THE
MAGNETIC MASS SUSCEPTIBILITIES
OF
MAGNESIUM AND ITS COMPOUNDS

Catherine H. Tinker.

INTRODUCTION

Although a great deal of work has been done by a number of investigators on the Magnetic Mass Susceptibilities of the chemical elements and their compounds, both inorganic and organic, ... has been carried out over a wide range of compounds of a single element. The following investigations represent practically the only ones in this field:-

Sugden, in 1934, investigated a range of Silver and Copper compounds; Spencer and Mollans, in 1935, investigated the compounds of Cadmium; and Trew, in 1935, investigated the Thallous compounds.

Previously, in 1929, Ikenmeyer had carried out work on the magnetic susceptibilities of the alkali metal halides, but this represents only one type of compound.

In the present work, the magnetic mass susceptibilities of Magnesium and thirty-five of its compounds, all of which have been highly purified, have been measured.

An attempt was made to prepare for investigation a number of magnesium amalgams, but these proved very
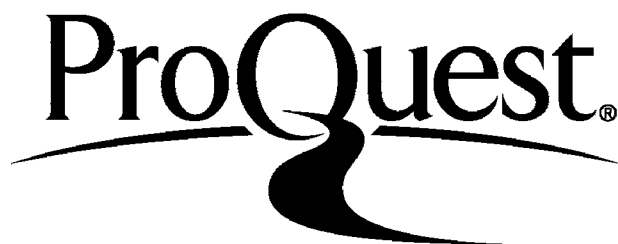
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ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
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ABSTRACT OF THESIS.

THE MASS SUSCEPTIBILITIES OF MAGNESIUM AND ITS COMPOUNDS.

The previous literature concerning the magnetic mass susceptibilities of Magnesium and its compounds is scanty and often only correct to two figures (giving an error of about 5%)

Measurements have been carried out over a range of some 35 highly purified compounds of Magnesium in the solid state and the resulting mass susceptibility values have been compared with existing values.

The ionic susceptibility of Magnesium has been determined. The compounds have been grouped according to the valency of the negative radical and the ionic susceptibility has been found to differ with the groups, due to the valency of the negative radical having a constitutive effect.

From the ionic susceptibility, the value of the mean square radius of the ion has been determined, and the value has been compared with theoretical values calculated by various methods.

The Additivity Law of the mass susceptibilities of the constituent components of the compounds, has been shown to hold good in some cases, and where deviations occur, suggestions for explanation have been put forward.

C. H. Tinker

THE MAGNETIC MASS SUSCEPTIBILITIES
OF MAGNESIUM AND ITS COMPOUNDS

INTRODUCTION

Although a great deal of work has been done by a
number of investigators on the Magnetic Mass Susceptibilities
of the chemical elements and their compounds, both inorganic
and organic, very little systematic work has been carried
out over a wide range of compounds of a single element.
The following investigations represent practically the
only ones in this field:-

[1]Sugden, in 1934, investigated a range of Silver
and Copper compounds; [2]Spencer and Hollens, in 1935,
investigated the compounds of Cadmium; and [3]Trew, in
1936, investigated the Thallous compounds.

Previously, in 1929, [4]Ikenmeyer had carried out work
on the magnetic susceptibilities of the alkali metal
halides, but this represents only one type of compound.

In the present work, the magnetic mass susceptibilities
of Magnesium and thirty-five of its compounds, all of
which have been highly purified, have been measured.

An attempt was made to prepare for investigation
a number of magnesium amalgams, but these proved very

difficult to handle due to their instability in the air, and required an elaborate technique which could not be developed in the time available.

From a certain number of the resulting molar susceptibilities, the gram ionic susceptibility of Magnesium has been determined, and the mean value obtained has been compared with the values calculated from the theoretical considerations of [5]Pauling, [6]Stoner, and [7]Slater, and with some experimental values measured by [8]Hocart, [9]Pascal, [10]Kido, [4]Ikenmeyer.

Values for the average mean square radius, and the approximate radius of the outer orbit of the Magnesium ion have been calculated from experimental data, and these have been compared with the corresponding values obtained theoretically from [7]Slater's approximate wave-functions.

EXPERIMENTAL

I. PREPARATION AND ANALYSIS.

Many of the compounds were obtained in a purified
state, and further purification was effected, where
possible, by recrystallisation.

For the preparation of the remaining compounds,
the starting materials used were pure commercial
Magnesium sulphate heptahydrate (Epsom Salts), which
was further purified by recrystallisation; Magnesium
oxide and Magnesium carbonate, each containing the other
as impurity.

All the compounds were tested for ferromagnetic
impurities, e.g. Iron, Nickel and Cobalt, by sensitive
characteristic reactions, as follows:-

(a) Iron. The presence of iron is demonstrated when a
purple colouration is produced on the addition of an
ammoniacal aqueous solution of thioglycollic acid
to the test solution, the reaction being sensitive
to the presence of 1 part in 5,000,000 parts of the
material.

(b) Nickel. The presence of nickel is demonstrated when
a red colouration is produced on the addition of a
dilute alcoholic solution of α-Benzildioxime and
ammonia to the test solution, the reaction being

sensitive to 1 part in 1,000,000 parts of the material.

(c) <u>Cobalt</u>. The presence of Cobalt is demonstrated when

an orange colouration is produced on the addition

of an aqueous solution of α-nitroso-β-naphthol, to

which dilute caustic soda solution and a little

ammonium chloride have been added. The reaction is

sensitive to 1 part in 100,000.

In all cases the result was negative or negligible;

that is, the whole of the materials used for the suscepti-

bility measurements were shown to contain less of the

ferromagnetic elements than the minimum quantity which

could affect the value of the measured susceptibility.

The method of analysis used was the determination

of the magnesium content (unless otherwise stated), by

the Pyrophosphate method of [11]B. Schmitz. By this method,

the magnesium is precipitated as the double magnesium

ammonium phosphate, and this is ignited at dull red heat

to the pyrophosphate:

$$2MgNH_4PO_4 \longrightarrow 2 NH_3 + H_2O + Mg_2P_2O_7$$
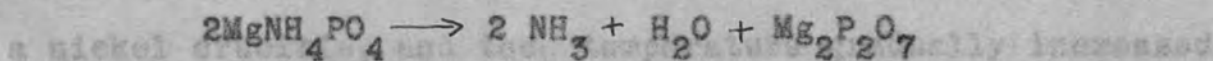
From 0.1 to 1.8 gram of the magnesium salt was

weighed out. This weight was dissolved in dilute hydrochloric

acid, and to this acidified solution, 5 grams of ammonium

acetate and an excess (about 5 grams) of dibasic ammonium

phosphate and a few drops of phenol-phthalein, were added.

The solution was heated to near the boiling-point, and

then ammonium hydroxide was added slowly. This precipitates the double salt, and the precaution of adding the ammonium hydroxide slowly enables the precipitate, which is amorphous at first, to become crystalline. Stirring is avoided if possible, as the precipitate adheres to the glass vessel wherever the stirrer touches it. The ammonium hydroxide is added until a faint pink colour is produced by the phenol phthalein. When the precipitate is entirely crystalline, more ammonium hydroxide is added until the colour is deep pink. The precipitate is allowed to stand for at least four hours, preferably overnight.

The precipitate is then filtered through a dry sintered alundum crucible of constant weight, and washed carefully and thoroughly with a more dilute ammonium hydroxide solution than that used for the precipitation. The ammoniacal washing solution is used because the precipitate is less soluble in ammonia than in water. The precipitate is then heated gently, after drying, in a nickel crucible, and the temperature gradually increased up to a dull red heat, which is maintained until the porcelain crucible containing the precipitate has reached a constant weight. The gradual increase of temperature ensures the formation of the pyrophosphate in preference to the meta-phosphate, which results from too rapid heating initially. The presence of meta-phosphate yields

results which are too high.

(1). Magnesium, Mg.

Pure powdered metal was used.

Analysis.

		A.	B.
Wt. Magnesium	=	0.2430 gm.	0.1421 gm.
Wt. $Mg_2P_2O_7$	=	1.1182 gm.	0.6538 gm.
Magnesium found	=	100.5 %	100.2 %

∴. The material used is evidently pure.

(2). Magnesium Oxide, MgO.

The commercial specimen contained magnesium
carbonate as impurity. An attempt was made to remove
the combined carbon dioxide by heating the material in
an electric furnace. This was unsuccessful, as was also
the attempt to remove oxides of nitrogen from the nitrate
by heating in the blow-pipe flame.

The commercial oxide was therefore digested with
very dilute hydrochloric acid, boiling the suspension.
In this way the magnesium carbonate in the specimen was
changed to the soluble magnesium chloride, and the remaining
insoluble oxide became "slaked", reacting with the water
to form magnesium hydroxide. This was filtered off and
washed as quickly as posible with boiling water to remove

(2). Magnesium Sulphate Heptahydrate, $MgSO_4.7H_2O$

all soluble impurities, dried as much as possible on a porous plate, and further dried in a desiccator over anhydrous calcium chloride, in air which had been freed of carbon dioxide by caustic soda.

The magnesium oxide was prepared from this pure hydroxide by heating it in an electric furnace at a cherry-red heat, i.e., about $1100^{\circ}C$.

$$Mg(OH)_2 \rightleftharpoons MgO + H_2O$$
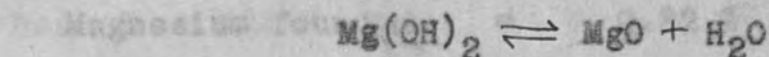
Analysis.

		A.	B.
Wt. MgO	=	0.1104 gm.	0.0898 gm.
Wt. $Mg_2P_2O_7$	=	0.3046 gm.	0.2482 gm.
Magnesium found	=	60.27 %	60.37 %
" calc.			60.33 %

(3). Magnesium Hydroxide, $Mg(OH)_2$.

The hydroxide was prepared as above in the preparation of magnesium oxide.

Analysis.

Wt. $Mg(OH)_2$	=	0.5078 gm.
Wt. $Mg_2P_2O_7$	=	0.2638 gm.
Magnesium found	=	42.05 %
" calc.	=	41.69 %

(4). <u>Magnesium Sulphate Heptahydrate</u>, $MgSO_4.7H_2O$

  Purified commercial Epsom Salts were recrystallised twice from water.

<center>Analysis.</center>

	A.	B.
Wt. $MgSO_4.7H_2O$	= 1.3096 gm.	1.3132 gm.
Wt. $Mg_2P_2O_7$	= 0.5887 gm.	0.5943 gm.
Magnesium found	= 9.82 %	9.89 %
" calc.		9.87 %

(5). <u>Magnesium Sulphate Monohydrate</u>, $MgSO_4.H_2O$

  Purified magnesium sulphate heptahydrate was heated at 130-140°C., the temperature not being allowed to exceed 150°C., as the anhydrous salt begins to be produced above that temperature. The salt is white and micro-crystalline.

<center>Analysis.</center>

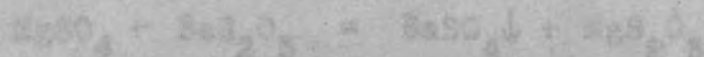 The sulphate ion was precipitated as barium sulphate. An excess of hot barium chloride solution was added to a boiling solution of the magnesium sulphate, barium sulphate being precipitated. This precipitate was filtered hot through a sintered glass crucible and thoroughly washed with hot water as quickly as possible, dried in air at 110°C., and weighed as barium sulphate.

		A.	B.
Wt. $MgSO_4.H_2O$	=	0.4542 gm.	0.4606 gm.
Wt. $BaSO_4$	=	0.7680 gm.	0.7812 gm.
Magnesium found	=	17.62 %	17.67 %
" calc.			17.57 %

(6). <u>Magnesium Sulphate (anhydrous)</u>, $MgSO_4$.

Purified magnesium sulphate heptahydrate was
heated at 200°C., until it ceased to lose weight. The
anhydrous salt thus obtained is a white amorphous powder.

<u>Analysis</u>.

The sulphate was precipitated with barium chloride
and the precipitate weighed as barium sulphate.

		A.	B.
Wt. $MgSO_4$	=	0.4381 gm.	0.4618 gm.
Wt. $BaSO_4$	=	0.8581 gm.	0.9114 gm.
Magnesium found	=	20.41 %	20.54 %
" calc.			20.22 %

(7). <u>Magnesium Thiosulphate Hexahydrate</u>, $MgS_2O_3.6H_2O$.

The salt was prepared by the double decomposition
of magnesium sulphate in solution with barium thiosulphate
in an aqueous suspension, the reaction taking place at
the boiling-point.

$$MgSO_4 + BaS_2O_3 = BaSO_4\downarrow + MgS_2O_3$$

The barium thiosulphate was prepared by mixing hot
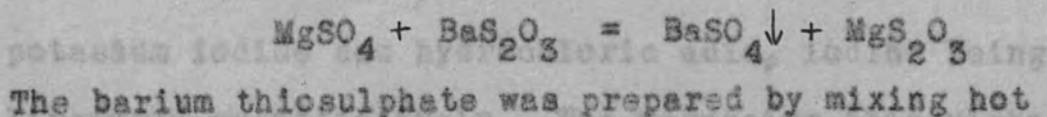
concentrated solutions containing the required molecular
quantities of recrystallised barium chloride and sodium
thiosulphate, and allowing to cool. The barium thiosulphate
was deposited as sparingly soluble shining white plates,
which were filtered off and washed well with distilled
water and dried in air.

$$BaCl_2 + Na_2S_2O_3 = 2NaCl + BaS_2O_3 \downarrow$$
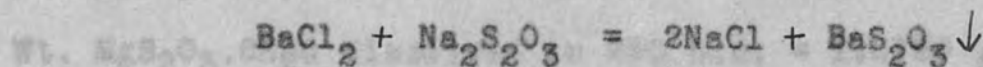
A hot suspension of the barium thiosulphate in water
was added to a hot solution of magnesium sulphate and
digested well, and the resulting precipitate of granular
barium sulphate was filtered off and any excess magnesium
sulphate was removed by careful addition of a solution
of barium thiosulphate in water - i.e., until there was
no further precipitate.

The solution of magnesium thiosulphate was then
evaporated until concentrated, when the crystals separated.
These were filtered off and recrystallised twice from
water.

Analysis.

The salt was analysed volumetrically as thiosulphate.
A solution of known concentration of magnesium thiosulphate
in water was titrated against a standard solution of
potassium dichromate, to which had been added excess
potassium iodide and hydrochloric acid, iodine being
liberated quantitatively. The magnesium thiosulphate

(9). Magnesium Fluoride monohydrate, $MgF_2.H_2O$.

reduced the iodine to magnesium iodide and magnesium

tetrathionate was formed:

$$K_2Cr_2O_7 + 14\ HCl + 6\ KI = 3\ I_2 \quad Cr_2Cl_6 + 8\ KCl + 7\ H_2O$$

$$2\ MgS_2O_3 + I_2 = MgI_2 + MgS_4O_6$$
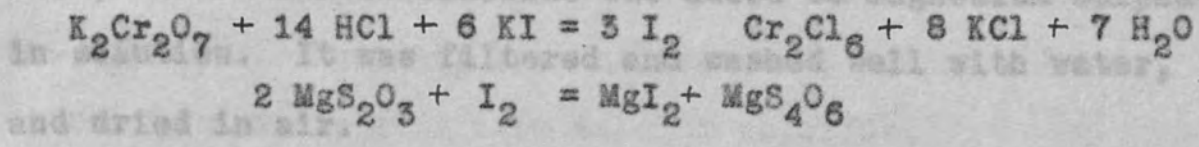
Normality of potassium dichromate solution = 0.9879 N/10.

