution	7·41	0·97
From 2 per cent. solution	15·04	2·00
From 4 per cent. solution	30·72	4·08
From 8 per cent. solution	67·68	9·00

The increasing diffusibility with the larger proportions of acid here observed is unusual, at least in the degree exhibited by the 8 per cent. solution. Other substances, as will be immediately observed of nitric acid, appear to lose proportionally in diffusibility as their solutions are concentrated.

Hydrochloric acid belongs to the most diffusive class of substances known; it appears to exceed hydrate of potash at 53°·5, as 7·56 to 6·12, or as 100 to 80·9*.

The rapidity with which hydrochloric acid diffuses, and the facility with which that substance may be estimated, induced me to examine the progression with which its diffusion takes place with increasing times in a minute manner. The 2 per cent. solution was diffused for times increasing by six hours, from twelve hours or 0·5 day to 4·75 days, six cells being diffused for every period. Instead of determining the acid diffused separately in each jar or pair of jars, the contents of the six jars of each experiment were mixed together, and a definite proportion of the liquid precipitated by nitrate of silver, so as to obtain at once the mean result. Another observation for 5·75 days is added, although made at a sensibly higher temperature.

Diffusion of Hydrochloric Acid, 2 per cent. solution; one cell.

Time.	Temperature.	Diffusate in grains.	Differences.
days.	°		
0·5	53·75	0·909	
0·75	53·75	1·312	·403
1	53·75	1·766	·454
1·25	53·75	2·353	·587
1·5	53·75	2·596	·243
1·75	53·58	3·178	·582
2	53·58	3·410	·232
2·25	53·42	3·967	·557
2·5	53·58	4·339	·372
2·75	53·50	4·618	·279
3	53·50	4·969	·351
3·25	53·50	5·304	·335
3·5	54·85	5·857	·553
3·75	54·85	6·254	·397
4	54·85	6·407	·153
4·25	54·85	6·795	·388
4·5	54·71	7·034	·239
4·75	54·71	7·473	·339
5·75	56·46	8·363	

The differences are evidently affected by accidental errors of observation. The diffusion at 3·5 days is also increased by a rise of temperature of more than 1° in that and the following experiments. The diffusion always increases with the time, but less rapidly, according to a gradually diminishing progression.

2. *Hydriodic Acid, Hydrobromic Acid and Bromine.*

Hydriodic Acid.—Time of diffusion five days, as for hydrochloric acid. The acid diffused was estimated from the iodide of silver which it gave when precipitated by nitrate of silver.

Hydriodic acid, 1·98 per cent.; density 1·0142. Diffused at 53°·5, in eight cells, 14·90, 15·67, 15·25, 15·27; mean 15·27 grs. for two cells. Calculated for 2 per cent., 15·42 grs. at 53°·5 for two cells, or 15·11 grs. at 51°.

* Philosophical Transactions, 1850, p. 39.

These experiments indicate a similarity of diffusion between the two isomorphous substances, hydrochloric and hydriodic acids.

Diffusion from 2 per cent. solutions at 51° Fahr.

Hydrochloric acid	15·04	100
Hydriodic acid	15·11	100·46

Hydrobromic Acid.—Time of diffusion five days. The diffusate was estimated from the bromide of silver.

(1.) Hydrobromic acid, 1·556 per cent.; density 1·0112. Diffused at 59°·7, in eight cells. The whole diffusates mixed together gave by analysis a mean of 12·90 grs. of hydrobromic acid in two cells; calculated for 2 per cent., 16·58 grs. in two cells, at 59°·7.

(2.) The experiment was repeated at 59°·8, with a solution containing 1·578 per cent. of hydrobromic acid, of density 1·0116, with five diffusion phials not employed above. The mean diffusate for a pair of cells was 13·05 grs. of hydrobromic acid; that is, 16·53 grs. for a 2 per cent. solution, which is as nearly as possible the result of the preceding series of experiments.

(3.) Another solution containing exactly 2 per cent. of hydrochloric acid was diffused for comparison in eight cells, in the same circumstances of time and temperature as (1.); its density was 1·0104.

Diffusate from 2 per cent. solutions at 59°·7 Fahr.

Hydrochloric acid	16·55	100
Hydrobromic acid	16·58	100·18

Hydrobromic acid appears therefore to coincide in diffusibility with hydrochloric acid at this temperature. It may be remarked that these three acids, hydrochloric, hydrobromic and hydriodic, do not exhibit the same correspondence in another physical property, namely, the densities of their aqueous solutions containing the same proportion of acid. The densities of 2 per cent. solutions of hydrochloric and hydriodic acids appear to be respectively 1·0104 and 1·0143, at 60° Fahr., and that of hydrobromic acid will obviously be an intermediate number. The same acids are also known to differ considerably in the boiling-points of solutions containing the same proportion of acid. A considerable diversity of physical properties appears here to be compatible with equal diffusibility in substances which are isomorphous.

Bromine.—Pure water readily dissolves more than 1 per cent. of this substance. The solution prepared, however, contained only 0·864 per cent. of bromine, as was ascertained by treating it with sulphurous acid and afterwards precipitating by nitrate of silver. Its density was 1·0070. It was evident, from the slow appearance of the brown colour in the exterior cell, that bromine diffuses less rapidly than hydrobromic acid.

The diffusion-time of bromine was made ten days, or double the time of hydrobromic acid. Two cells contained together a diffusate of 5·80 grs. of bromine; another two cells a diffusate of 5·88 grs.; mean 5·84 grs. at 60°·1 FAHR.; or 6·76 grs. for a 1 per cent. solution. Doubling the last result we have 13·52 grs. for a 2 per cent. solution, which is still considerably under the diffusate of hydrobromic acid (16·58 grs.) in half the time.

3. *Hydrocyanic Acid.*

Time of diffusion five days. The acid diffused was estimated from the cyanide of silver which it gave with nitrate of silver.

Hydrocyanic acid, 1·766 per cent., made up to a density of 1·0142 with sulphate of potash. Diffused at 64°·2, in six cells, 11·40, 11·86, 11·80; mean 11·68 grs. for two cells. Calculated for 2 per cent., 13·23 grs. at 64°·2 in two cells, or about 13·10 grs. at 62°·8, assuming this acid to be affected in the same way by temperature as hydrochloric acid.

Hydrocyanic acid here appears less diffusive than hydrochloric acid, at the same temperature 62°·8, as 13·10 to 16·40, or as 79·6 to 100, and not to belong therefore to the same class of diffusive substances.

4. *Nitric Acid.*

Time of diffusion five days. The quantity of this acid diffused was always determined with great exactness by neutralization by means of a normal solution of carbonate of soda.

1. Nitrate of water ($HO.NO_5$), 1 per cent.; density 1·0052. Diffused at 50°·8, in eight cells, 6·77, 6·77, 7·26, 6·97; mean 6·94 grs. of nitrate of water in two cells at 50°·8, and 6·99 grs. by estimate at 51°·2.

2. Nitrate of water, 1 per cent.; density 1·0052. Diffused at 53°·5, in six cells, 7·32, 7·32, 7·20; mean 7·28 grs. in two cells.

3. Nitrate of water, 1·92 per cent.; density 1·0112. Diffused at 51°·2, in eight cells, 14·34, 14·24, 14·10, 13·96; mean 14·16 grs. in two cells. Calculated for 2 per cent., 14·74 grs. at 51°·2 in two cells.

4. Nitrate of water, 2 per cent.; density 1·0106. Diffused at 63°·2, in eight cells, 16·97, 16·64, 16·81, 16·64; mean 16·76 grs. in two cells.

5. Nitrate of water, 3·88 per cent.; density 1·0209. Diffused at 51°·2, in eight cells, 27·76, 28·34, 27·90, 27·62; mean 27·90 grs. in two cells. Calculated for 4 per cent., 28·76 grs. at 51°·2 in two cells.

6. Nitrate of water, 7·96 per cent.; density 1·0432. Diffused at 51°·2, in four cells, 29·17, 29·17, 29·17, 27·76; mean 28·82 grs. in one cell. Calculated for 8 per cent., 28·96 grs. at 51°·2 in one cell.

For the difference of temperature between 51°·2 and 63°·2, the diffusion rises, in the 2 per cent. solution, from 14·74 to 16·76 grs., or from 100 to 113·7; which gives an increase of 1·142 per cent. for one degree of temperature.

The diffusion of the different proportions of this acid at one temperature is as follows:—

Diffusion of Nitrate of Water in five days at 51°·2; two cells.

	Grs.	Ratio.
From 1 per cent. solution	6·99	0·95
From 2 per cent. solution	14·74	2
From 4 per cent. solution	28·76	3·90
From 8 per cent. solution	57·92	7·86

The 2 per cent. solution is taken as the standard of comparison for the ratios, instead of the 1 per cent. solution, from the greater accuracy with which the diffusion of the former can be observed.

The usual approach to equality of diffusion, between chlorides and nitrates, is observable in hydrochloric and nitric acids, at least in the 1 and 2 per cent. solutions.

Diffusion from 1 per cent. solution at 53°·5.

Hydrochloric acid	7·56	100
Nitrate of water	7·28	96·3

Diffusion from 2 per cent. solution.

Hydrochloric acid at 51°	15·04	100
Nitrate of water at 51°·2	14·74	98·0

The 2 per cent. solutions of both acids were also diffused at higher temperatures.

Diffusion from 2 per cent solution.

Hydrochloric acid at 62°·8 . . .	16·46	100
Nitrate of water at 63°·2	16·76	101·8

Here the diffusibility of the two acids is as nearly as possible equal.

Diffusion from 4 per cent. solution.