Wt. $MgS_2O_3.6H_2O$ dissolved in 250 c.c. = 1.8720 gm.

Mean Titration Value = 32.458 c.c. - using 25 c.c. of

standard dichromate solution.

∴ Normality of Magnesium Thiosulphate solution

= 0.7610 N/10.

∴ Magnesium found = 9.89 %

" calculated = 9.95 %

(8). Magnesium Chromate pentahydrate, $MgCrO_4.5H_2O$.

"Kahlbaum" material was used and recrystallised

from water at 30°C.

Analysis.

	A.	B.
Wt. $MgCrO_4.5H_2O$ =	1.5214 gm.	1.0293 gm.
Wt. $Mg_2P_2O_7$ =	0.7310 gm.	0.4922 gm.
Magnesium found =	10.50 %	10.45 %
" calc. =	10.55 %	

(9). <u>Magnesium Fluoride monohydrate</u>, $MgF_2.H_2O$.

The salt was precipitated as a white gelatinous mass, when ammonium fluoride was added to magnesium sulphate in solution. It was filtered and washed well with water, and dried in air.

<u>Analysis.</u>

		A.	B.
Wt. $MgF_2.H_2O$	=	0.9226 gm.	0.9592 gm.
Wt. $Mg_2P_2O_7$	=	1.2921 gm.	1.3540 gm.
Magnesium found	=	30.59 %	30.84 %
" calc.	=		30.28 %

(10). <u>Magnesium Chloride hexahydrate</u>, $MgCl_2.6H_2O$.

Magnesium oxide was neutralised with hydrochloric acid, and the solution evaporated until crystals began to be deposited, and then allowed to cool when the salt crystallised out. The crystals were filtered and dried in air, and as they were deliquescent, they were stored in a desiccator over calcium chloride.

<u>Analysis.</u>

		A.	B.
Wt. $MgCl_2.6H_2O$	=	0.9385 gm.	0.6467 gm.
Wt. $Mg_2P_2O_7$	=	0.5060 gm.	0.3536 gm.
Magnesium found	=	11.78 %	11.94 %
" calc.	=		11.96 %

(11). <u>Magnesium Bromide hexahydrate</u>, $MgBr_2.6H_2O$.

Prepared similarly to the chloride by neutralising magnesium oxide with hydrobromic acid, and crystallising from the solution. The salt was deliquescent, and so was so stored in a desiccator over calcium chloride.

<div align="center">Analysis.</div>

	A.	B.
Wt. $MgBr_2.6H_2O$ =	0.8406 gm.	0.7708 gm.
Wt. $Mg_2P_2O_7$ =	0.3248 gm.	0.2968 gm.
Magnesium found. =	8.44 %	8.46 %
" calc. =	8.32 %	8.32 %

(12). <u>Magnesium Iodide octahydrate</u>, $MgI_2.8H_2O$.

Magnesium powder and iodine were mixed in approximately molecular proportions, there being a slight excess of magnesium. Distilled water was dropped slowly on to this mixture in a flask. The reaction was a violent one, and a large amount of heat was evolved. When the reaction was over, the slightly yellowish solution of magnesium iodide was filtered off, and evaporated until very concentrated. In the evaporation most of the excess iodine in solution was boiled off. Just before the salt crystallised from the solution, a very dilute solution of sulphur dioxide (about 5-6 bubbles passed into 200 c.c. water) was added until the solution was rendered

colourless, due to the iodine being reduced to hydriodic acid. The salt crystallised out as white plates, and was filtered off. It was recrystallised twice from water. As the crystals became brown when exposed to air, due to air oxidation, the salt was kept in a vacuum. It is very deliquescent.

Analysis.

		A.	B.
Wt. $MgI_2 \cdot 8H_2O$	=	0.6714 gm.	1.2056 gm.
Wt. $Mg_2P_2O_7$	=	0.1784 gm.	0.3246 gm.
Magnesium found	=	5.81 %	5.88 %
" calc.	=	5.76 %	

(13). Magnesium Chlorate hexahydrate, $Mg(ClO_3)_2 \cdot 6H_2O$.

Magnesium carbonate was neutralised by chloric acid, carbon dioxide being evolved. The colourless solution was filtered off from any excess carbonate. The salt crystallised out in white plates from a very concentrated solution, on cooling in ice. The crystals melt at $40^{\circ}C.$, and the salt is deliquescent.

Analysis.

		A.	B.
Wt. $Mg(ClO_3)_2 \cdot 6H_2O$	=	0.8600 gm.	1.4148 gm.
Wt. $Mg_2P_2O_7$	=	0.3258 gm.	0.5288 gm.
Magnesium found	=	8.27 %	8.17 %
" calc.	=	8.13 %	

(14). <u>Magnesium Perchlorate hexahydrate</u>, $Mg(ClO_4)_2.6H_2O$.

Magnesium carbonate was neutralised by aqueous perchloric acid, and the solution evaporated when needle-like crystals separated. The salt is slightly deliquescent.

Analysis.

	A.	B.
Wt. $Mg(ClO_4)_2.6H_2O$	= 0.6730 gm.	0.5477 gm.
Wt. $Mg_2P_2O_7$	= 0.2287 gm.	0.1849 gm.
Magnesium found	= 7.42 %	7.37 %
" calc.	=	7.35 %

(15). <u>Magnesium Bromate trihydrate</u>, $Mg(BrO_3)_2.3H_2O$.

The salt was prepared by the double decomposition of magnesium sulphate and barium bromate solutions, containing the molecular quantities of the salts, barium sulphate being precipitated. This was filtered off and the concentrated solution of magnesium bromate was treated with alcohol which precipitated the salt as small colourless rhombohedral crystals, which were slightly efflorescent in the air. The crystals melt at about 40°C.

Analysis.

	A.	B.
Wt. $Mg(BrO_3)_2.3H_2O$	= 0.8722 gm.	0.9690 gm.
Wt. $Mg_2P_2O_7$	= 0.2848 gm.	0.3200 gm.
Magnesium found	= 7.13 %	7.21 %
" calc.	=	7.26 %

(16). <u>Magnesium Iodate tetrahydrate</u>, $Mg(IO_3)_2 \cdot 4H_2O$.

The salt had been prepared by the addition of a solution of potassium iodate to a solution of a magnesium salt, each containing the required molecular quantities. The more insoluble magnesium iodate was precipitated.

Analysis.

The salt was analysed volumetrically. 25 c.c. portions of a solution of known concentration of magnesium iodate were heated with excess potassium iodide and sulphuric acid (hydrochloric acid was avoided owing to formation of iodine chloride), and iodine was liberated quantitatively.

$$Mg(IO_3)_2 + 10KI + 6H_2SO_4 = 6I_2 + MgSO_4 + 6H_2O + 5K_2SO_4$$
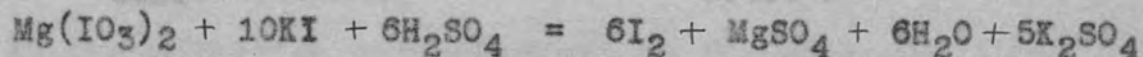
The iodine was then titrated by a standardised solution of sodium thiosulphate, using "starch solution" as indicator.

Normality of Sodium thiosulphate solution = 0.9908 N/10

Titration value of $Na_2S_2O_3$ = 51.79 c.c.

∴ Normality of magnesium iodate solution = 2.052 N/10

∴ No. of gms. magnesium in solution = 0.4165 gm.

No. of gms. magnesium iodate weighed out = 0.7685 gm.

Magnesium found = 5.42 %

" calc. = 5.45 %

(17). <u>Magnesium Nitrate hexahydrate</u>, $Mg(NO_3)_2.6H_2O$.

Magnesium oxide was neutralised with nitric acid, and the solution evaporated, when colourless crystals of the nitrate separated. These were filtered off and recrystallised from water. They were dried on a porous plate, and stored in a desiccator over anhydrous calcium chloride, since the salt is deliquescent.

Analysis.

		A.	B.
Wt. $Mg(NO_3)_2.6H_2O$	=	1.8655 gm.	1.8203 gm.
Wt. $Mg_2P_2O_7$	=	0.7958 gm.	0.7874 gm.
Magnesium found	=	9.317 %	9.448 %
" calc.	=	9.484 %	

(18). <u>Magnesium mono-Hydrogen Orthophosphate trihydrate</u>, $MgHPO_4.3H_2O$.

A solution of disodium hydrogen phosphate was added to a solution of magnesium sulphate, when the magnesium acid phosphate was precipitated as a gelatinous white mass. It was allowed to stand overnight before filtering.

$$Na_2HPO_4 + MgSO_4 = MgHPO_4 + Na_2SO_4$$
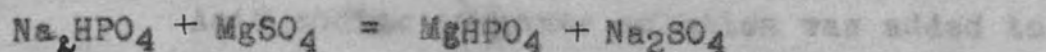
The precipitate was dried in air and analysed by conversion into the pyrophosphate.

Analysis.

	A.	B.
Wt. $MgHPO_4.3H_2O$ =	1.1933 gm.	0.9093 gm.
Wt. $Mg_2P_2O_7$ =	0.7660 gm.	0.5843 gm.
Magnesium found =	14.02 %	14.04 %
" calc. =		13.95 %

(19). <u>Magnesium Pyrophosphate</u>, $Mg_2P_2O_7$.

Magnesium ammonium phosphate was ignited gently
at first and later in an electric furnace. It is a
white amorphous powder.

$$2MgNH_4PO_4 \longrightarrow 2NH_3 + H_2O + Mg_2P_2O_7$$
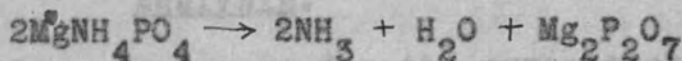
Analysis.

As the magnesiun pyrophosphate is the weighed
product of the analyses, and is obtained pure, no analysis
for the compound, used for susceptibility measurements,
was made.

(20). <u>Magnesium mono-Hydrogen ortho-Arsenate hemi-tridecahydrate</u>,
$2MgHAsO_4.13H_2O$.

Acid sodium arsenate solution was added to
a solution of magnesium sulphate, when the magnesium arsenate
was precipitated. It is a white amorphous powder.
After filtration the salt was dried in air.

Analysis.

		A.	B.
Wt. $2MgHAsO_4.13H_2O$	=	0.5802 gm.	0.6692 gm.
Wt. $Mg_2P_2O_7$	=	0.2299 gm.	0.2640 gm.
Magnesium found	=	8.656 %	8.618 %
" calc.	=	8.644 %	

(21). <u>Magnesium pyroarsenate</u>, $Mg_2As_2O_7$.

Magnesium ammonium arsenate was ignited directly
to the pyroarsenate, similarly to the preparation of
magnesium pyrophosphate.

Analysis.

No analyses made, as for the pyrophosphate.

(22). <u>Magnesium Ammonium Sulphate hexahydrate</u>, $MgSO_4.(NH_4)_2SO_4.6H_2O$

"A.R." material was recrystallised from water.

Analysis.

		A.	B.
Wt. $MgSO_4(NH_4)_2SO_4.6H_2O$	=	0.7253 gm.	0.8152 gm.
Wt. $Mg_2P_2O_7$	=	0.2243 gm.	0.2501 gm.
Magnesium found	=	6.754 %	6.700 %
" calc.	=	6.745 %	

(23). <u>Magnesium Ammonium Chloride hexahydrate</u>, $MgCl_2.NH_4Cl.6H_2O$.

"A.R." material was recrystallised from water.

<center>Analysis.</center>

		A.	B.
Wt. $MgCl_2.NH_4Cl.6H_2O$	=	0.5022 gm.	0.5150 gm.
Wt. $Mg_2P_2O_7$	=	0.2182 gm.	0.2195 gm.
Magnesium found	=	9.49 %	9.31 %
" calc.	=	9.47 %	

(24). <u>Magnesium Ammonium Bromide hexahydrate</u>, $MgBr_2.NH_4Br.6H_2O$.

The required molecular quantities of magnesium bromide and recrystallised ammonium bromide were dissolved in water and mixed and the solution evaporated on the water-bath, when the double salt crystallised out as white needle-shaped crystals. These were recrystallised twice from water. The salt is slightly deliquescent, and was there-fore stored over anhydrous calcium chloride in a desiccator.

<center>Analysis.</center>

		A.	B.
Wt. $MgBr_2NH_4Br.6H_2O$	=	0.7354 gm.	0.6128 gm.
Wt. $Mg_2P_2O_7$	=	0.2101 gm.	0.1780 gm.
Magnesium found	=	6.24 %	6.35 %
" calc.	=	6.23 %	

(25). <u>Magnesium Ammonium Phosphate hexahydrate</u>, $MgNH_4PO_4.6H_2O$.

"A.R." material used.

<center>Analysis.</center>

A weighed quantity was ignited directly to the

(25). pyrophosphate.

	A.	B.
Wt. $MgNH_4PO_4.6H_2O$	= 0.5942 gm.	0.5816 gm.
Wt. $Mg_2P_2O_7$	= 0.2699 gm.	0.2638 gm.
Magnesium found	= 9.915 %	9.908 %
" calc.	=	9.906 %

(26). **Magnesium Ammonium Arsenate hexahydrate**, $MgNH_4AsO_4.6H_2O$.
"Kahlbaum" material used.

Analysis.

A weighed quantity was ignited directly to the pyroarsenate, similarly to the double phosphate, above.

	A.	B.
Wt. $MgNH_4AsO_4.6H_2O$	=	0.7176 gm.	0.6672 gm.
Wt. $Mg_2As_2O_7$	=	0.3901 gm.	0.3618 gm.
Magnesium found	=	8.51 %	8.50 %
" calc.	=	8.41 %	

(27). **Magnesium Ferricyanide penta-decahydrate**, $Mg_3[Fe(CN)_6]_2.15H_2O$.
"Kahlbaum" material used. It is a brownish-yellow salt.

Analysis.

	A.	B.
Wt. $Mg_3[Fe(CN)_6]_2.15H_2O$	= 0.9281 gm.	0.9301 gm.
Wt. $Mg_2P_2O_7$	= 0.4060 gm.	0.4104 gm.
Magnesium found	= 9.56 %	9.64 %
" calc.	=	9.52 %

(28). <u>Magnesium Carbonate trihydrate</u>, $MgCO_3.3H_2O$.

     As the commercial magnesium carbonate (anhydrous) proved to be about 12 per cent. impure, it was rejected. The trihydrated salt was prepared by dissolving the required molecular quantities of sodium bicarbonate and magnesium sulphate in water and mixing the two solutions. A solution of magnesium bicarbonate was thus obtained, and the magnesium carbonate was precipitated from this by the addition of alcohol. The precipitate was flocculent at first, but became crystalline on standing. It was filtered off, washed well with water, and dried in air.