Hydrochloric acid at 51°	30·72	100
Nitrate of water at 51°·2	28·76	93·7

Diffusion from 8 per cent. solution.

Hydrochloric acid at 51°	67·68	100
Nitrate of water at 51°·2	57·92	85·3

The wide divergence between these two acids, in the 8 per cent. solution, is produced by the remarkably increased diffusion of hydrochloric acid in that high proportion.

5. *Sulphuric Acid.*

That time of diffusion arbitrarily chosen for this acid was ten days. The diffusate of this acid was determined in the same manner as that of nitric acid.

1. Sulphate of water ($HO.SO_3$), 0·993 per cent.; density 1·0065. Diffused at 51°·7, in eight cells, 8·87, 8·87, 8·87, 8·69; mean 8·82 grs. of sulphate of water for two cells. Calculated for 1 per cent., 8·91 grs. at 51°·7 for two cells, and 8·69 grs. at 49°·7.

2. Sulphate of water, 1·89 per cent.; density 1·0130. Diffused at 49°·7, in eight cells, 16·13, 16·16, 15·58, 16·03; mean 15·98 grs. for two cells. Calculated for 2 per cent., 16·91 grs. at 49°·7 for two cells.

3. Sulphate of water, 2 per cent.; density 1·0133. Diffused at 63°·5, in eight cells, 19·80, 20·05, 19·67, 19·41; mean 19·73 grs. for two cells.

4. Sulphate of water, 3·87 per cent.; density 1·0261. Diffused at 49°·7, in eight cells, 32·72, 32·72, 33·06, 32·58; mean 32·77 grs. for two cells. Calculated for 4 per cent., 33·89 grs. at 49°·7 for two cells.

5. Sulphate of water, 7·90 per cent.; density 1·0513. Diffused at 49°·7, in four cells, 34·08, 34·76, 33·74, 33·63; mean 34·05 grs. for one cell. Calculated for 8 per cent., 34·48 grs. at 49°·7 for one cell.

In the 2 per cent. solution the diffusion rises, with the difference of temperature between 49°·7 and 63°·5, from 16·91 to 19·73 grs., or from 100 to 116·68. This is an increase of 1·209 per cent. for one degree of temperature.

The diffusion of the different proportions of sulphuric acid is as follows:—

Diffusion of Sulphate of Water in ten days at 49°·7; two cells.

	Grs.	Ratio.
From 1 per cent. solution	8·69	1·03
From 2 per cent. solution	16·91	2
From 4 per cent. solution	33·89	4·01
From 8 per cent. solution	68·96	8·16

The diffusibility of different strengths of this acid appears to be pretty uniform, but with a slight tendency to increase in the higher proportions, like hydrochloric acid.

Sulphuric acid is greatly inferior in velocity of diffusion to hydrochloric acid, but still appears to possess considerably more than half the diffusibility of the latter.

6. *Chromic Acid.*

Time of diffusion ten days. The diffusates from four cells of the 2 per cent. solution were mixed together, and the quantity of chromic acid diffused for two cells reduced by means of hydrochloric acid and alcohol, and weighed as oxide of chromium.

1·762 per cent. of anhydrous chromic acid, density 1·01404, diffused at 67°·3, gave 19·78 grs. of chromic acid in two cells. Calculated for 2 per cent., 22·43 grs. of chromic acid, in two cells, at 67°·3. The diffusion of sulphuric acid at 63°·5, was 19·73 grs., which would give about 21 grs. of that acid at 67°·3.

7. *Acetic Acid.*

Time of diffusion ten days. This acid cannot be determined accurately by the acidimetrical method, owing to the acetates of potash and soda being essentially alkaline to test-paper, like the carbonates of the same bases, although neutral in composition. The weight of carbonate of baryta dissolved by the acid was had recourse to.

1. Acetate of water ($HO.C_4H_3O_3$), 2 per cent.; density 1·0030. Diffused at 48°·8, in eight cells, 12·62, 10·94, 11·10, 11·39 grs. of acetate of water; mean 11·51 grs. for two cells.

2. Acetate of water, 4 per cent.; density 1·0060. Diffused at 48°·8, in eight cells, 22·12, 21·71, 21·59, 22·67; mean 22·02 grs. for two cells.

3. Acetate of water, 8 per cent.; density 1·0117. Diffused at 48°·8, in four cells, 21·19, 20·13, 21·84, 20·44; mean 20·90 grs. for one cell. The diffusion of the different proportions of acetic acid is as follows:—

Diffusion of Acetate of Water in ten days at 48°·8; two cells.

	Grs.	Ratio.
From 2 per cent. solution	11·31	2
From 4 per cent. solution	22·02	3·83
From 8 per cent. solution	41·80	7·26

The diffusibility diminishes with the larger proportions of acid. This acid appears to be considerably less diffusive than sulphuric acid. I was led to over-estimate the diffusion of acetic acid in a preliminary observation of my former paper, by trusting to the acidimetrical method of determination. Hydrochloric acid appears to diffuse about two and a half times more rapidly than acetate of water, at the same temperature.

8. *Sulphurous Acid.*

The time of diffusion chosen for this acid was ten days, for comparison with sulphuric acid. The usual number of eight cells of the 1 and 2 per cent. solutions were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together, and the proportional quantity of liquid representing two cells in the 1 and 2 per cent. solutions, and 1 cell in the 4 and 8, was converted into sulphuric acid by a slight excess of bromine, and determined from the sulphate of baryta.

1. 0·982 per cent. of sulphurous acid, density 1·0056, diffused at 68°·1, gave 7·94 grs. in two cells. Calculated for 1 per cent., 8·09 grs. of sulphurous acid in two cells at 68°·1.

2. 1·965 per cent. of sulphurous acid, density 1·01055, diffused at 68°·1, gave 16·66 grs. for two cells. Calculated for 2 per cent., 16·96 grs. of sulphurous acid in two cells at 68°·1.

3. 3·93 per cent. of sulphurous acid, density 1·01991, diffused at 68°·1, gave

16·21 grs. for one cell. Calculated for 4 per cent., 16·50 grs. of sulphurous acid in one cell at 68°·1.

4. 7·86 per cent. of sulphurous acid, density 1·0384, diffused at 68°·1, gave 32·60 grs. for one cell. Calculated for 8 per cent., 33·19 grs. of sulphurous acid in one cell at 68°·1.

Diffusion of Sulphurous Acid in ten days at 68°·1 ; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	8·09	0·954
From 2 per cent. solution . . .	16·96	2
From 4 per cent. solution . . .	33·00	3·891
From 8 per cent. solution . . .	66·38	7·827

This substance appears to be less diffusive than sulphuric acid at the same temperature; the diffusion of sulphurous acid at 68°·1 considerably resembles that of sulphuric acid at 49°·7 (p. 811).

9. *Ammonia.*

The time of diffusion chosen was 4·041 days, or that of hydrate of potash with chloride of sodium at seven days. The usual number of eight cells of the 1 and 2 per cent. solutions were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together, and the quantity of ammonia diffused for two cells determined by an alkalimetrical experiment, which was always repeated twice. It was necessary for diffusion to have the ammoniacal solution made denser than water, which was effected by the addition of common salt.

1. 1·005 per cent. of ammonia, density made up to 1·00352 with chloride of sodium, diffused at 63°·4, gave 4·96 grs. for two cells; calculated for 1 per cent., 4·93 grs. of ammonia in two cells at 63°·4.

2. 2·01 per cent. of ammonia, density made up to 1·00617 with chloride of sodium, diffused at 63°·4, gave 9·64 grs. for two cells; calculated for 2 per cent., 9·59 grs. of ammonia in two cells at 63°·4.

3. 4·02 per cent. of ammonia, density made up to 1·01141 with chloride of sodium, diffused at 63°·4, gave 9·91 grs. for one cell; calculated for 4 per cent., 9·86 grs. of ammonia, in one cell, at 63°·4.

4. 8·04 per cent. of ammonia, density made up to 1·0215 with chloride of sodium, diffused at 63°·4, gave 20·71 grs. for one cell; calculated for 8 per cent., 20·61 grs. of ammonia in one cell at 63°·4.

Diffusion of Ammonia in 4·04 days at 63°·4 ; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	4·93	1·029
From 2 per cent. solution . . .	9·59	2
From 4 per cent. solution . . .	19·72	4·117
From 8 per cent. solution . . .	41·22	8·605

Ammonia appears to have a diffusibility approaching to that of hydrate of potash. It appears somewhat less diffusive than hydrocyanic acid at the same temperature, in the proportion of 12 to 13 nearly; or to possess about three-fourths of the diffusibility of hydrochloric acid.

10. *Alcohol.*

Time of diffusion ten days. The quantity of alcohol diffused was determined by careful distillation.

1. Alcohol, 2 per cent.; density made up to 1·0237 with chloride of sodium. Diffused at 40°·7, in eight cells, 17·80, 16·70; mean 17·25 grs. for four cells, or 8·62 grs. for two cells.

2. Alcohol, 4 per cent.; density made up to 1·0203 with chloride of sodium. Diffused at 48°·7, in eight cells, 34·30, 30·20; mean 32·25 grs. for four cells, or 16·12 grs. for two cells.

3. Alcohol, 8 per cent.; density made up to 1·0154 with chloride of sodium. Diffused at 48°·7, in four cells, 30·80, 40·2; mean 35·50 grs. for two cells, or 17·75 grs. for one cell.

The results accord less closely with each other than usual, owing, I believe, chiefly to the difficulties of manipulation when the density of the liquid placed in the phials to be diffused approaches so nearly to that of water. This is more particularly true of the 8 per cent. solution.

Diffusion of Alcohol in ten days at 48°·7; two cells.

From 2 per cent. solution	8·62
From 4 per cent. solution	16·12
From 8 per cent. solution	35·50

It would be unsafe to draw any conclusion as to the proportionality of the diffusion of alcohol to the strength of the solution from these experiments.

Alcohol does not appear to belong to the same class of diffusive substances as acetic acid, which might be expected from their similarity of composition, but possesses a considerably lower diffusibility.

Diffusion from 2 per cent. solutions in ten days.

Acetate of water at 48°·8 . . .	11·51	100
Alcohol at 48°·7	8·62	74·9

The diffusion of alcohol approaches to one-half of that of sulphate of water at nearly the same temperature, p. 811.

Alcohol may be substituted for water to dissolve certain salts, and also as an atmosphere into which these salts may diffuse. From experiments which have been commenced on this subject, it appears that the diffusion of hydrate of potash, iodide of potassium, chloride of calcium and others is about four times slower into alcohol of density 0·840 than into water. The salts likewise often exhibit the same rela-

tions in their diffusibility in alcohol, as in water, with some singular exceptions, such as chloride of mercury.

11. *Nitrate of Baryta.*

Time of diffusion 11·43 days*. The salt diffused was precipitated by sulphuric acid, and calculated from the weight of the sulphate of baryta formed.

1. Nitrate of baryta, 1 per cent.; density 1·0083. Diffused at 51°·5, in eight cells, 6·71, 6·71, 6·84, 6·68; mean 6·73 grs. for two cells.

2. Nitrate of baryta, 0·993 per cent.; density 1·00886. Diffused at 64°·1, in eight cells, 7·64, 7·70, 7·74, 7·61; mean 7·67 grs. for two cells. Calculated for 1 per cent., 7·72 grs. for two cells.

3. Nitrate of baryta, 2 per cent; density 1·01686. Diffused at 64°·1, in eight cells, 15·63, 14·81, 14·41, 15·32; mean 15·04 grs. for two cells.

4. Nitrate of baryta, 4 per cent.; density 1·03319. Diffused at 64°·1, in four cells, 15·36, 14·78, 14·79, 14·30; mean 14·80 grs. for one cell.

5. Nitrate of baryta, 8 per cent; density 1·06556. Diffused at 64°·1, in four cells, 26·46, 26·77, 28·63, 27·13; mean 27·25 grs. for one cell.

The diffusion from the 1 per cent. solution increases by a rise of temperature from 51°·5 to 64°·1, from 6·73 grs. to 7·72, or from 100 to 114·7, which is an increase of 1·17 per cent for 1°.

Diffusion of Nitrate of Baryta in 11·43 days at 64°·1; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	7·72	1·026
From 2 per cent. solution . . .	15·04	2
From 4 per cent. solution . . .	29·60	3·936
From 8 per cent. solution . . .	54·50	7·247

12. *Nitrate of Strontia.*

Time of diffusion 11·43 days. Of anhydrous nitrate of strontia 0·82 per cent.; density 1·0063. Diffused at 51°·5, in eight cells, 5·59, 5·62, 5·44, 5·69; mean 5·59 grs. for two cells; calculated for 1 per cent., 6·79 grs. at 51°·5 for two cells.

The diffusion of nitrate of strontia almost coincides with that of the isomorphous nitrate of baryta at the same temperature.

Diffusion from 1 per cent. solutions at 51°·5 in 11·43 days.

Nitrate of baryta	6·73	100
Nitrate of strontia	6·79	100·89

* This time is to that of sulphate of magnesia (16·166 days) as the square root of 8 is to the square of 16; but does not appear to express the true relation between these salts.

13. *Nitrate of Lime.*

Time of diffusion 11·43 days. The diffusate was evaporated to dryness with an excess of sulphuric acid, and the nitrate of lime, which is always supposed anhydrous, was estimated from the sulphate of lime produced.

1. Nitrate of lime, 1·17 per cent; density 1·0088. Diffused at 51°·5, in eight cells, 7·39, 7·76, 7·69, 7·80; mean 7·66 grs. for two cells; calculated for 1 per cent., 6·54 grs. at 51°·5 for two cells.

2. Nitrate of lime, 0·985 per cent.; density 1·00802. Diffused at 64°·1, in eight cells, 7·47, 7·38, 7·63, 7·72; mean 7·55 grs. for two cells; calculated for 1 per cent., 7·66 grs. at 64°·1 for two cells.

3. Nitrate of lime, 1·97 per cent.; density 1·01508. Diffused at 64°·1, in eight cells, 15·04, 14·74, 14·55, 14·83; mean 14·79 grs. for two cells; calculated for 2 per cent., 15·01 grs. at 64°·1 for two cells.

4. Nitrate of lime, 3·94 per cent.; density 1·0296. Diffused at 64°·1, in four cells, 14·30, 15·29, 13·79, 13·93; mean 14·33 grs. for one cell; calculated for 4 per cent., 14·52 grs. at 64°·1 for one cell.

5. Nitrate of lime, 7·88 per cent.; density 1·0582. Diffused at 64°·1, in four cells, 27·95, 27·10, 26·80, 26·73; mean 27·14 grs. for one cell; calculated for 8 per cent., 27·55 grs. at 64°·1 for one cell.

By a rise of temperature from 51°·5 to 64°·1, the diffusion of the 1 per cent. solution increases from 6·54 to 7·66 grs., or from 100 to 117·1; which is an increase of 1·357 per cent. for 1°.

Diffusion of Nitrate of Lime in 11·43 days at 64°·1; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	7·66	1·021
From 2 per cent. solution . . .	15·01	2
From 4 per cent. solution . . .	29·04	3·872
From 8 per cent. solution . . .	55·10	7·334

The results throughout for this salt are almost identical with those of nitrate of baryta (p. 815), although these two salts differ greatly in solubility, and in one being a hydrated, and the other an anhydrous salt.

14. *Acetate of Lead.*

Diffused for 16·166 days; the time chosen before for sulphate of magnesia, with seven days for chloride of sodium. The solution contained 0·965 per cent. of anhydrous salt, with the density 1·0080. As this solution of acetate of lead was found to be precipitated by pure water, about 2 per cent. of strong acetic acid was introduced into the solution, and the same acid was added in a less proportion to the water jars. The salt of lead diffused was afterwards determined by means of sulphuric acid. Diffused in eight cells, at 53°·1, 7·45, 7·29, 7·46 and 8·07 grs.; mean 7·56; or 7·84 for 1 per cent. in two cells.

15. *Acetate of Baryta.*

Diffused for 16·166 days. The solution contained 0·977 per cent. of anhydrous salt, with the density 1·0073. The same addition of acetic acid was made to it as to the preceding acetate of lead, in order that the circumstances of diffusion might be similar for both salts. The salt diffused was estimated also in the form of sulphate.

Diffused at 53°·5, in eight cells, 7·30, 7·38, 7·40 and 7·21 grs. in two cells; mean 7·33; or 7·50 for 1 per cent. in two cells.

Diffusion of 1 per cent. solutions in 16·166 days; two cells.

Acetate of baryta at 53°·5	7·50	100
Acetate of lead at 53°·1	7·84	104·53

Here, of two isomorphous salts, that of greatest atomic weight sensibly exceeds the other in diffusibility.

16. *Chloride of Barium.*

Time of diffusion 11·43 days. The diffused salt was weighed as sulphate of baryta.

1. Chloride of barium, 0·99 per cent. Diffused at 50°·9, in eight cells, 7·91, 7·27, 7·42, 7·12; mean 7·43 grs. of chloride of barium for two cells; calculated for 1 per cent., 7·50 grs. at 50°·9 for two cells.

The diffusion of this salt being manifestly more rapid than that of the chloride of calcium, a shorter time was tried, which is to seven days, the time of chloride of sodium, as the square root of 3 to the square root of 4·5. Time of diffusion 8·57 days.

2. Chloride of barium, 1·01 per cent.; density 1·0095. Diffused at 63°, in eight cells, 6·46, 6·44, 6·41, 6·27; mean 6·39 grs. for two cells; calculated for 1 per cent., 6·32 grs. at 63° for two cells.

3. Chloride of barium, 2·02 per cent.; density 1·0183. Diffused at 63°, in eight cells, 11·98, 12·03, 12·75, 12·03; mean 12·20 grs. for two cells; calculated for 2 per cent., 12·07 grs. at 63° for two cells.

4. Chloride of barium, 4·04 per cent.; density 1·0359. Diffused at 63°, in four cells, 12·43, 12·30, 11·87, 11·86; mean 12·10 grs. for one cell; calculated for 4 per cent., 11·98 grs. at 63° for one cell.

5. Chloride of barium, 8·08 per cent.; density 1·0712. Diffused at 63°, in four cells, 23·17, 23·05, 22·98, 23·62; mean 23·20 grs. for one cell; calculated for 8 per cent., 22·96 grs. at 63° for one cell.

Diffusion of Chloride of Barium in 8·57 days at 63°; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	6·32	1·047
From 2 per cent. solution . . .	12·07	2
From 4 per cent. solution . . .	23·96	3·970
From 8 per cent. solution . . .	45·92	7·608

17. *Chloride of Strontium.*

First time of diffusion 11·43 days. The diffused salt was weighed as sulphate of strontia.

1. Chloride of strontium, 0·803 per cent.; density 1·0076. Diffused at 51°, in eight cells, 6·36, 6·06, 5·93, 5·73; mean 6·02 grs. of chloride of strontium for two cells; calculated for 1 per cent., 7·52 grs. at 51° for two cells.

Second time of diffusion 8·57 days.

2. Chloride of strontium, 1 per cent.; density 1·00936. Diffused at 63°, in eight cells, 6·10, 6·17, 6·02, 6·09; mean 6·09 grs. for two cells.