<div align="center">

Analysis.

		A.	B.
Wt. $MgCO_3.3H_2O$	=	0.3879 gm.	0.2960 gm.
Wt. $Mg_2P_2O_7$	=	0.3139 gm.	0.2412 gm.
Magnesium found	=	17.63 %	17.80 %
" calc.	=		17.58 %

</div>

(29). <u>Magnesium Ethyl Sulphate</u>, $Mg(C_2H_5SO_4)_2.3H_2O$.

     "Kahlbaum" material used.

<div align="center">

Analysis.

	A.	B.
Wt. $Mg.(C_2H_5SO_2)_2.5H_2O$ =	0.5960 gm.	0.6858 gm.
Wt. $Mg. P O$	= 0.2251 gm.	0.2589 gm.
Magnesium found	= 0 8.25 %	8.13 %
" calc.	=	8.114 %

</div>

(30). <u>Magnesium Formate dihydrate</u>, $Mg(HCOO)_2.2H_2O$.

     Magnesium carbonate was neutralised with formic acid.
The solution of magnesium formate was evaporated on the
water-bath, and white crystals were deposited. These
were filtered and dried in air.

<div align="center">Analysis.</div>

		A.	B.
Wt. $Mg(HCOO)_2.2H_2O$	=	1.0246 gm.	0.5596 gm.
Wt. $Mg_2P_2O_7$	=	0.7532 gm.	0.4174 gm.
Magnesium found	=	16.06 %	16.29 %
" calc.	=		16.17 %

(31). <u>Magnesium Acetate dihydrate</u>, $Mg(CH_3COO)_2.2H_2O$.

     Magnesium oxide was neutralised with acetic acid.
The solution of magnesium acetate was evaporated on the
water-bath. The salt does not crystallise out, but
becomes a thick colourless syrup, which was evaporated
to dryness, when it became the solid dihydrate.

<div align="center">Analysis.</div>

		A.	B.
Wt. $Mg(CH_3COO)_2.2H_2O$	=	0.3658 gm.	0.3979 gm.
Wt. $Mg_2P_2O_7$	=	0.2658 gm.	0.2851 gm.
Magnesium found	=	15.87 %	15.65 %
" calc.	=		15.74 %

(32). <u>Magnesium Butyrate tetrahydrate</u>, $Mg(CH_3(CH_2)_2COO)_2.4H_2O$.

"Kahlbaum" material used. White greasy plate-like crystals, which smell slightly of butyric acid.

<h3 style="text-align:center">Analysis.</h3>

		A.	B.
Wt. $Mg(CH_3(CH_2)_2COO)_2$	=	0.3142 gm.	0.3023 gm.
Wt. $Mg_2P_2O_7$	=	0.1320 gm.	0.1264 gm.
Magnesium found	=	9.18 %	9.14 %
" calc.	=		9.01 %

(33). <u>Magnesium Oxalate dihydrate</u>, $Mg(COO)_2.2H_2O$.

Purified "Kahlbaum" material was used. White powder.

<h3 style="text-align:center">Analysis.</h3>

The salt was analysed volumetrically as oxalate. 25 c.c. portions of a solution of magnesium oxalate, acidified with sulphuric acid, and warmed to 60°C., were titrated with a solution of potassium permanganate, which had been standardised with oxalic acid.

Wt. of magnesium oxalate in 250 c.c.	= 1.8178 gm.
Normality of Pot. permang. solution	= 1.061 N/10
Titration value of Pot. permang. soln.	= 22.837 c.c.
∴ Normality of magnesium oxalate soln.	= 0.9694 N/10
∴ No. of gms. magnesium in solution	= 0.2947 gm.
No. of gms. Mag. oxalate weighed out	= 1.8178 gm.
∴ % Magnesium found	= 16.21 %
" calc.	= 16.39 %

(34). <u>Magnesium Succinate tetrahydrate</u>, $Mg(CH_2COO)_2.4H_2O$.

Purified "Kahlbaum" material was used.

<u>Analysis</u>.

		A.	B.
Wt. $Mg(CH_2COO)_2.4H_2O$	=	0.8394 gm.	0.5343 gm.
Wt. $Mg_2P_2O_7$	=	0.4432 gm.	0.2806 gm.
Magnesium found		11.53 %	11.48 %
" calc.	=		11.45 %

(35). Magnesium d-Tartrate hemi-pentahydrate, $2Mg(C_4H_4O_6)_2.5H_2O$.

Magnesium carbonate was neutralised with a solution

of tartaric acid. After leaving the resulting solution

of magnesium tartrate to stand for a few hours, the salt

was deposited as a crystalline solid. This was filtered

and washed well with water, and dried in air.

<u>Analysis</u>.

		A.	B.
Wt. $2Mg(C_4H_4O_6)_2.5H_2O$	=	0.3705 gm.	0.2424 gm.
Wt. $Mg_2P_2O_7$	=	0.1900 gm.	0.1242 gm.
Magnesium found	=	11.20 %	11.18 %
" calc.	=		11.19 %

(36). <u>Magnesium salt of 8-hydroxy-Quinoline</u>,
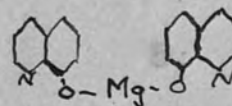
A solution of magnesium sulphate acidified with

hydrochloric acid (to prevent precipitation of magnesium

hydroxide by ammonium hydroxide), was made just alkaline

with ammonium hydroxide, and the solution heated to boiling.

A solution of 8-hydroxy-quinoline (M.P. 74°C.) in glacial acetic acid was added slowly. The magnesium salt of 8-hydroxy-quinoline was precipitated as a flocculent yellow mass. This was boiled for about 10 minutes, stirring all the time, until the precipitate became granular. The precipitate was filtered hot and washed with hot dilute ammonium hydroxide until all the base was removed from the solution. The precipitate was then dried in the air oven at 130 - 140°C. for about 8 - 10 hours.

This method of preparation is due to [12]Berg, and can be used as a gravimetric estimation of magnesium.

Analysis.

When the normal analysis of magnesium by the pyrophosphate method was carried out, the original 8-hydroxy-quinoline compound separated, on the addition of ammonium hydroxide. Therefore the weighed compound was ignited to decompose the organic radical, and the residue dissolved in hydrochloric acid and filtered. This filtrate was then analysed in the usual way.

Analysis (result)

	A.	B.
Wt. $Mg(C_9H_6NO)_2$ =	0.5615 gm.	0.8237 gm.
Wt. $Mg_2P_2O_7$ =	0.2007 gm.	0.2948 gm.
Magnesium found =	7.81 %	7.82 %
" calc. =	7.78 %	

(37). <u>Magnesium, Mg.</u>

The metal cast into sticks was also used. The sticks were cleaned with sand-paper before use to remove any adherent oxide. Lengths were cut off the ends, dissolved in hydrochloric acid, after weighing, and the resulting acid solution of magnesium chloride was made up to 500 c.c. with distilled water.

<u>Analysis.</u>

50 c.c. of the solution for each length was taken and the magnesium precipitated as the double ammonium phosphate in the usual way.

	Stick A.		Stick B.	
Wt. Mg. =	0.0901 gm.	0.0868 gm.	0.0855 gm.	0.0880 gm.
Wt. $Mg_2P_2O_7$ =	0.4174 gm.	0.3992 gm.	0.3944 gm.	0.4064 gm.
Magnesium found =	101.2 %	100.5 %	100.7 %	100.6 %

II. MEASUREMENT OF SUSCEPTIBILITIES

The method of measurement used is the modified Guoy method.

The measurement is made by weighing the force on the specimen which is suspended in a non-homogeneous magnetic field.

Diamagnetic substances:- force is negative and therefore the substance tends to move upwards from the field of greatest intensity.

Para- and Ferromagnetic substances:- the force is positive and therefore the substance tends to move downwards to the field of greatest intensity.

K_1 = Volume Susceptibility of substance.

K_2 = "are constant" for a " medium.

H_1 = Maximum field at centre of magnet at base of cylinder.

H_2 = Maximum field at the top of the cylinder.

l = Length of column of substance (in cm.).

N. S. = North and South poles of electromagnet.

A = Area of cross-section of substance (in cm^2.).

F = Force (upward or downward) in dynes.

μ_1 = Permeability of material.

μ_2 = " " medium (e.g. air).

Then the force on a material of permeability μ_1 in a medium of permeability μ_2 is given by:-

$$F = \frac{(\mu_1 - \mu_2).A.(H_1^2 - H_2^2)}{8\pi}$$

Since $\mu = 1 + 4\pi K$

$$\therefore F = \tfrac{1}{2}(K_1 - K_2).A.(H_1^2 - H_2^2)$$

i.e. $K_1 = \dfrac{2F}{A(H_1^2 - H_2^2)} + K_2$

Since χ = mass susceptibility = K/d, where d = density of column,

and since $d = \dfrac{W}{lA}$ (w = weight of column),

$$\therefore \chi = \frac{2Fl}{w(H_1^2 - H_2^2)} + \frac{K_2 lA}{w}$$

K_2 = volume susceptibility of air = 0.03×10^{-6}

i.e. $\chi \times 10^6 = \dfrac{2Fl}{w(H_1^2 - H_2^2)} + \dfrac{0.03\ lA}{w}$

If 'l' is large enough, H_2 becomes zero.

The length of the column, 'l', and the fields H_1 and H_2, are constant for a given length of column and aperture between the pole pieces.

$$\therefore \chi \times 10^6 = \frac{\alpha F}{w} + \frac{0.03\ lA}{w}$$

where α = a constant for the apparatus,

$$= \frac{2l}{H_1^2} \text{ in absolute unuts.}$$

Gouy Method

- - - - - - - Platinum Suspension.

- - - - - - Stirrup.

Tube packed
- - - - - - - with solid

Distance piece.

ew holding
net poles
position.

Soft iron pole
- - - piece of
electromagnet.

oil - - - - - Coil.

Vertical Section

Tube containing
Solid

Magnet
pole - - - - -

rew holding - -
gnet pole in
position.

Horizontal
Section

Aperture of
distance piece.
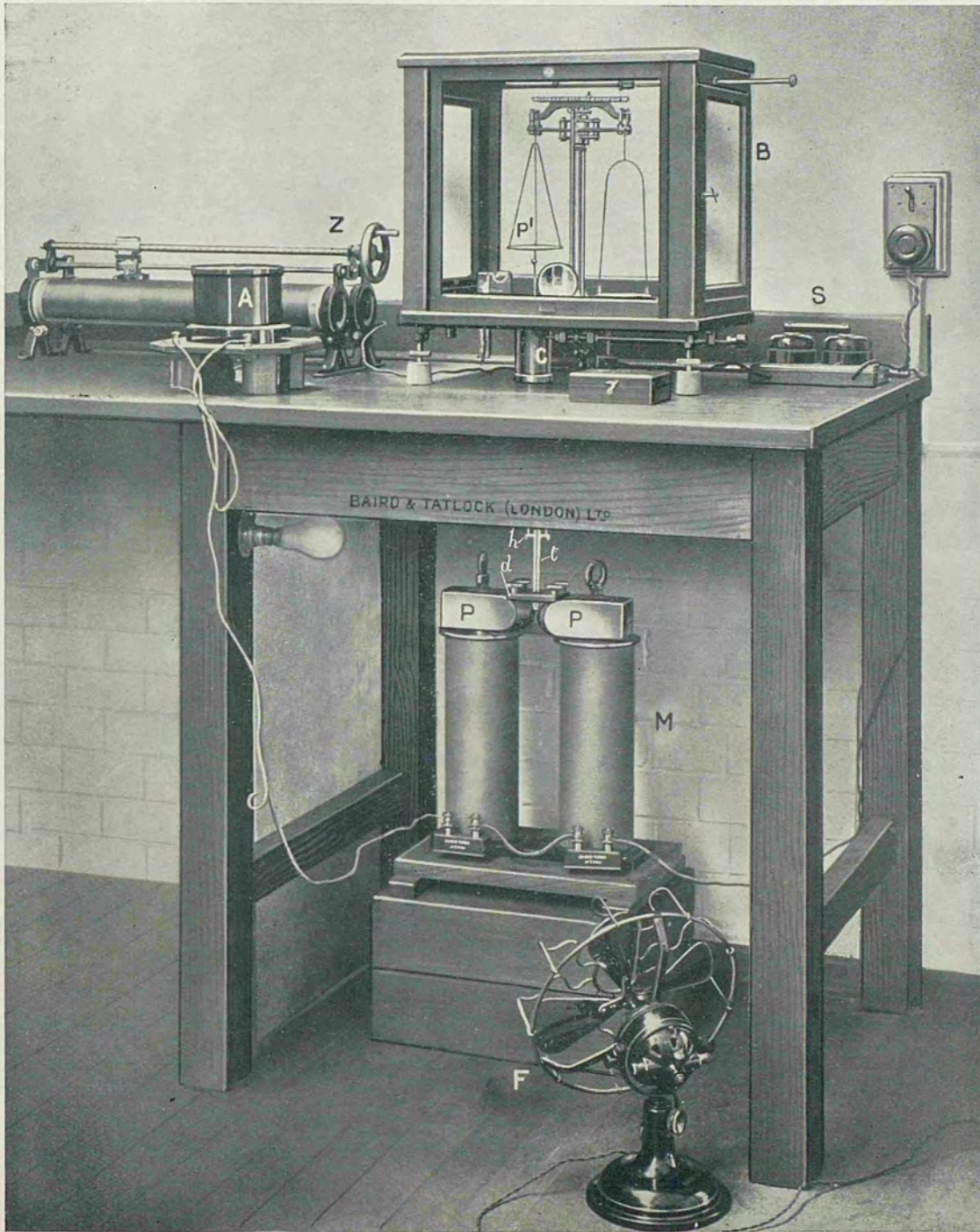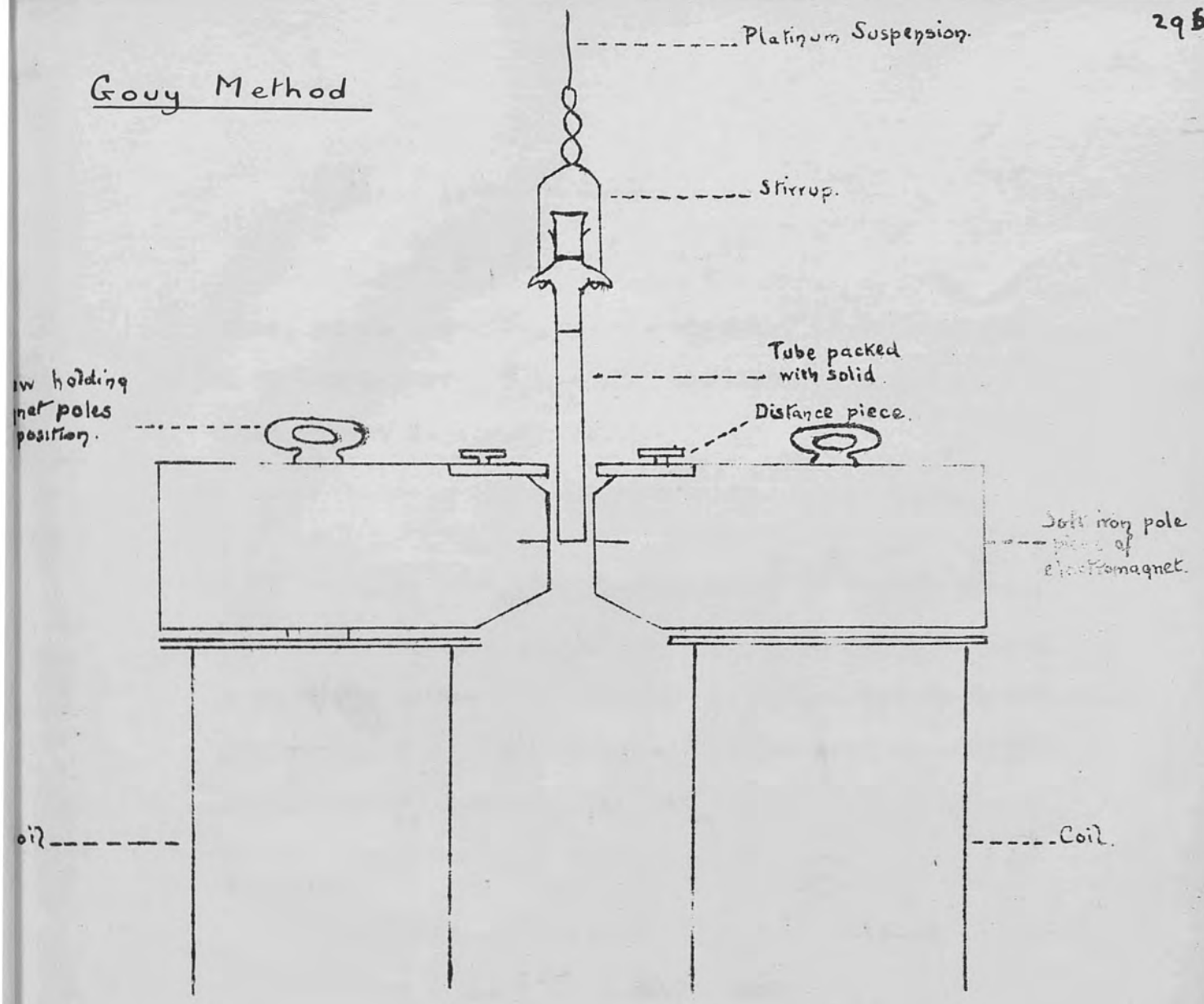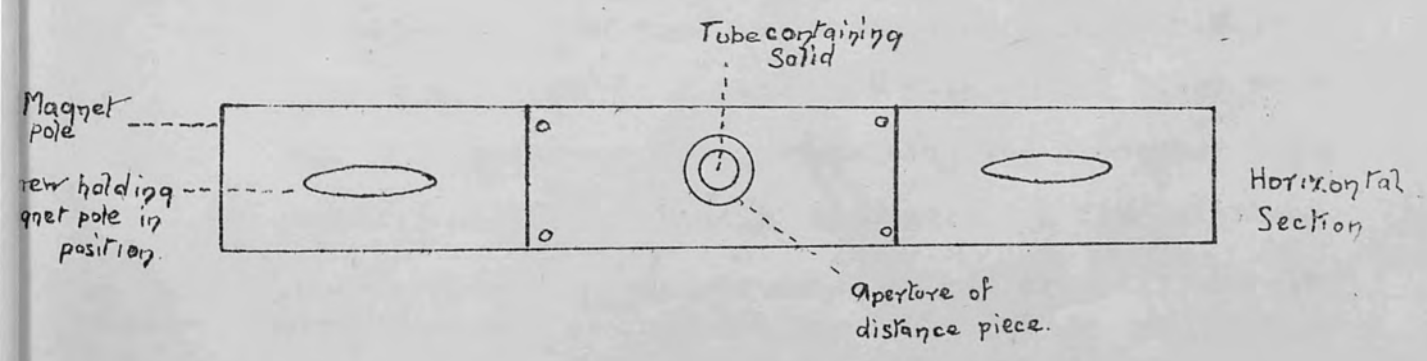
Since 1A = V = volume,