3. Chloride of strontium, 2 per cent.; density 1·01806. Diffused at 63°, in eight cells, 11·62, 11·71, 11·53, 11·79; mean 11·66 grs. for two cells.

4. Chloride of strontium, 4·014 per cent.; density 1·03537. Diffused at 63°, in four cells, 12·09, 11·75, 11·64, 11·79; mean 11·82 grs. for one cell; calculated for 4 per cent., 11·78 grs. at 63° for one cell.

5. Chloride of strontium, 8·028 per cent.; density 1·06959. Diffused at 63°, in four cells, 22·29, 22·34, 22·03, 22·57; mean 22·31 grs. for one cell; calculated for 8 per cent., 22·23 grs. at 63° for two cells.

Diffusion of Chloride of Strontium in 8·57 days at 63°; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	6·09	1·045
From 2 per cent. solution . . .	11·66	2
From 4 per cent. solution . . .	23·56	4·041
From 8 per cent. solution . . .	44·46	7·626

The series of ratios in the preceding table will be found on comparison to correspond closely with the ratios of chloride of barium. It may be useful to compare further the amounts diffused from similar solutions of these two isomorphous compounds.

Diffusion in 8·57 days at 63°; two cells.

Chloride of barium, 1 per cent. . .	6·32	100
Chloride of strontium, 1 per cent. .	6·09	96·36
Chloride of barium, 2 per cent. . .	12·07	100
Chloride of strontium, 2 per cent. .	11·66	96·90
Chloride of barium, 4 per cent. . .	23·96	100
Chloride of strontium, 4 per cent. .	23·56	99·16
Chloride of barium, 8 per cent. . .	45·92	100
Chloride of strontium, 8 per cent. .	44·46	96·83

The near coincidence of the 4 per cent. solutions probably arises from an accidental error of observation in the chloride of barium, for the latter departs here from the progression of its ratios. We appear then to have a small but constant difference of

about $3\frac{1}{2}$ per cent. in the diffusion of these two isomorphous salts, the chloride of barium, which possesses the highest atomic weight, having the advantage.

The diffusion of the 1 per cent. solution of the same salts for the longer period of 11·43 days, gives 7·50 for chloride of barium at 50°·9, and 7°·52 for chloride of strontium at 51°, or nearly the same temperature. For the first time we have in the barytic salts a divergence between chlorides and nitrates, for the nitrates of the same bases have a number about 6·8 only at the same temperature. I am led however to believe that this discrepancy becomes much less at low temperatures by experiments which are at present in progress.

18. *Chloride of Calcium.*

Time of diffusion 11·43 days. The salt diffused was weighed as sulphate of lime.

1. Chloride of calcium, 1·065 per cent.; density 1·0091. Diffused at 50°·9, in eight cells, 6·95, 7·09, 6·78, 6·94; mean 6·94 grs. of chloride of calcium for two cells; calculated for 1 per cent., 6·51 grs. at 50°·9 for two cells.

2. Chloride of calcium, 1·03 per cent.; density 1·0089. Diffused at 63°·8, in eight cells, 8·08, 8·13, 8·28, 8·19; mean 8·17 grs. for two cells; calculated for 1 per cent., 7·92 grs. at 63°·8 for two cells.

3. Chloride of calcium, 2·06 per cent.; density 1·0171. Diffused at 63°·8, in eight cells, 15·70, 15·33, 16·48, 15·82; mean 15·83 grs. for two cells; calculated for 2 per cent., 15·35 grs. at 63°·8 for two cells.

4. Chloride of calcium, 4·12 per cent.; density 1·0334. Diffused at 63°·8, in four cells, 15·24, 16·20, 15·89, 16·20; mean 15·88 grs. for one cell; calculated for 4 per cent., 15·39 grs. at 63°·8 for one cell.

5. Chloride of calcium, 8·23 per cent.; density 1·0652. Diffused at 63°·8, in four cells, 32·97, 31·17, 30·64, 31·90; mean 31·67 grs. for one cell; calculated for 8 per cent., 30·78 grs. at 62°·8 for one cell.

The diffusion of the 1 per cent. solution of chloride of calcium is increased by a rise of temperature from 50°·9 to 63°·8, from 6·51 to 7·92, or from 100 to 121·6, which is an increase of 1·674 per cent. for 1°.

Diffusion of Chloride of Calcium in 11·43 days at 63°·8; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	7·92	1·032
From 2 per cent. solution . . .	15·35	2
From 4 per cent. solution . . .	30·78	4·010
From 8 per cent. solution . . .	61·56	8·021

We may now observe how far the diffusion of the chloride of calcium is analogous to that of nitrate of lime. At the inferior temperatures, the results for the 1 per cent. solution of these two salts were as follows:—

Chloride of calcium at 50°·9 . . .	6·51	100
Nitrate of lime at 51°·5	6·54	100·46

While at the higher temperatures, namely, 63°·8 for the chloride of calcium, and 64°·1 for the nitrate of lime, the results for the different proportions of salt are—

Chloride of calcium, 1 per cent. . .	7·92	100
Nitrate of lime, 1 per cent. . . .	7·66	96·72
Chloride of calcium, 2 per cent. . .	15·35	100
Nitrate of lime, 2 per cent. . . .	15·01	97·79
Chloride of calcium, 4 per cent. . .	30·78	100
Nitrate of lime, 4 per cent. . . .	29·04	94·35
Chloride of calcium, 8 per cent. . .	61·56	100
Nitrate of lime, 8 per cent. . . .	55·10	89·51

The correspondence between the 1 and 2 per cent. solutions of chloride and nitrate is sufficiently close, but in the 4 and 8 per cent. the salts diverge, as happens also with hydrochloric and nitric acids themselves. The nitrate in both cases falls off, while the chloride sustains throughout the high diffusibility of the lower proportions.

19. *Chloride of Manganese.*

Time of diffusion 11·43 days. The salt diffused was estimated by means of nitrate of silver.

The 1 per cent. solution, of density 1·0085, gave at 50°·8, in eight cells, 6·67, 6·26, 6·79 and 6·81 grs.; mean 6·63 for two cells.

20. *Nitrate of Magnesia.*

Time of diffusion 11·43 days. The salt diffused was estimated as sulphate.

The 1 per cent. solution, of density 1·0073, gave at 50°·8, in eight cells, 6·29, 6·39, 6·52 and 6·76 grs.; mean 6·49 for two cells.

21. *Nitrate of Copper.*

Time of diffusion 11·43 days. The salt diffused was estimated from the oxide of copper obtained by ignition.

The 1 per cent. solution, of density 1·0075, in eight cells, at 50°·8, gave 6·52, 6·36, 6·18 and 6·70 grs.; mean 6·44 for two cells.

Comparing the preceding salts with chloride of calcium diffused at the same temperature, 50°·8, we have the following results:—

Chloride of calcium	6·51	100
Chloride of manganese	6·63	101·85
Nitrate of magnesia	6·49	99·69
Nitrate of copper	6·44	98·92

This group of salts, belonging to the same isomorphous family of bases, the magnesian, again correspond closely in diffusibility.

The following additional magnesian chlorides were diffused, all 1 per cent. solu-

tions, either in six or in eight cells. The salt diffused was estimated by means of nitrate of silver.

22. *Chloride of Zinc* at 51°, solution of density 1·0091, gave 6·55, 6·20, 6·21 and 6·28 grs.; mean 6·29 for two cells.

23. *Chloride of Magnesium* at 50°·6, density 1·0077, gave 6·40, 5·84 and 6·29; mean 6·17 for two cells.

24. *Chloride of Copper* at 50°·6, solution of density 1·0093, gave 6·08, 6·08 and 6·02 grs.; mean 6·06 for two cells.

The results referred to chloride of calcium, at nearly the same temperature, 50°·8, are as follows:—

Chloride of calcium	6·51	100
Chloride of zinc	6·29	96·61
Chloride of magnesium	6·17	94·77
Chloride of copper	6·06	93·08

These salts present a greater latitude in their diffusibility, if belonging to the same class, than is usual.

25. *Protochloride of Iron.*

A solution of this salt of 1·023 per cent. was diffused at 53°·5, a somewhat higher temperature than the corresponding chlorides. It gave 6·45, 6·48, 6·48 and 6·28 grs. in two cells; mean 6·44, or 6·30 for 1 per cent. in two cells. This salt appears therefore to belong to the last group.

26. *Sesquichloride of Iron.*

A full series of observations was made upon the diffusion of the different proportions of this salt from 1 to 8 per cent., but in all of them decomposition was determined by the diffusion, with turbidity also in the solution phial except in the 8 per cent. solution.

The mean diffusion from the 1 per cent. solution in 11·43 days, at 63°·3, was 4·13 grs. of sesquichloride of iron with 1·28 gr. of free hydrochloric acid, in two cells. This result indicates that one-half nearly of the sesquichloride of iron is decomposed in the diffusion.

The mean diffusion from the 8 per cent. solution, at 63°·3, was 55·88 grs. of sesquichloride of iron, with 6·66 grs. of free hydrochloric acid, in two cells. It appears from this experiment that perchloride of iron approaches the chloride of calcium in diffusibility. That the proto- and persalts of the magnesian metals should have a similar rate of diffusion, is not unlikely from other analogies which they exhibit.

27. *Sulphate of Magnesia.*

The time chosen for the diffusion of this salt, namely, 16·166 days, is a multiple by 2 of the time of sulphate of potash, and by 4 of the time of hydrate of potash. The diffusate was evaporated to dryness and weighed.