$$\therefore \chi \times 10^6 = \frac{\alpha F}{w} + \frac{0.03V}{w}$$

When, as is convenient, F is measured in milligrams,
l in centimetres, V in cubic centimetres and w in grams,
then α must be expressed:-

$$\alpha = \frac{21}{H_1^2} \cdot \frac{981 \times 10^6}{1000} \quad \text{in C.G.S. units}$$

The coil of the magnet consists of 20,000 turns.

A current of 3 amperes at 20 volts gives a field
H of 5,000 gauss. The current is controlled by a variable
rheostat and registered by an ammeter, and is switched
on and off by means of two pole switches.

Weighing.

This is done by means of a very sensitive balance
of the Bunge type, with a short beam.

The weighings are made to 0.01 mgm. by oscillations,
the scale being read through a lens.

The balance is mounted above the electro-magnet.
The left-hand scale-pan is replaced by a light aluminium
support and disc which carries a hook on its lower side.
From this hook, the tube, containing the substance under
investigation, is suspended by means of a fine platinum
wire (0.04" diameter), attached to a brass stirrup. The

off, and then on. The difference in weight thus obtained
is due to the force of attraction or of repulsion due to
magnetisation. From this weight difference, the suscepti-
bility can be calculated, by substitution in the equation:-

$$\chi \times 10^6 = \frac{\alpha F}{w} + \frac{0.03V}{w}$$

The force due to the tube must be substracted or
added according to the substance being Dia- or Para-
magnetic respectively. If the net force is greater than
the original, then the substance is Paramagnetic; if less,
then it is Diamagnetic.

Draughts must be excluded from the whole apparatus,
and also the coil must not be allowed to become hot, due
to the magnet being left on too long, as both these
upset the oscillations - convection currents in the latter
case being caused by heating.

The weights of the substance and tube were determined
to 0.01 mgm., weighing by oscillations, in zero field,
and in the experimental field.

Constants of the Balance for the Experimental Tube.

The pull of the tube was determined by weighing the
empty tube, in air, with the magnet off and then on.

The value α in the equation:-

$$\chi \times 10^6 = \frac{\alpha F}{w} + \frac{0.03V}{w}$$

was determined by measuring the pull of a pure substance

of known mass susceptibility such as benzene ($\chi = 0.716 \times 10^{-6}$).

The volume, V, of the tube up to the mark, was obtained by filling it with distilled water and weighing at a known temperature. Thus the density was known and the volume follows.

Pull of tube I.

Magnet off.	Magnet on.	Pull.
4.43 mgm.	4.12 mgm.	- 0.31 mgm.
4.50 "	4.20 "	- 0.30 "
4.51 "	4.19 "	- 0.32 "
7.92 "	7.60 "	- 0.32 "
3.18 "	2.87 "	- 0.31 "
3.14 "	2.74 "	- 0.40 "
	Mean Pull =	- 0.33 "

Constant of the Balance.

$$V \times 0.03 = 0.098 \text{ c.c.}$$

$$\chi_{Benzene} = - 0.716 \times 10^{-6}$$

Magnet off.	Magnet on.	Pull.
8.61 mgm.	4.72 mgm.	- 3.89 mgm.
8.36 "	4.45 "	- 3.91 "
7.89 "	4.02 "	- 3.87 "
	Mean Pull =	- 3.89 "

∴ Net Pull = - 3.89   0.33 = - 3.56 mgm.

Wt. of Benzene $=$ 3.0628 gm.

$$\therefore \quad \alpha = \frac{-(w \times \chi) - (V \times 0.03)}{-P}$$

$$= \frac{-(3.0628 \times 0.716) - 0.098}{-3.56}$$

$$\text{Mean} = \underline{0.631}$$

The values of α and V for other tubes used were determined similarly.

SUSCEPTIBILITY MEASUREMENTS

(1). <u>Magnesium</u>, Mg (Powder).

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	+5.61 mgm				
	+5.75 "	+ 5.66 mgm	+5.99 mgm	2.6358 gm	+ 1.471
	+5.63 "				
(b)	+5.79 "				
	+5.79 "	+ 5.75 "	+6.08 "	2.6309 "	+ 1.494
	+5.66 "				
(c)	+6.24 "				
	+6.27 "	+ 6.29 "	+6.62 "	2.6856 "	+ 1.591
	+6.35 "				
(d)	+6.26 "				
	+6.20 "	+ 6.22 "	+ 6.55 ""	2.6181 "	+ 1.615
	+6.20 "				

<u>Mean Value = + 1.540</u>

(2). <u>Magnesium Oxide</u>, MgO.

Pull of Tube I = -0.55 mgm.; α =0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-0.98 mgm				
	-1.00 "	-1.00 mgm	-0.67 mgm	1.9685 gm	-0.165
	-1.01 "				
(b)	-0.94 "				
	-0.97 "	-0.98 "	-0.65 "	2.0112 "	-0.160
	-1.02 "				
(c)	-1.08 "				
	-1.13 "	-1.11 "	-0.78 "	2.2082 "	-0.178
	-1.12 "				

<u>Mean Value = -0.168</u>

(3). <u>Magnesium Hydroxide</u>, $Mg(OH)_2$.

Pull of Tube I = −0.33 mgm.; α=0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	−1.44 mgm.				
	−1.47 "	−1.46 mgm.	−1.13 mgm.	1.8623 gm.	−0.330
	−1.48 "				
(b)	−1.47 "				
	−1.51 "	−1.51 "	−1.18 "	1.9402 "	−0.335
	−1.56 "				
(c)	−1.54 "				
	−1.54 "	−1.55 "	−1.22 "	1.9497 "	−0.346
	−1.57 "				

<u>Mean Value = −0.337</u>

(5) <u>Magnesium Sulphate monohydrate</u>, $MgSO_4.H_2O$.

Pull of Tube II = -0.55 mgm. α = 0.634; V x 0.03 = 0.101 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-4.63 mgm.				
	-4.58 "	-4.59 mgm.	-4.04 mgm.	5.9107 gm.	-0.416
	-4.56 "				
(b)	-4.56 "				
	-4.52 "	-4.54 "	-3.99 "	5.9735 "	-0.407
	-4.55 "				
(c)	-4.48 "				
	-4.53 "	-4.50 "	-3.95 "	5.8985 "	-0.407
	-4.50 "				

Mean Value = -0.410

(Tube I was used for the 3rd. Packing).

(6) <u>Magnesium Sulphate - anhydrous</u>, $MgSO_4$.

Pull of Tube II = $- 0.55$ mgm.; $\alpha = 0.634$; $V \times 0.03 = 0.101$ c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	$\chi \times 10^6$
(a)	−3.71 mgm.				
	−3.66 "	−3.68 mgm.	−3.13 mgm.	5.2388 gm.	−0.336
	−3.66 "				
(b)	−3.53 "				
	−3.49 "	−3.51 "	−2.96 "	5.2262 "	−0.339
	−3.50 "				
(c)	−2.77 "				
	−2.85 "	−3.82 "	−2.49 "	4.4023 "	−0.335
	−2.84 "				

(Tube I was used for the 3rd. Packing).

<u>Mean Value = −0.337</u>

(7). <u>Magnesium Thiosulphate hexahydrate</u>, $MgS_2O_3.6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634;   V x 0.03 = 0.101 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	$\chi \times 10^6$
(a)	-4.14 mgm.				
	-4.08 "	-4.11 mgm.	-3.56 mgm.	4.0604 gm.	-0.531
	-4.11 "				
(b)	-4.20 "				
	-4.29 "				
		-4.26 "	-3.71 "	4.2262 "	-0.534
	-4.30 "				
	-4.27 "				
(c)	-4.25 "				
	-4.28 "	-4.27 "	-3.72 "	4.2603 "	-0.531
	-4.28 "				

<u>Mean Value = -0.532</u>

(8). <u>Magnesium Chromate pentahydrate</u>, $MgCrO_4.5H_2O$.

Pull of Tube III= -0.64 mgm.; α= 0.640; V x 0.03 = 0.110 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -2.43 mgm.				
-2.42 "	-2.43 mgm.	-1.79 mgm.	5.2561 gm.	-0.197
-2.44 "				
(b) -2.36 "				
-2.34 "	-2.36 "	-1.72 "	5.1676 "	-0.191
-2.38 "				
(c) -2.42 "				
-2.40 "	-2.41 "	-1.77 "	5.2049 "	-0.192
-2.41 "				

<u>Mean Value = -0.193</u>

(9).<u>Magnesium Fluoride monohydrate</u>, $MgF_2.H_2O$.

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -3.20 mgm.				
-3.23 "	-3.22 mgm.	-2.58 mgm.	4.2699 gm.	-0.361
-3.22 "				
(b) -3.23 "				
-3.21 "	-3.22 "	-2.58 "	4.3036 "	-0.358
-3.23 "				
(c) -3.22 "				
-3.28 "	-3.25 "	-2.61 "	4.3117 "	-0.362
-3.26 "				

<u>Mean Value = -0.360</u>

(10).<u>Magnesium Chloride hexahydrate</u>, $MgCl_2.6H_2O$.

Pull of Tube I = 0.33 mgm.; α = 0.631;   V x 0.03 = 0.098 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -4.03 mgm.				
-4.00 "	-4.04 mgm.	-3.71 mgm.	4.1764 gm.	-0.538
-4.10 "				
(b) -3.80 "				
-3.76 "	-3.76 "	-3.43 "	3.8763 "	-0.534
-3.73 "				
(c) -4.28 "				
-4.29 "	-4.27 "	-3.94 "	4.4791 "	-0.533
-4.25 "				

<u>Mean Value = -0.535</u>

(11). Magnesium Bromide hexahydrate, MgBr$_2$.6H$_2$O.

Pull of Tube I = 0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-4.25 mgm.				
	-4.27 "	-4.28 mgm.	-3.95 mgm.	4.7460 gm.	-0.504
	-4.32 "				
(b)	-3.88 "				
	-3.92 "	-3.91 "	-3.58 "	4.1497 "	-0.521
	-3.93 "				
(c)	-4.30 "				
	-4.30 "	-4.29 "	-3.96 "	4.7066 "	-0.511
	-4.28 "				

Mean Value = -0.512

(12). <u>Magnesium Iodide octahydrate</u>, $MgI_2.8H_2O$.

Pull of Tube I = -0.33 mgm.; $\alpha = 0.631$; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	−5.06 mgm.				
	−5.08 "	−5.09 mgm.	−4.76 mgm.	5.6324 gm.	−0.516
	−5.13 "				
(b)	−5.08 "				
	−5.03 "	−5.06 "	−4.73 "	5.5486 "	−0.518
	−5.08 "				
(c)	−5.12 "				
	−5.11 "	−5.13 "	−4.80 "	5.6092 "	−0.522
	−5.16 "				

<u>Mean Value = −0.519</u>

(13). <u>Magnesium Chlorate hexahydrate</u>, $Mg(ClO_3)_2.6H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-360 mgm.				
	-3.62 mgm.	-3.60 mgm.	-3.27 mgm.	4.2404 gm.	-0.463
	-3.57 "				
(b)	-3.70 "				
	-3.70 "	-3.72 "	-3.39 "	4.3031 "	-0.474
	-3.76 "				
(c)	-3.78 "				
	-3.67 "	-3.74 ""	-3.41 "	4.4041 "	-0.466
	-3.77 "				
(d)	-3.28 "				
	-3.29 "	-3.29 "	-2.96 "	4.1040 "	-0.455
	-3.30 "				

<u>Mean Value = -0.468</u>

(14). <u>Magnesium Perchlorate hexahydrate</u>, $Mg(ClO_4)_2.6H_2O$.