1. 1·012 per cent. of anhydrous sulphate of magnesia, density 1·0108, diffused at 65°·4, in eight cells, 7·34, 7·66, 7·43, 7·18; mean 7·40 grs. for two cells; calculated for 1 per cent., 7·31 grs. of sulphate of magnesia in two cells at 65°·4.

2. 2·024 per cent. of sulphate of magnesia, density 1·02089, diffused at 65°·4, in eight cells, 12·91, 13·13, 12·83, 12·93; mean 12·95 grs. for two cells; calculated for 2 per cent., 12·79 grs. of sulphate of magnesia in two cells at 65°·4.

3. 4·048 per cent. of sulphate of magnesia, density 1·04033, diffused at 65°·4, in four cells, 12·06, 12·56, 10·63, 12·24; mean 11·87 grs. for one cell; calculated for 4 per cent., 11·73 grs. of sulphate of magnesia in one cell at 65°·4.

4. 8·096 per cent. of sulphate of magnesia, density 1·07830, diffused at 65°·4, in four cells, 22·25, 20·56, 21·80, 22·06; mean 21·67 grs. for one cell; calculated for 8 per cent., 21·41 grs. of sulphate of magnesia in one cell at 65°·4.

5. 8·07 per cent. of sulphate of magnesia, density 1·07830, diffused at 62°·8, in four cells, 21·12, 21·20, 22·13, 21·77; mean 21·55 grs. for one cell; calculated for 8 per cent., 21·33 grs. of sulphate of magnesia in one cell at 62°·8.

6. 16·14 per cent. of sulphate of magnesia, density 1·15054, diffused at 62°·8, in four cells, 37·08, 38·39, 38·65, 37·50; mean 37·90 grs. for one cell; calculated for 16 per cent., 37·53 grs. of sulphate of magnesia in one cell at 62°·8.

7. 24·22 per cent. of sulphate of magnesia, density 1·21882, diffused at 62°·8, in four cells, 49·38, 50·40, 53·36, 53·00; mean 51·53 grs. for one cell; calculated for 24 per cent., 51·02 grs. of sulphate of magnesia in one cell at 62°·8.

Diffusion of Sulphate of Magnesia in 16·16 days at 65°·4; two cells.

	Grs.	Ratio.
From 1 per cent. solution	7·31	1·144
From 2 per cent solution	12·79	2
From 4 per cent. solution	23·46	3·671
From 8 per cent. solution	42·82	6·701
From 8 per cent. solution at 62°·8 .	42·66	1
From 16 per cent. solution at 62°·8 .	75·06	1·759
From 24 per cent. solution at 62°·8 .	102·04	2·340

28. *Sulphate of Zinc.*

Time of diffusion 16·166 days. The diffused salt was evaporated to dryness and weighed.

1. 1·001 per cent. of anhydrous sulphate of zinc, density 1·01093, diffused at 65°·4, in eight cells, 6·66, 6·76, 6·51, 6·80; mean 6·68 grs. for two cells; calculated for 1 per cent., 6·67 grs. of sulphate of zinc in two cells at 65°·4.

2. 2·002 per cent. sulphate of zinc, density 1·02120, diffused at 65°·4, in eight cells, 12·16, 12·19, 12·52, 12·05; mean 12·23 grs. for two cells; calculated for 2 per cent., 12·22 grs. of sulphate of zinc in two cells at 65°·4.

3. 4·005 per cent. of sulphate of zinc, density 1·04146, diffused at 65°·4, in four cells, 11·63, 11·70, 11·00, 11·95; mean 11·57 grs. for one cell; calculated for 4 per cent., 11·56 grs. of sulphate of zinc in one cell at 65°·4.

4. 8·01 per cent. of sulphate of zinc, density 1·08063, diffused at 65°·4, in four cells, 21·22, 20·52, 21·06, 21·84; mean 21·16 grs. for one cell; calculated for 8 per cent., 21·13 grs. of sulphate of zinc in one cell at 65°·4.

5. 8·04 per cent. of sulphate of zinc, density 1·08084, diffused at 62°·8, in four cells, 20·70, 18·57, 20·32, 20·36; mean 19·99 grs. for one cell; calculated for 8 per cent., 19·81 grs. of sulphate of zinc in one cell at 62°·8.

6. 16·08 per cent. of sulphate of zinc, density 1·15734, diffused at 62°·8, in four cells, 36·70, 37·15, 37·51, 38·21; mean 37·39 grs. for one cell; calculated for 16 per cent., 37·20 grs. of sulphate of zinc in one cell at 62°·8.

7. 24·11 per cent. of sulphate of zinc, density 1·23156, diffused at 62°·8, in three cells, 51·12, 50·14, 51·66; mean 50·97 grs. for one cell; calculated for 24 per cent., 50·71 grs. of sulphate of zinc in one cell at 62°·8.

Diffusion of Sulphate of Zinc in 16·16 days at 65°·4; two cells.

	Grs.	Ratio.
From 1 per cent. solution	6·67	1·091
From 2 per cent. solution	12·22	2
From 4 per cent. solution	23·12	3·784
From 8 per cent. solution	42·26	6·916
From 8 per cent. solution at 62°·8 .	39·62	1
From 16 per cent. solution at 62°·8 .	74·40	1·878
From 24 per cent. solution at 62°·8 ..	101·42	2·560

It will be remarked that the diffusion of these two isomorphous salts, sulphate of magnesia and sulphate of zinc, differs so much, in the 1 per cent. solution, as 7·31 to 6·67, that is, as 100 to 91·25; or 8·75 per cent. This I have no doubt, however, is an accidental error, the disturbances from changes of temperature and other causes of dispersion being in direct proportion to the duration of the experiment, and therefore much increased with these long times; while the 1 per cent. solution also appears to be generally the proportion most exposed to such errors. The sulphate of zinc appears to be the truest throughout, in its diffusion, of these two salts. The approach to equality becomes close in the 4 per cent. and larger proportions of salt, particularly with the unusually high proportions of 16 and 24 per cent., which were observed in these salts. The diffusion of both salts falls off remarkably in the higher proportions. The result of the comparison of these two magnesian sulphates is no doubt favourable to the similarity of diffusion of isomorphous salts.

29. *Sulphate of Alumina.*

The time of diffusion chosen was 16·166 days, or the same as that for sulphate of magnesia. The usual number of eight cells of the 1 and 2 per cent. solutions were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together and the quantities of alumina and sulphuric acid, diffused for two cells, determined separately.

1. 1·045 per cent. of sulphate of alumina, density 1·01160, diffused at 65°·4, gave 1·80 gr. of alumina and 3·93 grs. of sulphuric acid, in all 5·73 grs. for two cells. Calculated for 1 per cent., 1·72 gr. alumina and 3·76 grs. sulphuric acid, in all 5·48 grs. of sulphate of alumina in two cells at 65°·4.

2. 2·091 per cent. of sulphate of alumina, density 1·02251, diffused at 65°·4, gave 3·32 grs. of alumina and 7·35 grs. of sulphuric acid, in all 10·67 grs. for two cells. Calculated for 2 per cent., 3·18 grs. of alumina and 7·03 grs. of sulphuric acid, in all 10·21 grs. of sulphate of alumina for two cells at 65°·4.

3. 4·182 per cent. of sulphate of alumina, density 1·0438, diffused at 65°·4, gave 3·17 grs. of alumina and 6·91 grs. of sulphuric acid, in all 10·08 grs. for one cell. Calculated for 4 per cent., 3·03 grs. of alumina and 6·61 grs. of sulphuric acid, in all 9·64 grs. of sulphate of alumina for one cell at 65°·4.

4. 8·364 per cent. of sulphate of alumina, density 1·08518, diffused at 65°·4, gave 5·37 grs. of alumina and 12·15 grs. of sulphuric acid, in all 17·52 grs. for one cell. Calculated for 8 per cent., 5·14 grs. of alumina and 11·62 grs. of sulphuric acid, in all 16·76 grs. of sulphate of alumina for one cell at 65°·4.

Diffusion of Sulphate of Alumina in 16·166 days at 65°·4; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	5·48	1·074
From 2 per cent. solution . . .	10·21	2
From 4 per cent. solution . . .	19·28	3·780
From 8 per cent. solution . . .	33·52	6·572

The diffusion of sulphate of alumina, it will be observed, is very sensibly less than that of sulphate of zinc at the same temperature.

30. *Nitrate of Silver.*

Time of diffusion seven days. The quantity of salt diffused was ascertained by precipitation with hydrochloric acid, and weighing the chloride of silver formed.

1. Nitrate of silver, 0·996 per cent.; density 1·0089. Diffusion at 51°·4, in eight cells, 5·39, 5·39, 5·74, 5·50; mean 5·50 grs. for two cells; calculated for 1 per cent., 5·52 grs. at 51°·4 for two cells.

2. Nitrate of silver, 1·98 per cent.; density 1·0161. Diffusion at 53°, in eight cells, 11·27, 11·16, 11·05, 11·06; mean 11·13 grs. for two cells; calculated for 2 per cent., 11·24 grs. at 53° for two cells.

3. Nitrate of silver, 1·967 per cent.; density 1·01696. Diffusion at 63°·41, in eight cells, 13·85, 13·29, 13·70, 12·73; mean 13·39 grs. for two cells; calculated for 2 per cent., 13·61 grs. at 63°·4 for two cells.

4. Nitrate of silver, 3·93 per cent.; density 1·032. Diffusion at 63°·4, in four cells, 13·27, 12·70, 12·90, 12·90; mean 12·94 grs. for one cell; calculated for 4 per cent., 13·17 grs. at 63°·4 for one cell.