Pull of Tube I = -0.33 mgm.; $\alpha = 0.631$; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	$\chi \times 10^6$
(a)	-3.41 mgm.				
	-3.32 "	-3.35 mgm.	-3.02 mgm.	4.0517 gm.	-0.445
	-3.33 "				
(b)	-3.45 "				
	-3.44 "	-3.46 "	-3.13 "	4.1465 "	-0.453
	-3.49 "				
(c)	-3.27 "				
	-3.28 "	-3.31 "	-2.98 "	4.1203 "	-0.432
	-3.37 "				
(d)	-3.28 "				Mean Value = -0.444
	-3.29 "	-3.29 "	-2.96 "	4.1645 "	-0.425
	-3.30 "				

<div align="right">Mean Value = <u>-0.439</u></div>

(15). <u>Magnesium Bromate trihydrate</u>, $Mg(BrO_3)_2 \cdot 3H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-3.82 mgm.				
	-3.78 "	-3.80 mgm.	-3.47 mgm.	4.7562 gm.	-0.440
	-3.80 "				
(b)	-3.79 "				
	-3.84 "	-3.80 "	-3.47 "	4.6762 "	-0.447
	-3.78 "				
(c)	-3.82 "				
	-3.76 "	-3.79 "	-3.46 "	4.6935 "	-0.445
	-3.79 "				

<div align="right">Mean Value = <u>-0.444</u></div>

(16). <u>Magnesium Iodate tetrahydrate, $Mg(IO_3)_2.4H_2O.$</u>

Pull of Tube I = −0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	−4.37 mgm.				
	−4.43 "	−4.40 mgm.	−4.07 mgm.	7.1916 gm.	−0.344
	−4.40 "				
(b)	−4.52 "				
	−4.54 "	−4.52 "	−4.19 "	7.1890 "	−0.354
	−4.50 "				
(c)	−4.41 "				
	−4.39 "	−4.41 "	−4.08 "	7.1807 "	−0.345
	−4.43 "				

<u>Mean Value = −0.348</u>

(17). <u>Magnesium Nitrate hexahydrate</u>, $Mg(NO_3)_2.6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -3.97 mgm.				
-3.97 "	-3.98 mgm.	-3.43 mgm.	4.4439 gm.	-0.466
-4.00 "				
(b) -4.02 "				
-4.00 "	-3.99 "	-3.44 "	4.4605 "	-0.466
-3.95 "				
(c) -3.99 "				
-4.00 "	-4.01 "	-3.46 "	4.4548 "	-0.470
-4.03 "				

<u>Mean Value = -0.467</u>

(18). <u>Magnesium mono-Hydrogen ortho-Phosphate trihydrate,</u>
$$MgHPO_4.3H_2O.$$

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-3.96 mgm.				
	-3.95 "	-3.96 mgm.	-3.32 mgm.	4.2941 gm.	-0.469
	-3.97 "				
(b)	-3.92 "				
	-3.93 "	-3.91 "	-3.27 "	4.3380 "	-0.457
	-3.89 "				
(c)	-3.97 "				
	-3.95 "	-3.95 "	-3.31 "	4.3310 "	-0.464
	-3.92 "				

Mean Value = -0.463

(19). <u>Magnesium Pyrophosphate</u>, $Mg_2P_2O_7$.

Pull of Tube I = -0.33 mgm.; α =0.631; V x 0.03 = 0.098 c.c.
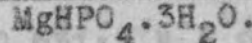
Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -1.79 mgm.				
-1.80 "	-1.80 mgm.	-1.47 mgm.	2.4906 gm.	-0.332
-1.80 "				
(b) -1.86 "				
-1.84 "	-1.85 "	-1.52 "	2.6752 "	-0.322
-1.85 "				
(c) -2.00 "				
-1.96 "	-1.98 "	-1.65 "	2.8359 "	-0.333
-1.98 "				

<u>Mean Value = -0.329</u>

(20). <u>Magnesium mono-Hydrogen ortho-Arsenate hemi-tridecahydrate</u>,
$$2MgHAsO_4.13H_2O.$$

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 cc.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -2.85 mgm.				
-2.77 "	-2.84 mgm.	-2.20 mgm.	1.8222 gm.	-0.713
-2.91 "				
(b) -2.79 "				
-2.83 "	-2.81 "	-2.17 "	1.7632 "	-0.726
-2.81 "				
(c) -2.75 "				
-2.75 "	-2.76 "	-2.18 "	1.6705 "	-0.707
-2.78 "				

<div align="right">Mean Value = -0.715</div>

(21). <u>Magnesium Pyroarsenate</u>, $Mg_2As_2O_7$.

Pull of Tube II = −0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) −1.93 mgm.				
−1.90 "	−1.92 mgm.	−1.37 mgm.	3.8197 gm.	−0.201
−1.93 "				
(b) −1.95 "				
−1.99 "				
−1.91 "	−1.95 "	−1.40 "	3.9813 "	−0.198
−1.95 "				
(c) −1.54 "				
−1.55 "	−1.56 "	−1.23 "	3.5767 "	−0.189
−1.58 "				

(Tube I was used for the 3rd. Packing).

<u>Mean Value = −0.196</u>

(22). <u>Magnesium Ammonium Sulphate hexahydrate,</u> $MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-4.97 mgm.				
	-4.83 "	-4.89 mgm.	-4.34 mgm.	5.0057 gm.	-0.530
	-4.88 "				
(b)	-4.85 "				
	-4.86 "	-4.85 "	-4.30 "	4.9355 "	-0.533
	-4.85 "				
(c)	-4.87 "				
	-4.86 "	-4.87 "	-4.32 "	4.9123 "	-0.536
	-4.87 "				

<u>Mean Value = -0.533</u>

(23). <u>Magnesium Ammonium Chloride hexahydrate</u>, $MgCl_2.NH_4Cl.6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-4.79 mgm.				
	-4.74 "	-4.71 mgm.	-4.16 mgm.	3.8345 gm.	-0.659
	-4.60 "				
(b)	-4.49 "				
	-4.51 "	-4.50 "	-3.95 "	3.6954 "	-0.650
	-4.50 "				
(c)	-4.74 "				
	-4.71 "	-4.68 "	-4.13 "	3.8177 "	-0.661
	-4.59 "				

<u>Mean Value = -0.656</u>

(24). <u>Magnesium Ammonium Bromide hexahydrate</u>, $MgBr_2.NH_4Br.6H_2O$.

Pull of Tube I = 0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-3.86 mgm.				
	-3.90 "	-3.87 mgm.	-3.54 mgm.	4.1869 gm.	-0.510
	-3.85 "				
(b)	-4.16 "				
	-4.11 ::	-4.14 "	-3.81 "	4.5755 "	-0.506
	-4.14 "				
(c)	-4.18 "				
	-4.13 "	-4.16 "	-3.83 "	4.5300 "	-0.512
	-4.17 "				

<u>Mean Value = -0.509</u>

(25). <u>Magnesium Ammonium ortho-Phosphate hexahydrate</u>, $MgNH_4PO_4.6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634; V x 0.03 = 0.101 cc.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -3.98 mgm.				
-3.98 "	-3.99 mgm.	-3.44 mgm.	3.6726 gm.	-0.566
-4.02 "				
(b) -4.20 "				
-4.17 "	-4.17 "	-3.62 "	3.8344 "	-0.572
-4.14 "				
(c) -4.07 "				
-4.07 "	-4.03 "	-3.48 "	3.7850 "	-0.556
-3.96 "				

<u>Mean Value = -0.565</u>

(26). <u>Magnesium Ammonium ortho-Arsenate hexahydrate</u>, $MgNH_4AsO_4.6H_2O$.

Pull of Tube II = -0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-2.71 mgm.				
	-2.80 "	-2.77 mgm.	-2.22 mgm.	3.4011 gm.	-0.383
	-2.79 "				
(b)	-2.89 "				
	-2.96 "	-2.91 "	-2.36 "	3.5228 "	-0.396
	-2.89 "				
(c)	-2.81 "				
	-2.77 "	-2.84 "	-2.29 "	3.4978 "	-0.386
	-2.89 "				
	-2.87 "				

<u>Mean Value = -0.385</u>

(27). <u>Magnesium Ferricyanide penta$\hat{\text{h}}$ydrate</u>, deca $Mg_3\left[Fe(CN)_6\right]_2 15H_2O.$

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 cc.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) + 31.0 mgm.				
+ 30.9 "				
+ 31.8 "	+31.4 mgm.	+ 32.04 mgm.	3.5329 gm.	+ 5.86
+ 31.8 "				
(b) + 32.1 :				
+ 32.2 "	+ 32.2 "	+ 32.84 "	3.5889 "	+ 5.89
+32.4 "				
(c) + 32.2 "				
+ 32.1 "	+ 32.1 "	+ 32.74 "	3.5837 "	+ 5.88
+ 32.1 "				

Mean Value = + 5.88

(28). <u>Magnesium Carbonate trihydrate</u>, $MgCO_3.3H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-3.01 mgm.				
	-2.99 "	-3.01 mgm.	-2.68 mgm.	3.2590 gm.	-0.489
	-3.04 "				
(b)	-2.91 "				
	-2.92 "	-2.92 "	-2.59 "	3.2251 "	-0.478
	-2.94 "				
(c)	-2.86 "				
	-2.88 "	-2.87 "	-2.54 "	3.1436 "	-0.493
	-2.87 "				

<u>Mean Value = -0.487</u>

(29). Magnesium Ethyl Sulphate hemi-trihydrate, $2Mg(C_2H_5SO_4)_2.3H_2O$.

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 cc.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -4.13 mgm.				
-4.16 "	-4.14 mgm.	-3.50 mgm.	4.2970 gm.	-0.495
-4.13 "				
(b) -4.12 "				
-4.11 "	-4.12 "	-3.48 "	4.2800 "	-0.495
-4.13 "				
(c) -3.94 "				
-3.93 "	-3.95 "	-3.31 "	4.1084 "	-0.489
-3.98 "				

Mean Value = -0.493

(30). <u>Magnesium Formate dihydrate</u>, $Mg(HCOO)_2.2H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -3.06 mgm.				
-3.04 "	-3.06 mgm.	-2.73 mgm.	3.7244 gm.	-0.436
-3.08 "				
(b) -3.20 "				
-3.20 "	-3.20 "	-2.87 "	3.8480 "	-0.446
-3.18 "				
(c) -3.11 "				
-3.14 "	-3.12 "	-2.79 "	3.7660 "	-0.441
-3.11 "				

<u>Mean Value = -0.441</u>

(31). <u>Magnesium Acetate dihydrate</u>, $Mg(CH_3COO)_2.2H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	$\chi \times 10^6$
(a)	-2.77 mgm.				
	-2.83 "	-2.81 mgm.	-2.48 mgm.	2.7626 gm.	-0.531
	-2.83 "				
(b)	-2.79 "				
	-2.81 "	-2.81 "	-2.48 "	2.7840 "	-0.527
	-2.82 "				
(c)	-2.81 "				
	-2.84 "	-2.82 "	-2.49 "	2.8188 "	-0.523
	-2.80 "				

<u>Mean Value = -0.527</u>

(32). <u>Magnesium Butyrate tetrahydrate</u>, $Mg(CH_3(CH_2)_2COO)_2 \cdot 4H_2O$.

Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)	-3.32 mgm.				
	-3.31 "	-3.36 mgm.	-3.03 mgm.	2.8500 gm.	-0.636
	-3.44 "				
(b)	-3.37 "				
	-3.38 "	-3.36 "	-3.03 "	2.8074 "	-0.646
	-3.32 "				
(c)	-3.25 "				
	-3.24 "	-3.26 "	-2.93 "	2.7688 "	-0.634
	-3.28 "				

<u>Mean Value = -0.639</u>

(d) -2.50 "

-2.54 "   -2.52 "   -1.66 "   2.9817 "   -0.556

-2.52 "

<u>Mean Value = -0.592</u>

(33).<u>Magnesium Oxalate dihydrate</u>, $Mg(COO)_2 \cdot 2H_2O$.

Pull of Tube III = -0.64 mgm.; α = 0.640; V x 0.03 = 0.110 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) -2.51 mgm.				
-2.53 "	-2.52 mgm.	-1.88 mgm.	3.0494 gm.	-0.368
-2.51 "				
(b) -2.62 "				
-2.58 "	-2.60 "	-1.96 "	3.1092 "	-0.368
-2.60 "				
(c) -2.54 "				
-2.61 "	-2.59 "	-1.95 "	3.2027 "	-0.355
-2.61 "				
(d) -2.50 "				
-2.54 "	-2.52 "	-1.88 "	2.9617 "	-0.369
-2.53 "				

<u>Mean Value = -0.363</u>

(34).<u>Magnesium Succinate tetrahydrate,</u> $Mg(CH_2COO)_2.4H_2O$.

Pull of Tube II = −0.55 mgm.; α = 0.634; V x 0.03 = 0.101 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a) −4.17 mgm.				
−4.10 "	−4.12 mgm.	−3.57 mgm.	4.1813 gm.	−0.517
−4.09 "				
(b) −4.11 "				
−4.05 "	−4.09 "	−3.54 "	4.1118 "	−0.521
−4.11 "				
(c) −4.11 "				
−4.12 "	−4.12 "	−3.57 "	4.1741 "	−0.518
−4.14 "				

<u>Mean Value = −0.519</u>

(35).<u>Magnesium d-Tartrate hemi-pentahydrate</u>, $2Mg(C_4H_4O_6)_2.5H_2O$.

Pull of Tube I = -0.33 mgm.; $\varkappa$ = 0.631; V x 0.03 = 0.098 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	$\varkappa$ x 10^6
(a) -2.40 mgm.				
-2.43 "	-2.44 mgm.	-2.11 mgm.	2.8297 gm.	-0.434
-2.48 "				
(b) -2.44 "				
-2.45 "	-2.44 "	-2.11 "	2.8681 "	-0.430
-2.44 "				
(c) -2.54 "				
-2.53 "	-2.54 "	-2.21 "	2.0527 "	-0.439
-2.54 "				

<u>Mean Value = -0.434</u>

(36).<u>Magnesium salt of 8-hydroxy-Quinoline</u>,
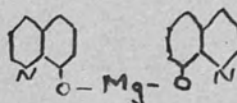
Pull of Tube I = -0.33 mgm.; α = 0.631; V x 0.03 = 0.098 c.c.

Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6
(a)-3.05 mgm.				
-3.08 "	-3.04 mgm.	-2.71 mgm.	2.6832 gm.	-0.601
-3.00 "				
(b)-3.11 "				
-3.05 "	-3.10 "	-2.77 "	2.7237 "	-0.606
-3.15 "				
(c)-3.08 "				
-3.07 "	-3.07 "	-2.74 "	2.7414 "	-0.596
-3.07 "				

<u>Mean Value = -0.601</u>

TABLE I

(37).<u>Magnesium,Mg (sticks)</u>.

Pull of Tube IV = -0.30 mgm.; α = 0.568; V x 0.03 = 0.084 c.c.

	Pull (gross)	Mean Pull (gross)	Pull (net)	Weight	χ x 10^6

(a) +74.0 mgm.
+70.5 "   +72.3 mgm. +72.60 mgm.   5.8276 gm. +7.089

(b) +74.1 "
+74.1 "   +74.1 "   +74.40 "   5.7009 "   +7.394

<u>Mean Value = +7.241</u>

TABLE I

Substance	N	$\chi \times 10^6$	$\chi_M \times 10^6$		$\delta\chi \times 10^6$
Mg (Powder)	12	+ 1.540	+ 37.45	—	—
Mg (Sticks)	12	+ 7.241	+170.6	—	—

(1). Univalent Anions.

Substance	N	$\chi \times 10^6$	$\chi_M \times 10^6$		$\delta\chi \times 10^6$
$Mg(OH)_2$	30	−0.337	−20.32	−15.06	−5.26 *
$MgF_2.H_2O$	40	−0.360	−28.94	−25.60	−3.34 *
$MgCl_2.6H_2O$	106	−0.535	−108.70	−118.20	+ 9.50
$Mg(NO_3)_2 6H_2O$	134	−0.467	−119.72	−112.40	−6.34 *
$MgBr_2.6H_2O$	142	−0.512	−149.60	−140.00 [a]	−9.60
$Mg(ClO_3)_2.6H_2O$	154	−0.468	−140.10	−130.00 [a]	−10.10
$Mg(ClO_4)_2.6H_2O$	170	−0.439	−145.40	−137.20 [b]	−8.20 *
$Mg(BrO_3)_2.3H_2O$	160	−0.444	−148.40	−121.20 [a]	−27.20
$MgI_2.8H_2O$	198	−0.519	−219.20	−194.00 [a]	−25.20
$Mg(IO_3)_2.4H_2O$	206	−0.348	−161.00	−142.00 [a]	−19.00

(2). Divalent Anions.

Substance	N	$\chi \times 10^6$	$\chi_M \times 10^6$		$\delta\chi \times 10^6$
MgO	20	−0.168	− 6.77	−4.60	−2.17 *
$MgSO_4$	60	−0.337	−40.53	−37.00 [b]	−3.53 *
$MgSO_4.H_2O$	70	−0.410	−56.74	−50.00 [b]	−6.74 *
$MgCO_3.3H_2O$	72	−0.487	−65.88	−61.20	−4.68 *
$MgHPO_4.3H_2O$	90	−0.463	−80.74	−77.4 [b]	−3.34 *
$MgCrO_4.5H_2O$	118	−0.193	−44.46	−32.00 [b]	−12.46

Substance	N	$\chi \times 10^6$	$\chi_m \times 10^6$	δ	$\chi_A \times 10^6$
$MgS_2O_3 6H_2O$	128	-0.532	-130.10	-121.59	-8.51 *
$MgSO_4 \cdot 7H_2O$	130	-0.537	-132.30	-128.00 [6]	-4.30 *
$2MgHAsO_4 \cdot 13H_2O$	286	-0.715	-402.40	-289.86	-56.27

(3). <u>Tervalent Anion.</u>

$Mg_3\left[Fe(CN)_6\right]_2 15H_2O$	394	+ 5.88	+ 4510.0	-	-

(4). <u>Double Amm. Salts.</u>

$MgNH_4PO_4 \cdot 6H_2O$	130	-0.565	-138.70	-130.75	-7.95 *
$MgCl_2NH_4Cl \cdot 6H_2O$	134	-0.656	-168.50	-155.58	-12.92
$MgNH_4AsO_4 \cdot 6H_2O$	148	-0.385	-111.40	-152.79	+ 41.39
$MgBr_2NH_4Br \cdot 6H_2O$	188	-0.509	-199.00	-187.10	-11.90
$MgSO_4(NH_4)SO_4 6H_2O$	190	-0.533	-192.20	-186.57	-5.63 *

(5). <u>Quadrivalent Anions.</u>

$Mg_2P_2O_7$	110	-0.329	-73.28	-	-
$Mg_2As_2O_7$	146	-0.196	-60.77	-	-

Substance	N	$\chi \times 10^6$	$\chi_M \times 10^6$	δ	$\chi_A \times 10^6$
(6). Organic Anions.					
$Mg(COO)_2 \cdot 2H_2O$	76	−0.363	−54.05	−53.09	−0.15 *
$Mg(HCOO)_2 \cdot 2H_2O$	78	−0.441	−66.36	−60.60	−5.76 *
$Mg(CH_3COO)_2 \cdot 2H_2O$	94	−0.527	−94.01	−86.00	−8.01 *
$Mg(CH_2COO)_2 \cdot 4H_2O$	112	−0.519	−110.30	−104.72	−5.62 *
$Mg(CH_3(CH)_{11}COO)_2 \cdot 4H_2O$	146	−0.639	−172.90	−159.02	−13.88
$Mg(C_9H_6NO)_2$	162	−0.601	−186.40	−184.60	−1.80 *
$2Mg(C_2H_5SO_4)_2 \cdot 3H_2O$	284	−0.493	−291.20	−295.60	+2.20
$2Mg(C_4H_4O_6)_2 \cdot 5H_2O$	378	−0.434	−317.20	−312.68	−4.27 *

The mean value of those denoted by * was taken

and $\therefore$ $\underline{\chi_A \times 10^6 = -5.05}$

RESULTS

MASS SUSCEPTIBILITIES PREVIOUSLY PUBLISHED

Substance	Temp $^{\circ}$C.	$\chi \times 10^6$	Observer
(1). Mg (M.P. $650 \pm 2^{\circ}$)	18 } 650	+0.55	[13]Honda
	650 } 700	+0.55 (liquid)	"
(2). MgO	17	−0.25	[14]Meyer
(3). MgCl$_2$	18	−0.58	"
(4). MgCl$_2$.6H$_2$O	18	−0.57	"
(5). MgBr$_2$	20	−0.57	"
(6). MgSO$_4$	room	−0.45(Aq)	[15]Studley
(7). MgSO$_4$.7H$_2$O	"	−0.551	[16]Pascal
(8). MgCO$_3$	"	−0.51	[14]Meyer
(9). MgCO$_3$.3H$_2$O	"	−0.525	[16]Pascal
(10). Mg(C$_2$H$_5$SO$_2$)$_2$.2H$_2$O	"	−0.525	"

RESULTS

Results are tabulated in Table I, according to the valency of the negative radicle, and in order of increasing number of electrons, N. The salts of magnesium with organic radicles are grouped separately. Column 3 contains the mean experimental magnetic mass susceptibility χ for each compound. In column 4, the molar susceptibility $\chi_M = \chi \times$ Mol. Wt., for each compound is shown. Column 5 contains the value δ which represents the ionic susceptibility of the negative ion plus the total molar susceptibility of the water of crystallisation of the compound. In the determination of the value δ, it was assumed that the molar susceptibility of the magnesium compound was the sum of the ionic susceptibilities (also assuming that the salts are polar) and of the molar susceptibility of the water of crystallisation. It was also assumed that the hydration was not part of the magnesium ion, in obtaining the value for the magnesium ion. The values of δ were taken from the International Critical Tables VI p. 349, except where otherwise stated:- (a) these values were taken from a paper by [2]Spencer and Hollens, and the values (b) from a paper by [3]Trew. The values of δ for the organic salts were calculated from Pascal's values for atoms and linkages; the carbonate ion was calculated by this method

also. Column 6 contains the resulting values of the susceptibility of the magnesium ion. This ionic value was not obtained for compounds that are non-polar, such as the pyrophosphate, pyroarsenate and ferricyanide. The 8-hydroxy-quinoline compound was treated as an organic compound, and it was assumed that the total molar susceptibility was the sum of the molar susceptibilities of the component systems and linkages.

DISCUSSION OF RESULTS

It will be seen from Table I that some values obtained for the magnesium ion diverge greatly from the mean value of -5.05×10^{-6}. The best set of results are those obtained from the salts of magnesium with a divalent radicle and those with an organic radicle. The compounds containing the halogens, are in particular, anomalous.

For a mononuclear spherically symmetrical atom or ion, the susceptibility is given by Langevin's equation:-

$$\chi_A = \frac{-e^2 L}{6mc^2} \sum \bar{r}^2 = -2.83 \times 10^{10} \sum \bar{r}^2$$

where $\sum \bar{r}^2$ on the classical theory is the mean square susceptibility.

radius summed for all the electrons in the atom or ion. On the newer quantum mechanical view, it is the average effective electron density distribution. From the equation, it can be seen that the ionic susceptibility is proportional to the same mean square radius, and therefore the radius of the atom or ion. In the determination of the gram ionic susceptibility of magnesium, the Langevin equation was assumed to hold good. However, it was originally deduced for polar compounds of two mononuclear spherically symmetrical ions, such as sodium and chlorine. It cannot, therefore, apply strictly to any other type of compound, of which the following include the magnesium compounds:-

(i)   Compounds with more than two ions, such as the double ammonium salts.

(ii) Covalent compounds, where the spherical symmetry of the component systems is mutually distorted.

(iii) Hydrated compounds, into which class the bulk of the magnesium compounds fall.

(iv) Complex salts, such as magnesium ferricyanide.

In solid crystals, inter-ionic forces limit the radii of the ions, and must necessarily influence the susceptibility.

With the exception of six compounds, all the compounds
of magnesium investigated are hydrated, the average number
of water molecules of crystallisation being six, which is
the normal coordination number of magnesium.

Since the water molecules are evidently coordinated
to the magnesium ion, it would seem that it is this factor
which affects the ionic susceptibility, and therefore the
ionic radius.

The attractive power of the positively charged
nucleus of a metal ion towards electrons, must necessarily
decrease with increasing distance from it. Therefore it
would seem that the ionic radius of magnesium is decreased
in order to bring the water molecules closer to the nucleus,
in order that they may be firmly held. Although this would
make the actual radius of the ion smaller than in an un-
hydrated ion, the effective ionic radius influencing the
susceptibility, may be larger, due to the water molecules
being incorporated and forming a shell round the ion.

Adjacent ions in a solid crystal limit the ionic
radius so that the ionic susceptibility is less than that
of the free ion, or ion in solution.

A large value for the ionic susceptibility of
magnesium is noticeable where the anion is univalent, and
especially so when it is large, or complex, as in the
chlorate, bromate and iodate.

GRAPH I

MgI₂.8H₂O

MgBr₂.6H₂O

MgCl₂.6H₂O

MgF₂.H₂O

N →

− Xₘ × 10⁶ →
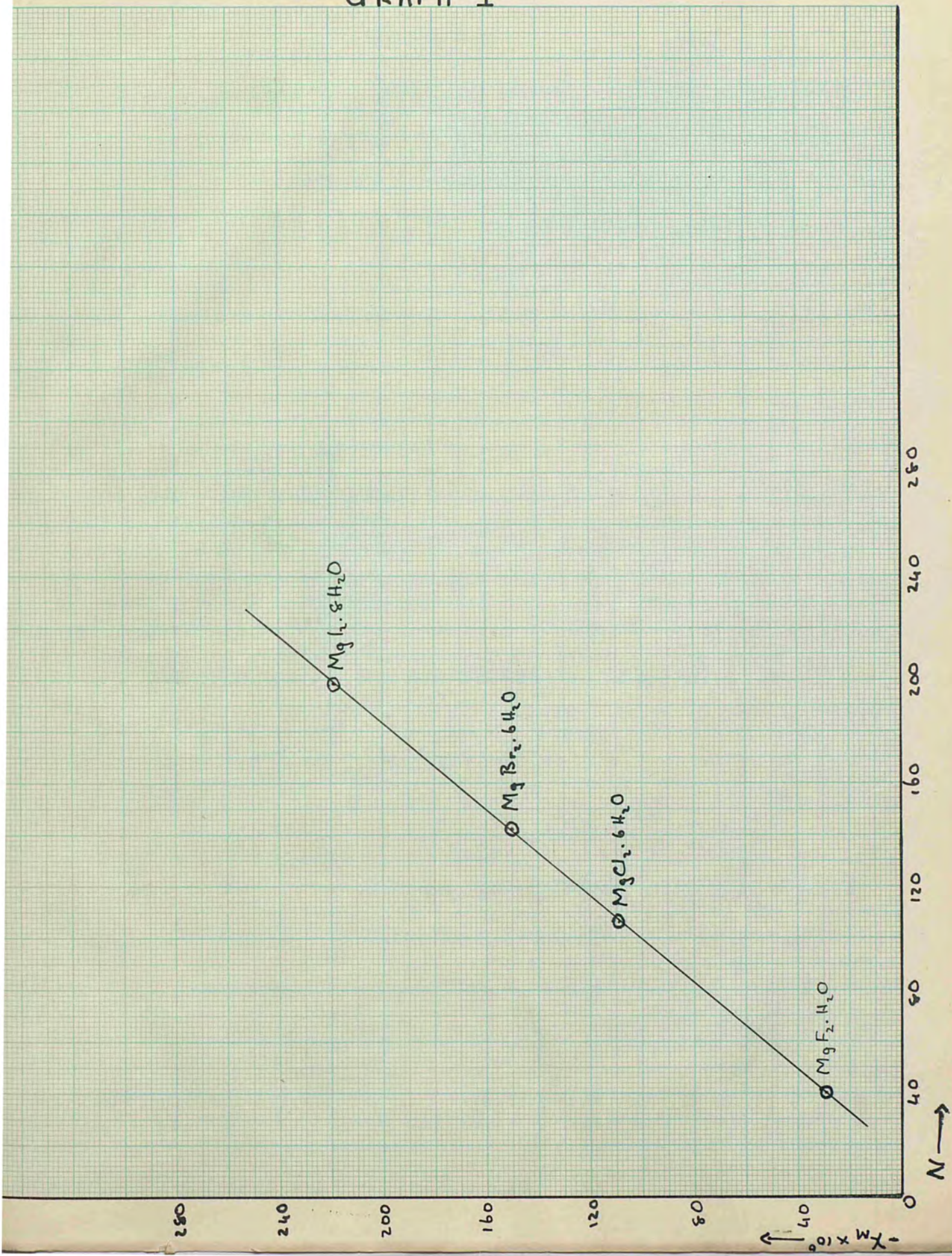
In Graph I, the molar susceptibilities of the halides
of magnesium have been plotted against the total number
of electrons within the molecule. It will be seen that
the values fall on a straight line. In definitely polar
salts of the halides, it has been found that the value for
the chloride does not fall on the line, but at a point
in the direction of increasing susceptibility. The fact
that, in the graph, the value for the chloride falls on
the line shows that either, or both, the ionic susceptibilities
of the hydrated magnesium ion or of the chloride ion have
been decreased. Upon reference to Table I, it will be
seen that the resulting value for the ionic susceptibility
of magnesium, from the molar susceptibility of the chloride,
is quite anomalous, the rest of the series being quite
linear and showing an increase of ionic susceptibility
with increasing number of electrons. Therefore it appears
more likely that the chloride ions should decrease in size
and hence in ionic susceptibility, rather than the single
magnesium ion with its shell of water molecules.