5. Nitrate of silver, 7·88 per cent.; density 1·066. Diffusion at 63°·4, in four cells, 26·45, 25·49, 24·57, 25·73; mean 25·56 grs. for one cell; calculated for 8 per cent., 25·94 grs. at 63°·4 for one cell.

A rise of 10°·4 of temperature, or from 53° to 63°·4, increases the diffusibility of this salt from 11·24 to 13·61, or from 100 to 121·2; which is an increase of 2·04 per cent. for 1°.

Diffusion of Nitrate of Silver for seven days at 63°·4; two cells.

	Grs.	Ratio.
From 2 per cent. solution	13·61	2
From 4 per cent. solution	26·34	3·87
From 8 per cent. solution	51·88	7·62

31. *Nitrate of Soda.*

Time of diffusion seven days. The quantity of salt diffused was ascertained by evaporation to dryness.

1. Nitrate of soda, 1·987 per cent.; density 1·0130. Diffusion at 53°, in eight cells, 11·37, 10·44, 10·76, 10·40; mean 10·74 grs. for two cells; calculated for 2 per cent., 10·81 grs. for two cells.

2. Nitrate of soda, 1·998 per cent. Diffusion at 63°·4, in eight cells, 12·53, 12·38, 12·39, 12·06; mean 12·34 grs. for two cells; calculated for 2 per cent., 12·35 grs. for two cells.

3. Nitrate of soda, 3·98 per cent.; density 1·027. Diffusion at 63°·4, in four cells, 12·21, 11·32, 12·10, 11·31; mean 11·73 grs. for one cell; calculated for 4 per cent., 11·78 grs. for one cell.

4. Nitrate of soda, 7·96 per cent.; density 1·053. Diffusion at 63°·4, in four cells, 24·96, 22·53, 23·16, 24·38; mean 23·76 grs. for one cell; calculated for 8 per cent., 23·87 grs. for one cell.

A rise of temperature from 53° to 63°·4 increases the diffusibility of nitrate of soda from 10·81 to 12·35, or from 100 to 114·3, which is an increase of 1·37 per cent. for 1°. The increase on the nitrate of silver for the same rise of temperature appeared to be considerably greater, namely, 2·04 per cent. for 1°.

Diffusion of Nitrate of Soda in seven days at 63°·4; two cells.

	Grs.	Ratio.
From solution of 2 per cent. . . .	12·35	2
From solution of 4 per cent. . . .	23·56	3·82
From solution of 8 per cent. . . .	47·74	7·73

The ratios of the last column of the preceding Table are sensibly the same as those already obtained for nitrate of silver. But the diffusibility of nitrate of soda appears to be increased less rapidly by temperature than nitrate of silver. Hence the diffusibility of these two salts appears more similar at low than high temperatures.

Diffusion from 2 per cent. solutions in seven days at 53°.

Nitrate of silver	11·24	100
Nitrate of soda	10·81	96·17

Diffusion from 2 per cent. solutions in seven days at 63°·4.

Nitrate of silver	13·61	100
Nitrate of soda	12·35	90·74

32. *Chloride of Sodium.*

Time of diffusion seven days. The salt diffused was treated with nitrate of silver, and the chloride of silver weighed.

1. Chloride of sodium, 1 per cent. Diffused at 50°·5, in eight cells, 5·96, 5·69, 5·54, 5·50; mean 5·70 grs. of chloride of sodium for two cells.

2. Chloride of sodium, 0·985 per cent. Diffused at 53°·4, in eight cells, 5·86, 5·86, 5·77, 5·76; mean 5·81 grs. for two cells; calculated for 1 per cent., 5·89 grs. at 53°·4 for two cells.

3. Chloride of sodium, 1 per cent.; density 1·00776. Diffused at 63°·4, in eight cells, 6·30, 6·18, 6·52, 6·30; mean 6·32 grs. for two cells.

4. Chloride of sodium, 2 per cent.; density 1·01483. Diffused at 63°·4, in eight cells, 12·37, 12·08, 12·45, 12·53; mean 12·37 grs. for two cells.

5. Chloride of sodium, 4 per cent.; density 1·02879. Diffused at 63°·4, in four cells, 12·56, 12·65, 12·55, 12·17; mean 12·48 grs. for one cell.

6. Chloride of sodium, 8 per cent.; density 1·0562. Diffused at 63°·4, in four cells, 25·11, 25·36, 22·82, 23·59; mean 24·22 grs. for one cell.

The rise of temperature from 50°·5 to 63°·4 increases the diffusion of the 1 per cent. solution of chloride of sodium from 5·70 to 6·32, or from 100 to 110·9, which is an increase of 0·843 per cent. for 1°.

Diffusion of Chloride of Sodium in seven days at 63°·4; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	6·32	1·023
From 2 per cent. solution . . .	12·37	2
From 4 per cent. solution . . .	24·96	4·036
From 8 per cent. solution . . .	48·44	7·832

These numbers resemble closely those obtained in the diffusion of chloride of barium during the longer period of 8·57 days.

The chloride of sodium and nitrate of soda will be seen to exhibit the usual approach to parallelism between the chloride and nitrate of the same metal, by the following comparison:—

Diffusion of Chloride of Sodium and Nitrate of Soda, both at 63°·4.

Chloride of sodium, 2 per cent. . .	12·37	100
Nitrate of soda, 2 per cent. . . .	12·35	99·83
Chloride of sodium, 4 per cent. . .	24·96	100
Nitrate of soda, 4 per cent. . . .	23·58	94·48
Chloride of sodium, 8 per cent. . .	48·44	100
Nitrate of soda, 8 per cent. . . .	47·74	98·55

As usual the chloride is slightly more rapid in its diffusion than the nitrate.

33. *Chloride of Potassium.*

Time of diffusion 5·71 days. The salt diffused was treated with nitrate of silver, and the chloride of silver weighed.

1. Chloride of potassium, 1 per cent.; density 1·00697. Diffused at 62°, in eight cells, 6·70, 6·75, 6·53, 6·77; mean 6·69 grs. of chloride of potassium for two cells.

2. Chloride of potassium, 2 per cent.; density 1·01333. Diffused at 62°, in eight cells, 13·36, 13·35, 13·60, 12·96; mean 13·32 grs. for two cells.

3. Chloride of potassium, 4 per cent.; density 1·0258. Diffused at 62°, in four cells, 12·51, 13·21, 13·46, 12·71; mean 12·97 grs. for one cell.

4. Chloride of potassium, 8 per cent.; density 1·0503. Diffused at 62°, in four cells, 26·88, 26·64, 26·15, 27·63; mean 26·82 grs. for one cell.

Diffusion of Chloride of Potassium in 5·71 days at 62°; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	6·69	1·005
From 2 per cent. solution . . .	13·32	2
From 4 per cent. solution . . .	25·94	3·895
From 8 per cent. solution . . .	53·64	8·054

The ratios are in remarkably close accordance with the proportions of salt diffused.

The times 5·71 and seven days chosen for the chloride of potassium and sodium, it will be observed, are as the square roots of 2 and 3. A certain deviation from this ratio of the times of equal diffusion, appears on comparing the experimental results obtained at present for these salts.

Diffusion of Chloride of Potassium in 5·71 days at 62°, and of Chloride of Sodium in 7 days at 63°·4.

Chloride of potassium, 1 per cent. .	6·69	100
Chloride of sodium, 1 per cent. . .	6·32	94·47
Chloride of potassium, 2 per cent. .	13·32	100
Chloride of sodium, 2 per cent. . .	12·37	92·86
Chloride of potassium, 4 per cent. .	25·94	100
Chloride of sodium, 4 per cent. . .	24·96	96·23
Chloride of potassium, 8 per cent. .	53·64	100
Chloride of sodium, 8 per cent. . .	48·44	90·30

The difference would be about 1 per cent. greater if the diffusion of both salts were reduced to the same temperature. The chloride of potassium deviates of course from the nitrate of soda in a similar manner. But chloride of potassium corresponds more closely with nitrate of silver than with chloride of sodium and nitrate of soda, at the temperature of the experiments.

Diffusion of Chloride of Potassium for 5·71 days at 62°, and of Nitrate of Silver for 7 days at 63°·4.

Chloride of potassium, 2 per cent. .	13·32	100
Nitrate of silver, 2 per cent. . . .	13·61	102·18
Chloride of potassium, 4 per cent. .	25·94	100
Nitrate of silver, 4 per cent. . . .	26·34	101·54
Chloride of potassium, 8 per cent. .	53·64	100
Nitrate of silver, 8 per cent. . . .	51·88	96·71

The coincidence in rate would appear even closer in the 2 and 4 per cent. solutions, if the diffusion of the nitrate of silver was diminished about 1 per cent., on account of its higher temperature. It might thus be supposed that the nitrate of silver followed the sodium rate more accurately than the nitrate of soda and chloride of sodium themselves do.

A series of observations were made upon the diffusion of the 1 per cent. solution of chloride of potassium at a nearly constant temperature of 56°, but for different times, varying from five days to eight days, and eighteen hours, to discover the progression, which proved to be pretty similar to that of the 2 per cent. solution of hydrochloric acid. Six cells were diffused for each period, of which the mean result is given: the times advance by ten hours.

Diffusion of Chloride of Potassium, 1 per cent. solution; two cells.