In Graph II, the molar susceptibilities of the
chlorate, bromate and iodate have been plotted similarly,
together with the nitrate which has a similar constitution,
This series is linear, with the exception of the iodate.
It must be noted that in this series the salt containing
chlorine in the complex anion does not give an anomalous

GRAPH II
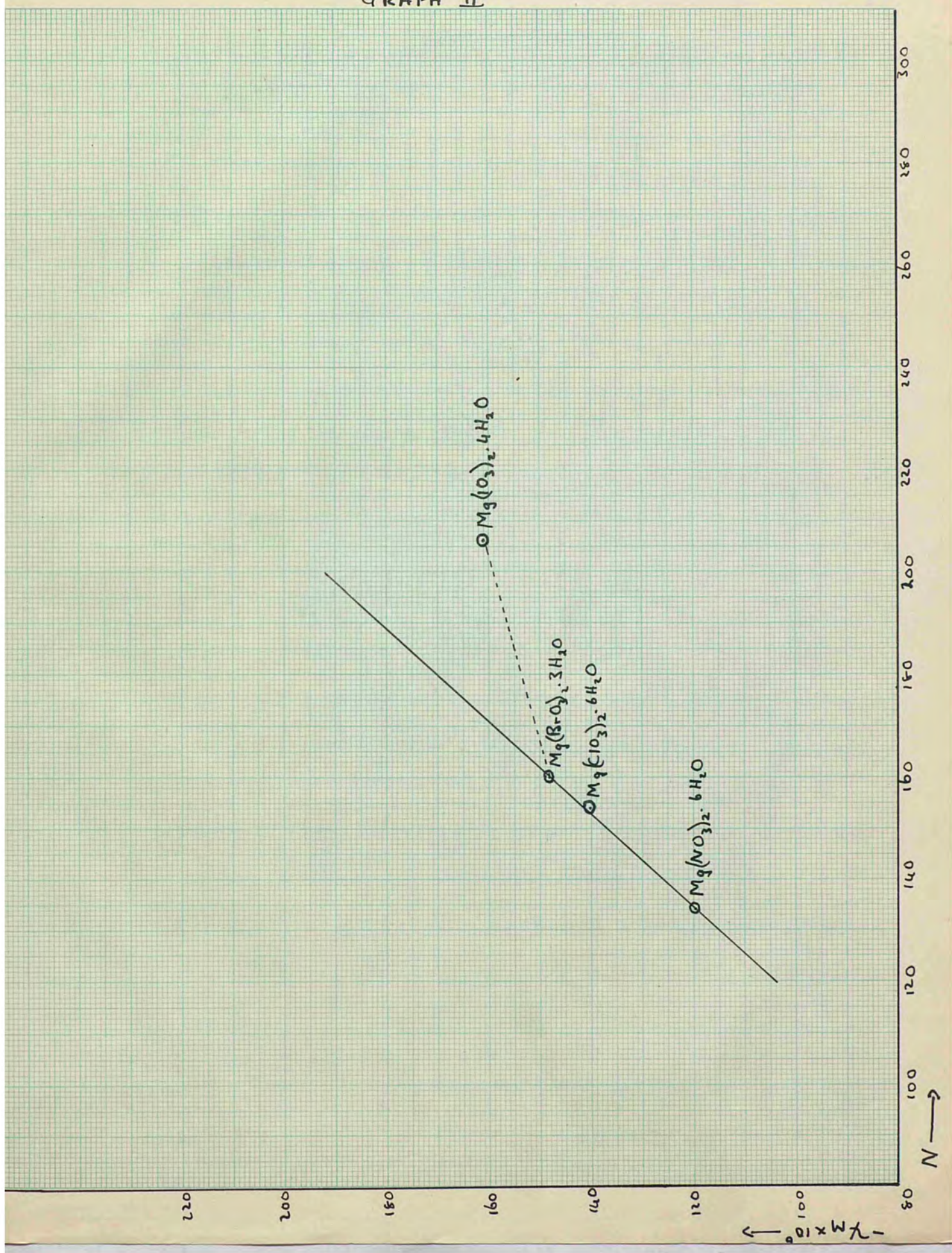
value for the ionic susceptibility of magnesium; and also
that the ionic susceptibility of magnesium increases with
increasing size of anion.

From these two sets of results giving, on the
whole, high values for the susceptibility of the magnesium
ion, it would appear that the influence of two large anions
upon the hydrated magnesium ion, is one of "dilution" of
the ionic charge and an increase in the distance of the
shell of water molecules from the nucleus. This expansion
of the ionic radius of magnesium must occur, also, to
allow the two large anions to become electrostatically held
to the cation.

The salts of magnesium with a divalen anion, show
more consistent, and lower, values for the susceptibility
of the magnesium ion, in spite of the fact that they are
somewhat larger than the nitrate-iodate series of anions.
However, the molecule of the salt only contains one cation
and one anion, and therefore the hydrated magnesium ion
does not have to expand so much to accomodate the anion.

Graph III shows the molar susceptibilities of the
sulphate series, i.e. anhydrous and hydrated sulphates,
thiosulphate and chromate plotted against the total number
of electrons. The series is linear, with the exception
of the chromate, which is due to the fact that the chromate
ion is paramagnetic. It should be noted that the substi-
tution of sulphur for oxygen, as shown by the thiosulphate

GRAPH III

81 a
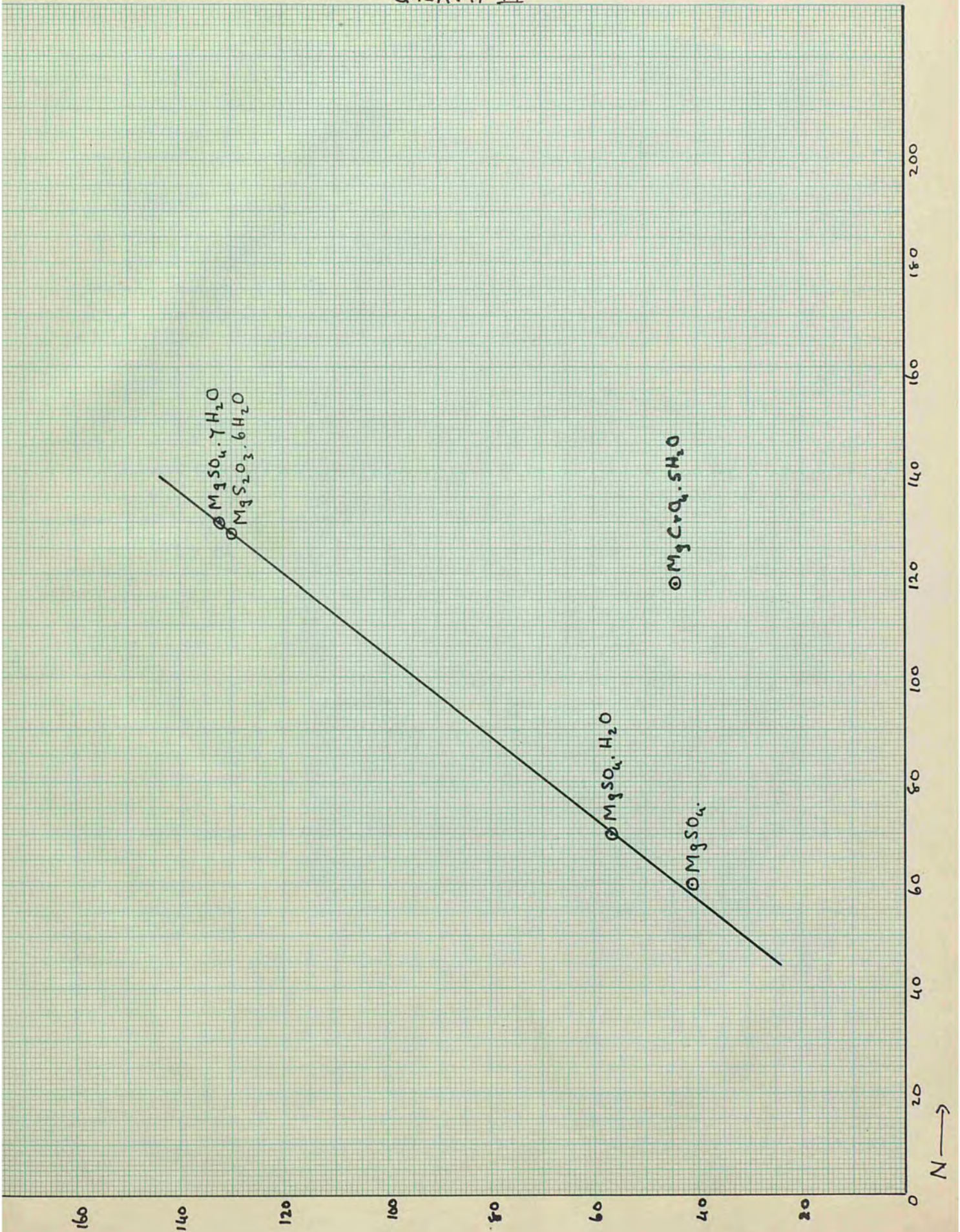
does not affect the susceptibility.

The compounds of magnesium with organic radicles, also give a fairly consistent set of results for the susceptibility of the magnesium. The molar susceptibility increases regularly with an increasing number of carbon atoms. In the Fatty Acid series, the formate, acetate, and butyrate, there is an increasing susceptibility of the magnesium ion with increasing number of carbon atoms. This is also shown by the oxalate and succinate in the Dibasic Acid series. This indicates that the organic radicles, with increasing size, have a "diluting" effect on the charge surrounding the magnesium ion, and thus the ionic susceptibility and hence the ionic radius is increased. This was also found by [3]Trew. It must be noted, too, that the number of water molecules of crystallisation is less in the organic salts than in the inorganic salts.

From the salts of the Fatty Acid series, and from those of the Dibasic Acid series, the value of the molar susceptibility of the $-CH_2-$ group, χ_{-CH_2-} can be obtained by difference of the molar susceptibilities of succeeding salts. The values are shown in Table II:-

Substance	$\chi_M \times 10^6$	$\chi_{-CH_2-} \times 10^6$

(a) <u>Fatty Acid Series</u>:-

$Mg(HCOO)_2 \cdot 2H_2O$	-66.56	
		-13.83
$Mg(CH_3COO)_3 \cdot 2H_2O$	-94.01	
		-13.20
* $Mg(CH_3(CH_2)_2COO)_2 \cdot 4H_2O$	-172.90	

(b) <u>Dibasic Acid Series</u>:-

$Mg(COO)_2 \cdot 2H_2O$	-54.05	
		-15.12
* $Mg(CH_2COO)_2 \cdot 4H_2O$	-110.30	

<u>Mean Value</u>:- -14.07

TABLE II

In the salts denoted by *, the molar susceptibility of two molecules of water were also subtracted.

This mean value of $\chi_{-CH_2-} = -14.07$ is to be compared with the mean value of $\chi_{-CH_2-} = -12.35 \times 10^{-6}$ obtained by [17]Pascal in his classical work on organic compounds in 1909.
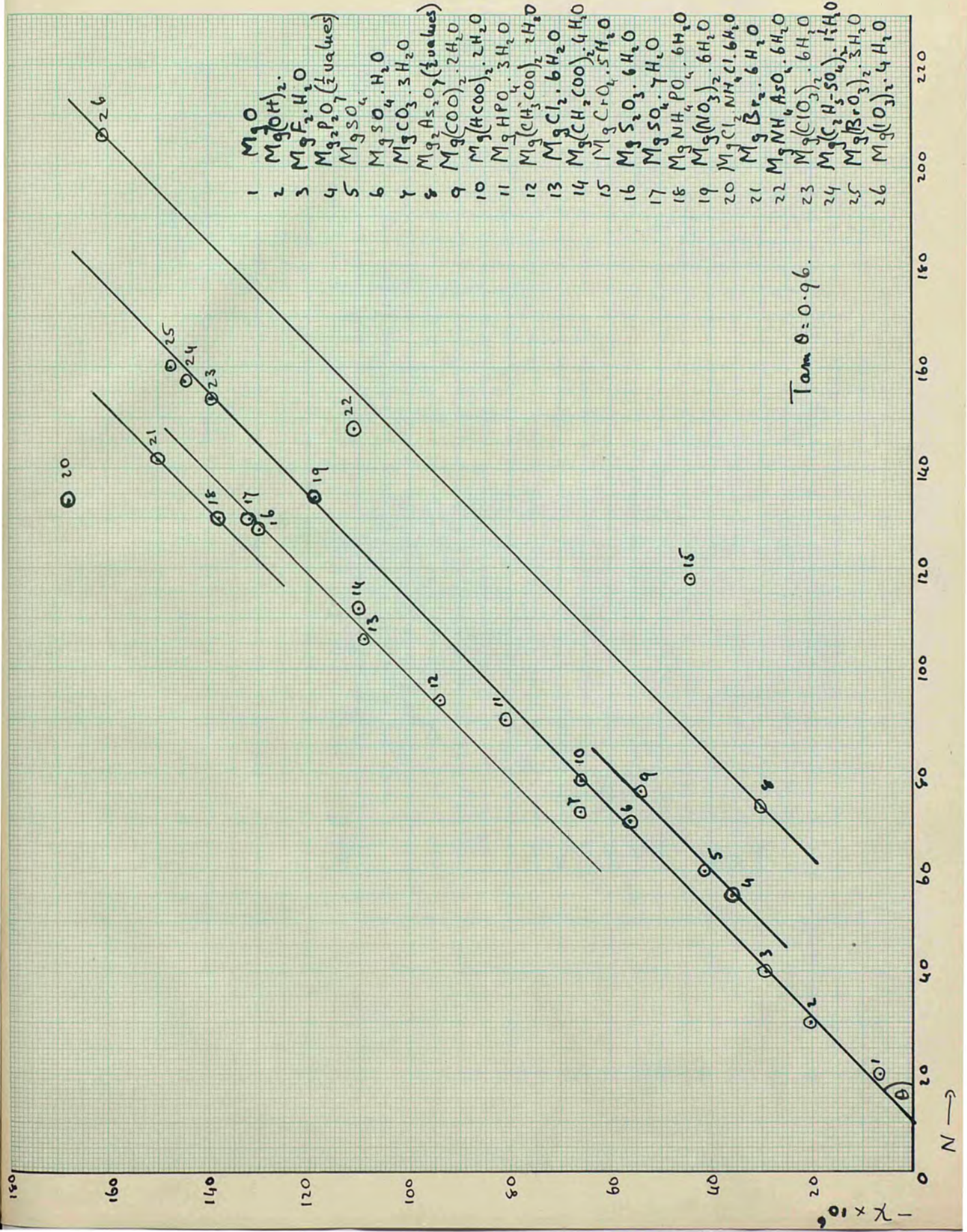
The susceptibility of magnesium metal is of interest. Two very divergent results were obtained for the metal, when cast into sticks, and when powdered. No ferromagnetic material was present in the specimens. The metal when

cast into sticks gave a large paramagnetic mass suscepti-
bility of $\chi = +7.241 \times 10^{-6}$. When the powdered metal
was used, the value was very considerably smaller,
$\chi = +1.540 \times 10^{-6}$.   [13]Honda in 1910, using the Curie-
Cheneveaux balance gave the value as $\chi = +0.550 \times 10^{-6}$.
From the results above it would seem that the smaller
the particles of metal, the smaller the susceptibility
value.