Time.	Temperature.	Diffusion in two cells.	Differences.
5 days.	55°·71	5·89	
5 days 10 hours.	55·90	6·25	0·36
5 days 20 hours.	55·79	6·55	0·30
6 days 6 hours.	55·79	6·71	0·16
6 days 16 hours.	55·90	6·95	0·24
7 days 2 hours.	55·9	7·48	0·53
7 days 12 hours.	55·9	7·58	0·10
7 days 22 hours.	56·03	8·08	0·50
8 days 8 hours.	56·28	8·34	0·26
8 days 18 hours.	56·15	8·60	0·26

When the quantities of chloride of potassium are placed beside the same quantities of hydrochloric acid in the former Table, it is found that the times of diffusion of the salt and acid exhibit an approximately constant ratio. The squares of these times of equal diffusion are as 1 to 2·04 for the shortest period of the chloride of potassium, and as 1 to 2·10 for the longest period but one. The variation in the differences towards the middle of the Table is too great to be explained, except I fear by some error of observation, although no ordinary precaution was neglected in the execution of this laborious series of experiments.

34. *Iodides and Bromides of Potassium and Sodium.*

Iodide of Potassium.—Time of diffusion 5·716 days. The diffusate was estimated by means of nitrate of silver.

(1.) Iodide of potassium, 1·977 per cent.; density 1·0145. Diffused at 53°·5, in eight cells, 11·415, 11·506, 10·942 and 11·062 grs.; mean 11·24 for two cells, and 11·36 for two per cent.

Comparing this salt with the isomorphous chloride of potassium, we have—

Diffusion of 2 per cent. solutions in 5·716 days.

Chloride of potassium at 55° . . .	11·48	100
Iodide of potassium at 53°·5 . . .	11·36	99·65

The diffusion of the iodide would slightly exceed that of the chloride, instead of falling below it as in the Table, if the temperatures were made equal.

(2.) Again, iodide of potassium 1·971 per cent., observed density 1·01486. Diffused at 59°·8, in eight cells, and the mean diffusate of the whole cells determined, it gave 12·33 grs. of iodide of potassium for two cells; or 12·51 grs. for a 2 per cent. solution.

Bromide of Potassium.—Time of diffusion and mode of estimating diffusate as above. The solution contained 1·975 per cent. of salt, and had a density of 1·014850. Diffused

at 59°·8, in eight cells, it gave a mean diffusate of 12·30 grs. for two cells; or 12·46 grs. for 2 per cent.

For comparison, a solution of *chloride of potassium*, containing exactly 2 per cent. of salt and having the density 1·0133, was diffused in the same circumstances of time and temperature as the two preceding salts. The mean diffusate of eight cells was 12·24 grs. for two cells.

Hence the following result of the diffusion of three isomorphous salts:—

Diffusion of 2 per cent. solutions in 5·716 days, at 59°·8.

	Grs.	Ratio.
Chloride of potassium	12·24	100
Bromide of potassium	12·46	101·80
Iodide of potassium	12·51	102·21
Mean	12·40	

Iodide of Sodium.—Time of diffusion 7 days, temperature 59°·8. A solution of 2·011 per cent. and density 1·01618, diffused in eight cells, gave a mean diffusate of 12·24 grs. for two cells; that is, 12·18 grs. for 2 per cent. solution.

Bromide of Sodium.—Time of diffusion and temperature as above. A solution of 2·146 per cent., of density 1·01726, diffused in eight cells, gave a mean diffusate of 12·80 grs.; that is, 11·93 grs. for 2 per cent.

A comparative experiment was made with a solution of *chloride of sodium*, containing 1·917 per cent. of salt and of density 1·01376, in eight cells, at 60°. The diffusates for four pairs of cells were 11·65, 11·75, 11·63 and 11·47 grs.; mean 11·63 grs., which gives by proportion 12·14 grs. for a 2 per cent. solution. As the present salt differs only 0°·2 Fahr. in diffusion-temperature from the two preceding salts, which is inadequate to produce an assignable difference of diffusion, the three salts may be supposed to be diffused at the same temperature, without sensible error.

Diffusion of 2 per cent. solutions for 7 days.

	Grs.	Ratio.
Chloride of sodium at 60°	12·14	100
Bromide of sodium at 59°·8 . . .	11·93	98·27
Iodide of sodium at 59°·8	12·18	100·33
Mean	12·08	

In both these isomorphous groups of salts of potassium and sodium, there is certainly a near approach to equality of diffusion. The times for the salts of the two bases being in the empirical proportion of the square roots of 2 and 3, the mean diffusates also approach pretty closely; namely, 12·40 grs. for the salts of potassium and 12·08 grs. for the salts of sodium, which are as 100 to 97·42. Here the members of each group are certainly very similar to each other in density and probably other physical pro-

perties, which was not the case with the equidiffusive group containing the hydrogen acids of the same salt-radicals (p. 807).

35. *Chloride of Ammonium.*

Time of diffusion 5·716 days. The salt diffused was estimated by means of nitrate of silver.

Solution 0·988 per cent.; density 1·0036. Diffused at 53°, in eight cells, 6·09, 6·07, 5·67, 5·87; mean 5·92 grs., and 5·99 for one per cent. in two cells. This is somewhat more than 5·68, one-half of the diffusate of the 2 per cent. solution of iodide of potassium, at nearly the same temperature. The diffusion, however, of the small proportions of salts of ammonium, such as the 1 per cent. solution, is apt to be given in excess, from their low density.

36. *Dichloride of Copper.*

Time of diffusion seven days, or that of chloride of sodium. The salt diffused was obtained by evaporation to dryness, in an air-bath, after treating the liquid with an excess of chlorine, in the form of chloride, from which the dichloride was calculated.

It was an object of interest to discover whether the dichloride of copper (Cu_2Cl), which should be isomorphous with the chloride of sodium, may separate from the protochloride of copper and other magnesian salts, and assume the high diffusibility of the salts of alkaline metals. But the salt in question is entirely insoluble in water. A solution, however, was obtained by dissolving an equivalent quantity of the red suboxide of copper recently precipitated, in hydrochloric acid, of density 1·033, so as to give one grain of dichloride in every hundred water-grain measures of the solution. This acid solution did not precipitate by dilution with water. The salt was diffused into pure water at a mean temperature of 53°·2.

1. Dichloride of copper diffused, 6·66, 6·57, 7·01 and 6·48 grs.; mean 6·68 grs. in two cells. Chloride of sodium at 53°·4, nearly the same temperature, gave 5·90 grs. in the same time. Reducing the result to the temperature of 51° by an approximative correction, we should have 6·48 grs. of dichloride of copper for that temperature, at which chloride of calcium gave 6·51 grs. in 11·43 days, and protochloride of copper (Cu Cl) 6·06 grs. at nearly the same temperature, also in 11·43 days.

So far as we can judge from an experiment at a single temperature, it would appear that the diffusion of dichloride of copper is more rapid than that of the chloride (Cu Cl), in a proportion which supposes the former compound to possess half the "solution-density" of the latter, the times of equal diffusion 7 and 11·43 days, being when squared as 1 to 2.

With the view of discovering whether the large proportion of hydrochloric acid, amounting to 7 per cent., present in the preceding solution of dichloride of copper, modified the diffusion of the salt, a portion of the same acid solution was treated with chlorine gas, to convert the copper salt into chloride, and diffused into water, after

the excess of chlorine was removed by agitation of the solution with air. The proportion of salt present was thus increased in weight from 1 to 1·36 per cent. The time of diffusion was 11·43 days, and the temperature 53°.

2. Chloride of copper diffused from a 1·36 per cent. solution of the salt in hydrochloric acid, 5·83, 5·66, and 5·30 grs. in two cells; mean 5·60 grs.

The corresponding diffusion from a 1 per cent. solution may be supposed to be less than 5·6 grs., in the proportion of 1·36 to 1, without any great error. The results thus become chloride of copper diffused, 3·98, 3·85 and 3·58 grs.; mean 3·80 grs. in two cells.

It hence appears that the diffusion of chloride of copper is much diminished by the presence of a great excess of hydrochloric acid in the same solution. Different causes suggest themselves for this result, such as the possibility of a combination existing of chloride of copper with chloride of hydrogen, in the acid solution; or the influence which must be admitted of the more soluble substance, in a mixture of two similar substances, in repressing the diffusion of the less soluble. The present result, however, is entirely opposed to the idea that the high diffusibility of the dichloride of copper, observed before, is due to the hydrochloric acid present.

3. The diffusion of chloride of sodium also appears to be repressed by contact with a large excess of hydrochloric acid. One per cent. of chloride of sodium raised the density of dilute hydrochloric acid from 1·035 to 1·0408. Diffused into pure water for seven days at 52°·9, in eight cells, the diffusates of chloride of sodium were 3·80, 3·87, 4·00 and 3·86 grs.; mean 3·88 for two cells. The diffusion of chloride of sodium is thus reduced in a corresponding measure with that of chloride of copper by association with seven times its weight of hydrochloric acid.

These results are interesting in a very different point of view. I have always watched for the appearance of some absorbent or imbibing power on the part of the acids, more analogous to an endosmotic attraction for water, as usually conceived. If such an attraction existed, it would complicate the phenomena of diffusion, for the volume of water absorbed by the acid would displace and project a portion of the latter into the reservoir, the phial not being extensible. The high diffusibility of hydrochloric and nitric acids would be thus explained. But by such a mechanical displacement the chloride of sodium would be thrown out in the preceding experiment, as well as the hydrochloric acid, which is not the case.

4. Even in hydrochloric acid of density 1·124 (25 per cent.), the diffusion of 1 per cent. of chloride of sodium for seven days, at 56°·6, was found to amount to 4·7 grs. only in two cells, and is less than from a solution in pure water.

5. In comparing the influence of nitric acid with that of hydrochloric acid upon the diffusion of chloride of sodium, it was found that in a 7 per cent. solution of nitric acid, the chloride of sodium (1 per cent.) was entirely decomposed in the diffusive process, at 56°·6, and gave hydrochloric acid in the full diffusive equivalent of that acid, together with nitrate of soda.