[18]Pauli has put forward a theory of paramagnetism
due to free electrons present in the metal in bulk. It
is known that a metal in bulk often has a different
magnetic effect than when in the atomic state. Silver
and copper, for example, show paramagnetism for the separate
atoms, while the metals in bulk are diamagnetic. It was
thought that if the extreme paramagnetism was due to free
electrons, this might be eliminated if the metal were in
solution. For this purpose, an attempt was made to
make magnesium amalgams in order to measure the suscepti-
bilities. As stated before, the amalgams are very
difficult to handle, and a technique for so doing could
not be developed in the time available.

In graph IV, most of the magnesium compounds have
been plotted, as before, - the molar susceptibilities against

GRAPH IV

84a

1 - MgO
2 - Mg(OH)₂.
3 - MgF₂.H₂O
4 - Mg₂P₂O₇ (½ values)
5 - MgSO₄
6 - MgSO₄.H₂O
7 - MgCO₃.3H₂O
8 - Mg₂As₂O₇ (½ values)
9 - Mg(COO)₂.2H₂O
10 - Mg(HCOO)₂.2H₂O
11 - Mg(CH₃COO)₂.2H₂O
12 - MgCl₂.6H₂O
13 - Mg(CH₂COO)₂.4H₂O
14 - MgCrO₄.5H₂O
15 -
16 - MgS₂O₃.6H₂O
17 - MgSO₄.7H₂O
18 - MgNH₄PO₄.6H₂O
19 - Mg(NO₃)₂.6H₂O
20 - MgCl₂.NH₄Cl.6H₂O
21 - MgBr₂.6H₂O
22 - MgNH₄AsO₄.6H₂O
23 - Mg(ClO₃)₂.6H₂O
24 - Mg(C₂H₅SO₄)₂.1½H₂O
25 - Mg(BrO₃)₂.3H₂O
26 - Mg(IO₃)₂.4H₂O

$\text{Tan } \theta = 0.96.$

$N \rightarrow$

$-\chi \times 10^6$

the total number of electrons. It will be seen that the
majority of the compounds form definitely linear series.
[4]Ikenmeyer has similarly shown in graph form that a linear
relationship holds for the gram molar susceptibilities
of the alkali halides, determined from measurements in
solution. The susceptibility can be represented by the
equation $-\chi_M \times 10^6 = C_1 N + C_2$

where N = total number of electrons

" C_1 = a general constant = 0.803×10^{-6}

and C_2 = a specific constant for the given

series of salts.

For magnesium the salts the value C_1 (which is the
slope of the curve in Graph IV and = $\tan \theta$), is = 0.96×10^{-6}.
This is the average increase in diamagnetism per electron.
The deviation from Ikenmeyer's value is probably due to
the hydration of the salts. The value of C_2 is = -8.5×10^{-6}
on an average.   The average line on the graph includes
the nitrate series of ions.   In unhydrated salts,
this series usually gives a higher value for C_2.

Comparison of Theoretical and Experimental Susceptibilities.

The value of -5.05×10^{-6} for the experimental
ionic susceptibility, can, at the best, be only approximate
for the magnesium ion. With an ion possessing a higher

value, the same deviations on either side of the mean
value are of less percentage than those for a small value
of ionic susceptibility.

The Langevin equation shows that the ionic sus-
ceptibility depends on the value of $\sum \overline{r^2}$ for the different
groups of electrons in the ion. This value has been
calculated by [5]Pauling, [19]Hartree and [7]Slater. Pauling's
value was obtained from screening constants and hence the
effective nuclear charge, for the different groups of
electrons in atoms or ions. This method, however, involves
a number of rough approximations. He calculated the
ionic susceptibility using the equation:-

$$\chi_A = -0.81 \times 10^{-6} \sum \frac{\overline{n^2}}{Z^2} \left\{ \frac{5}{2}n^2 - \frac{3l(l + 1) - 1}{2} \right\}$$

where l = orbital quantum number. Hartree's method is
one of a "self-consistent field" for spherically symmetrical
atoms or ions. In this the charge distribution satisfying
the Schrödinger equation of wave mechanics is worked out. He has shown
that for a number of atoms and ions the curve showing
the charge per unit radical distance (in a spherical shell
of unit thickness) is a function of the distance from the
nucleus. [6]Stoner has calculated the diamagnetic sus-
ceptibility using Hartree's method, from the equation:-

$$\chi_A = -2.85 \times 10^{10} \int_0^\infty \overline{r^2} . \frac{dN}{dr} . dr$$

Slater's method is from space charge distributions also, using the wave function of the electron in a symmetrical form. [20]Brindley has used Slater's expression and calculated the diamagnetic susceptibilities of a large number of atoms and ions. His results show that this method gives the most consistent agreement with experimental results, the best agreement, however, being for those atoms and ions of larger values of "r" (i.e. ionic radius). Experimental values for the diamagnetic susceptibility of the magnesium ion have been given by [8]Hocart, [9]Pascal, [10]Kido, and [4]Ikenmeyer:-

Theoretical   Experimental

Pauling	Stoner (Hartree)	Hocart	Pascal	Kido	Ikenmeyer	I.C.T.
3.2	4.3	5.15±2.6	8.0	4.3	4.5	10.1

— values are $-\chi_A \times 10^{-6}$

The theoretical diamagnetic susceptibility of the magnesium ion has been calculated using Slater's rules for determining the screening constants for the various electrons in an atom or ion.

The screening constant for each electron consists

of contributions from all the other electrons, both in the same group and in groups from orbits of lower quantum number. From this the value of the mean square radius of the orbit, $\overline{r^2}$, is calculated from the equation:-

$$\overline{r^2} = \frac{(n')^2 \ (n' + \frac{1}{2}) \ (n' + 1)}{(Z - S)^2}$$

where n' = effective principal quantum number

Z = atomic number

S = derived screening constant for any electron.

& (Z - S) = effective nuclear charge for each electron.

In the magnesium there are ten electrons, two of which are in the 1S orbit and eight in the 2SP orbit. Of these eight, two are in the 2S orbit and six in the 2P orbit.

Slater's rules are as follows:-

For S and P electrons in same group S = 0.35

and S = 0.30 when in the 2S orbit.

For S and P electrons in higher groups S = 0.00

" " " " " " lower " S = 0.85 where

$n' = (n' - 1)$

and S = 1.00 for all

lower groups.

For d and f electrons   S = 1.00 for all electrons
                                            in lower groups.

For Magnesium ion, Z = 12.

$1S^2$ orbit:- n' = 1.0; S = 0.30; i.e. $\sum \bar{r}^2 = \dfrac{2 \times 1.1\frac{1}{2}.2}{(11.70)^2}$

                                          = 0.044

$2S^2$, $2P^6$ " :- n' = 2.0; S = (2 x 0.85) + (7 x 0.35) = 4.15

                                  i.e. $\sum \bar{r}^2 = \dfrac{8 \times 4.2\frac{1}{2}.3}{(7.85)^2}$

                                          = 3.894

. . Total $\sum \bar{r}^2$ = 3.894 + 0.044

                        = 3.938

- this value is in Atomic Units.

Brindley has shown that the gram ionic susceptibility is

calculated from the equation

$$10^6 \times \chi_{ion} = -0.790 \times \sum \bar{r}^2 \quad \text{(in Atomic Units)}$$

By substituting the calculated value of 3.938 for $\sum \bar{r}^2$,

the theoretical value for the gram ionic susceptibility

of Magnesium can be obtained:-

$$\chi_{ion} \times 10^6 = -0.790 \times 3.938$$

                        = -3.12

This value is in fairly good agreement with the experimental value of -5.05×10^{-6}, bearing in mind that the discrepancy would not be such a large percentage in an ion with a higher value. It must also be noted that this theoretical value is for the free ion, whereas the experimental value is influenced by hydration and other interionic forces in the crystal.

Determination of the Ionic Radius.

By means of the Langevin equation, the mean square radius summed over all the electrons in the ion, can be calculated from the experimental value of the gram ionic susceptibility of magnesium.

$$-\chi_A \times 10^6 = \frac{-e^2 L}{6mc^2} \sum \bar{r}^2 \qquad (r^2 \text{ in Å.U.})$$

$$= -2.83 \times 10^{10} \sum \bar{r}^2$$

By substitution:-

$$-5.05 \times 10^{-6} = -2.83 \times 10^{10} \sum \bar{r}^2$$

$$\therefore \sum \bar{r}^2 = \frac{-5.05 \times 10^{-6}}{-2.83 \times 10^{10}}$$

$$= 1.784 \times 10^{-16}$$

The value obtained by Slater's method was = 3.938 in Atomic Units.

$$\text{Since 1 Å.U.} = \frac{1}{0.528} \text{ Atomic Units}$$

$$\therefore \sum \bar{r}^{-2}_{\text{theor.}} = 3.938 \times 0.528 \text{ Å.U.}$$

$$= 2.079 \text{ Å.U.}$$

These values for $\sum \bar{r}^2$ are not the square of the outer radius of the ion. The value for the actual outer radius cannot be determined from it, as the contribution of the various shells to the mean square radius is not known. However, a rough value for the outer radius can be obtained by Slater's method, because in the magnesium ion it can be seen that the 2SP orbit contributes by far the largest amount.

The effective radial electron density, which is a measure of the radius, is given by the equation:-

$$\bar{r}' = \frac{(n')^2}{(Z - S)}$$

Since n' = 2.0 for the outer orbit

and Z - S = 7.85 "   "   "   "

$$\therefore \bar{r}' = \frac{4}{7.85} \text{ in Atomic Units.}$$

i.e. $\bar{r}' = \frac{4}{7.85} \times 0.528 \text{ in Å.U.}$

$$= 0.27 \text{ Å.U.}$$

A value for the ionic radius can also be determined from experimental data. It will be seen that

$$\sqrt{\sum \bar{r}_e^2} : \sqrt{\sum \bar{r}_t^2} :: \bar{r}_e' : \bar{r}_t'$$

where $\sum \bar{r}^2$ and $\bar{r}'$ have the same meaning as before and the subscripts e and t denote the experimental and theoretical values respectively.

Substituting -

$$\bar{r}_e' = \frac{\sqrt{1.784}}{\sqrt{2.079}} \times 0.27 \qquad \text{Å.U.}$$

$$= 0.34 \quad \text{Å.U.}$$

These values of the ionic radius of magnesium are to be compared with values obtained by [21]Goldschmidt, [22]Pauling, and [23]Zachariasen, who give 0.78 Å.U., 0.65 Å.U., and 0.71 Å.U. respectively. Goldschmidt's value was obtained from empirical data from crystal structure by X-ray scattering. The values by Pauling and Zachariasen are calculated values.

Although it was stated that the Slater method for determining the ionic radius was only approximate, yet it is interesting to note that the values of 0.34 Å.U., and 0.27 Å.U. are nearly half those obtained by other workers. In this connection it is to be noted that Goldschmidt used anhydrous compounds of magnesium with a monomolecular anion, such as the halides and sulphide.

The results presented here are for several types of
magnesium compounds, that is:-

(1) Polar compounds, e.g. ahydrous magnesium sulphate,

　　and magnesium hydroxide;

(2) Hydrated compounds, and

(3) Complex compounds, such as the organic salts and the

　　double ammonium salts.

The results tend to show that by far the larger
number of magnesium compounds of the latter types (2) and
(3) do not conform to the Langevin equation, and therefore
strict or even slight additive relationships are not found.
The compounds of cadmium, investigated by [2]Spencer and
Hollens, are comparable with the magnesium compounds, whilst
on the other hand, the thallous compounds investigated
by [3]Trew, and the alkali halides, investigated by [4]Ikenmeyer,
show that the Langevin equation is applicable, and that
the gram ionic susceptibilities bear a simple additive
relationship to the molar susceptibility. These two latter
types of compounds are definitely polar, and this is borne
out by the consistent results for the gram ionic suscepti-
bility obtained. (loc. cit.)

The results of [1]Sugden on silver compounds show
that where it can be assumed that the molecules conform
with the fundamental hypotheses of the Langevin equation
additivity is observed, whereas, where the assumptions
can not be made, as in the complex compounds with pyridine,

there is a large para-magnetic susceptibility and no evidence of an additive character.

From which it is to be concluded that a definite constitutive factor due to hydration comes into the value of the molar susceptibility for all types of compounds except those which are strictly polar.

[24]Gray and Farquharson have put forward a theory of a "merger" atom. In the example of the formation of the potassium chloride molecule, they suggest that the two steps are taken, first, the formation of the molecule, and second, the formation of a single "merger" atom, by an imaginary forced merging of the ionic nuclei. This, in their opinion, would bring about diamagnetic changes. The molecule thus formed would have three nuclei, two real and one virtual, the latter assuming control over certain of the electrons originally controlled by one or both of the other real nuclei, and this would tend to bring about the development of weak paramagnetism.

This might also be the case in the formation of a hydrated ion, such as magnesium. The results of the present investigation, do not, however, appear to confirm this view. It will be seen from Table I, that the molecule instead of becoming less diamagnetic under the conditions which could give rise to a "merger" atom, in actual fact is more diamagnetic.

SUMMARY

(1) The magnetic mass susceptibilities of magnesium and thirty-
five of its compounds have been measured, and the values
compared with those previously published.

(2) The gram ionic susceptibility calculated from nineteen
compounds has the value χ_A = -5.05 x 10^{-6}, but this can
only be an approximate value since the Langevin equation
is not strictly applicable to many of the compounds used
in the calculation.

(3) The limiting effect of hydration on the magnesium ion
has been discussed in relation to the gram ionic suscepti-
bility. It is shown that hydration is a definite con-
stitutive factor in establishing the dimensions of the ion.

(4) The mean square radius of the ion has been calculated
from Slater's rules, and has the value $\sum \bar{r}^2$ = 2.079 Å.U.
Using this value, the theoretical ionic susceptibility
of magnesium has been calculated from Brindley's equation
and a value of χ_A = -3.12 x 10^{-6} obtained, which compares
favourably with the experimental value, considering the
approximate nature of the theoretical deduction, and the
constitutive effect of hydration on the ion.

(5) The approximate ionic radius of magnesium has also been
determined from Slater's rules, and the value of $\bar{r}'$ = 0.27 Å.U.
and the subsequent value of $\bar{r}'$ = 0.34 Å.U. obtained from

experimental data are compared with the value obtained

by Goldschmidt from polar compounds of magnesium.

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