37. *Bicarbonate of Potash.*

Time of diffusion 8·083 days, or double that of hydrate of potash. The water of the jars was partially charged with carbonic acid gas, to prevent the decomposition of this and the other bicarbonates in the act of diffusion. The usual number of eight cells of the 1 and 2 per cent. solutions were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together, and the quantity of bicarbonate of potash diffused for two cells, converted into the chloride of potassium, evaporated to dryness and weighed.

1. 1·059 per cent. of bicarbonate of potash ($HO . CO_2 + KO . CO_2$), density 1·00788, diffused at 68°·2, gave 7·66 grs. for two cells. Calculated for 1 per cent., 7·23 grs. of bicarbonate of potash in two cells.

2. 2·12 per cent. of bicarbonate of potash, density 1·01489, diffused at 62°·2, gave 14·88 grs. for two cells. Calculated for 2 per cent., 14·05 grs. of bicarbonate of potash in two cells.

3. 4·236 per cent. of bicarbonate of potash, density 1·0288, diffused at 68°·2, gave 14·15 grs. for 1 cell. Calculated for 4 per cent., 13·36 grs. of bicarbonate of potash in one cell.

4. 8·472 per cent. of bicarbonate of potash, density 1·05600, diffused at 68°·2, gave 27·55 grs. for one cell. Calculated for 8 per cent., 26·01 grs. of bicarbonate of potash in one cell.

Diffusion of Bicarbonate of Potash in 8·08 days at 68°·2; two cells.

	Grs.	Ratio.
From 1 per cent. solution . . .	7·23	1·029
From 2 per cent. solution . . .	14·05	2
From 4 per cent. solution . . .	26·72	3·806
From 8 per cent. solution . . .	52·01	7·408

38. *Bicarbonate of Ammonia.*

Time of diffusion 8·083 days. The usual number of eight cells of the 1 and 2 per cent. solutions of this substance were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together, and the quantity of bicarbonate of ammonia, diffused for two cells, determined by an alkalimetrical experiment, which was always repeated twice.

1. 1·109 per cent. of bicarbonate of ammonia ($HO . CO_2 + NH_4O . CO_2$), density 1·00553, diffused at 68°·2, gave 7·66 grs. for two cells. Calculated for 1 per cent., 6·91 grs. of bicarbonate of ammonia in two cells.

2. 2·218 per cent. of bicarbonate of ammonia, density 1·01056, diffused at 68°·2, gave 15·14 grs. for two cells. Calculated for 2 per cent., 13·65 grs. of bicarbonate of ammonia in two cells.

3. 4·436 per cent. of bicarbonate of ammonia, density 1·02000, diffused at 68°·2,

gave 14·98 grs. for one cell. Calculated for 4 per cent., 13·50 grs. of bicarbonate of ammonia in one cell.

4. 8·872 per cent. of bicarbonate of ammonia, density 1·03856, diffused at 68°·2, gave 27·78 grs. for one cell. Calculated for 8 per cent., 25·05 grs. of bicarbonate of ammonia in one cell.

Diffusion of Bicarbonate of Ammonia in 8·08 days at 68°·2 ; two cells.

	Grs.	Ratio.
From 1 per cent. solution	6·91	1·013
From 2 per cent. solution	13·65	2
From 4 per cent. solution	27·00	3·959
From 8 per cent. solution	50·10	7·346

The amount and progression of the diffusion of this salt correspond well, for all the proportions diffused, with the preceding isomorphous bicarbonate of potash.

39. *Bicarbonate of Soda.*

Time of diffusion 9·875 days. The usual number of eight cells of the 1 and 2 per cent. solutions were diffused, and four cells of the 4 and 8 per cent. solutions. The whole diffusates of each proportion were then mixed together, and the quantity of bicarbonate of soda, diffused for two cells, converted into chloride of sodium, evaporated to dryness and weighed.

1. 1·135 per cent. of bicarbonate of soda, $HO.CO_2+NaO.CO_2$, density 1·00892, diffused at 68°·1, gave 8·30 grs. for two cells. Calculated for 1 per cent., 7·31 grs. of bicarbonate of soda in two cells.

2. 2·27 per cent. of bicarbonate of soda, density 1·01703, diffused at 68°·1, gave 15·68 grs. for two cells. Calculated for 2 per cent., 13·81 grs. of bicarbonate of soda in two cells.

3. 4·54 per cent. of bicarbonate of soda, density 1·03306, diffused at 68°·1, gave 15·16 grs. for one cell. Calculated for 4 per cent., 13·35 grs. of bicarbonate of soda in one cell.

4. 9·08 per cent. of bicarbonate of soda, density 1·06386, diffused at 68°·1, gave 29·73 grs. for one cell. Calculated for 8 per cent., 26·19 grs. of bicarbonate of soda in one cell.

Diffusion of Bicarbonate of Soda in 9·87 days at 68°·1 ; two cells.

	Grs.	Ratio.
From 1 per cent. solution	7·31	1·059
From 2 per cent. solution	13·81	2
From 4 per cent. solution	26·70	3·869
From 8 per cent. solution	52·38	7·590

A remarkable approach to equality in the diffusion of the bicarbonates of potash

and soda, in the times chosen, is observed equally in all the proportions of salt from 1 to 8 per cent.

The results for the three bicarbonates may be stated as follows, the diffusate of the 2 per cent. solution of bicarbonate of potash being made equal to 200, as a standard of comparison.

Diffusion of Bicarbonates of Potash and Ammonia in 8·08 days, at 68°·2, and of Bicarbonate of Soda in 9·875 days, at 68°·1 :

	Bicarbonate of potash.	Bicarbonate of ammonia.	Bicarbonate of soda.
From 1 per cent. solution	102·9	98·3	104·0
From 2 per cent. solution	200·0	194·3	196·4
From 4 per cent. solution	380·6	384·3	380·0
From 8 per cent. solution	740·8	712·6	748·3

Or, making the diffusate from each proportion of the bicarbonate of potash equal to 100 :—

	Bicarbonate of potash.	Bicarbonate of ammonia.	Bicarbonate of soda.
From 1 per cent. solution	100	95·53	101·07
From 2 per cent. solution	100	97·15	98·20
From 4 per cent. solution	100	100·97	99·84
From 8 per cent. solution	100	96·19	101·03

The bicarbonate of ammonia is slightly lower in general than the bicarbonate of potash, possibly from a small loss of the former salt by evaporation in the different operations. The times chosen for these two bicarbonates is to that of the bicarbonate of soda, as the square root of 2 to the square root of 3, and the remarkable agreement observed in the diffusion of these salts gives support therefore to that relation. In alluding to this relation, however, it is proper to add that the carbonates of potash and soda deviate from it in a sensible degree, and the hydrates of potash and soda very considerably. If the relation therefore has a real foundation, it must be masked in the salts last named by differences existing between them in certain properties, the discovery and investigation of which is of the last importance for the theory of liquid diffusion.

40. *Hydrochlorate of Morphine.*

Time of diffusion 11·43 days. The crystallized salt was assumed to be of the composition $C_{34}H_{18}NO_6 . HCl + 6HO$, with the equivalent 374·5. The quantity diffused was determined from the chlorine, which was precipitated as chloride of silver in an acid solution. Hydrochlorate of morphine, 1·88 per cent. of the salt supposed anhydrous, diffused at 64°·1, in six cells, 11·03, 10·72, 11·01 ; mean 10·92 grs. of the anhydrous salt for two cells. Calculated for 2 per cent., 11·60 grs. at 64°·1 for two cells.

41. *Hydrochlorate of Strychnine.*

Time of diffusion 11·43 days. The crystallized salt was assumed to be of the composition $C_{42}H_{22}N_2O_4.HCl+3HO$, with the equivalent 397·5. Hydrochlorate of strychnine, 2 per cent., density 1·0065, diffused at 64°·1, in six cells, 11·54, 11·62, 11·31; mean 11·49 grs. for two cells. The quantities refer to anhydrous salt, and were estimated from the chlorine, as with hydrochlorate of morphine.

These two analogous salts appear to approach very closely in diffusibility.

Diffusion from 2 per cent. solutions at 64°·1; two cells.

Hydrochlorate of morphine	11·60	100
Hydrochlorate of strychnine	11·49	99·05

For a similar period of 11·43 days, but at a lower temperature, 53°·4, the 1 per cent. solution of hydrochlorate of morphine gave a mean result of 5·49 grs. from two cells, and the hydrochlorate of strychnine 5·77 grs. from two cells. But the weights of chloride of silver from which these numbers are deduced were too small to admit of much precision.

The diffusion of these salts of organic bases in 11·43 days, is exceeded by the diffusion of chloride of ammonium or potassium in 5·71 days, or half the former time. The vegeto-alkalies appear thus to be divided from ammonia and potash.

The new observations of the present paper are favourable to the existence of a relation amounting to close similarity or equality in diffusibility between certain classes of substances.

The chlorides and nitrates of the same metal generally exhibit this corespondence, as in the chloride of calcium and nitrate of lime, the chloride of sodium and nitrate of soda, and also in hydrochloric and nitric acids.

Isomorphous salts exhibit the same relation, as has been observed in the chlorides, bromides and iodides of potassium, sodium and hydrogen, in various salts of baryta, strontia and lead, in numerous magnesian salts, in the salts of silver, soda, and probably those of suboxide of copper, and in several additional salts of potash and ammonia.

Corresponding salts of two of the vegeto-alkalies are also found to be equidiffusive.

Before discussing the relations between the different groups of equidiffusive substances which are thus formed, it will be necessary to examine their diffusion at widely different temperatures, a subject attended with considerable difficulty.