Investigations on Magnecrystallic Action.

Paramagnetics: Pascal Vol. IV

(For absol. measurements see Vol II)

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11. Nickel Sulphate Hepta hydrate ($NiSO_4 \cdot 7H_2O$)

Rhombic.

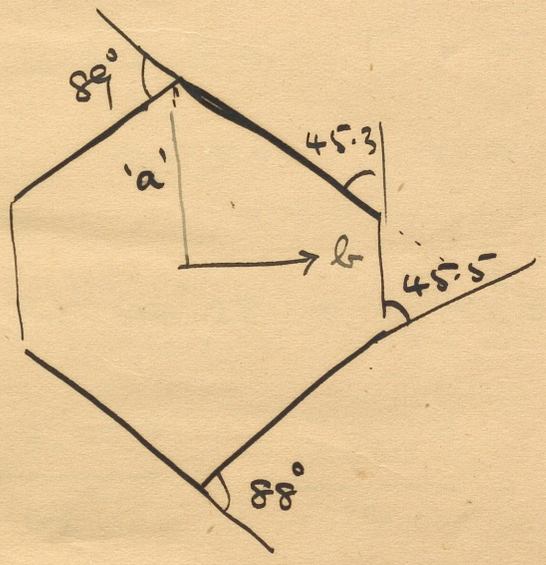
$$a : b : c = 0.9815 : 1 : 0.5656.$$

In the form of elongated plates bounded by (110) and (010) faces, the longest dimension corresponding to the 'c' axis. (For fig. see p. 429 fig. 673 in Groth II.).

Since ~~the a and b~~ a : b is very nearly unity the m(110) faces practically subtend 90°. (actually 88° 56' and 91° 4') ~~Since the~~ The difference in the ~~a~~ two angles being only 2°, the identification of the 'a' and 'b' axes by measurement of the angles between the (110) faces is ~~not~~ likely to be uncertain. But ~~as~~ since Groth describes only the (010) face as well-developed and does not mention (100) face ~~in~~ at all, the

$Ni\,SO_4 \cdot 7H_2O$

identification presents no difficulty in practice. In the actual case the angle measurements between the (110)'s also supported this identification. When the crystal was suspended with its 'c' axis vertical, and the angle measurements between the different vertical faces were made, the results were



The oscillation measurements gave the following values.

1) 'a' axis vertical. [(010) plane at ½° to vertical and 'c' axis at about ½° to horizontal.]
'c' axis set along the field.

$T = 2.16$ secs. $T' = 3.41$ secs. $M = 280.9$

$NiSO_4 \cdot 7H_2O$.

$m = 0.0847$ gms. $c = 0.00876$ $H = 600.5$ gms

$$\therefore \chi_c - \chi_b = \frac{5.57 \times 1.25}{2.16^2} \times \frac{280.9}{.0847} \times \frac{.00876}{600.5^2}$$

$$= 120 \times 10^{-6}$$

2). (110) plane horizontal.

'c' axis set itself along the field.

$T = 4.62$ secs. $T' = 5.89$ secs. $m = 0.1071$ gms

$c = .00859$ $H = 613.4$ gauss.

$$\therefore \chi_c - \left(\chi_a \sin^2 44^\circ 28' + \chi_b \cos^2 44^\circ 28'\right) =$$

$$= \frac{10.51 \times 1.27}{4.62^2} \times \frac{280.9}{.1071} \times \frac{.00859}{613.4^2} = 37 \times 10^{-6}$$

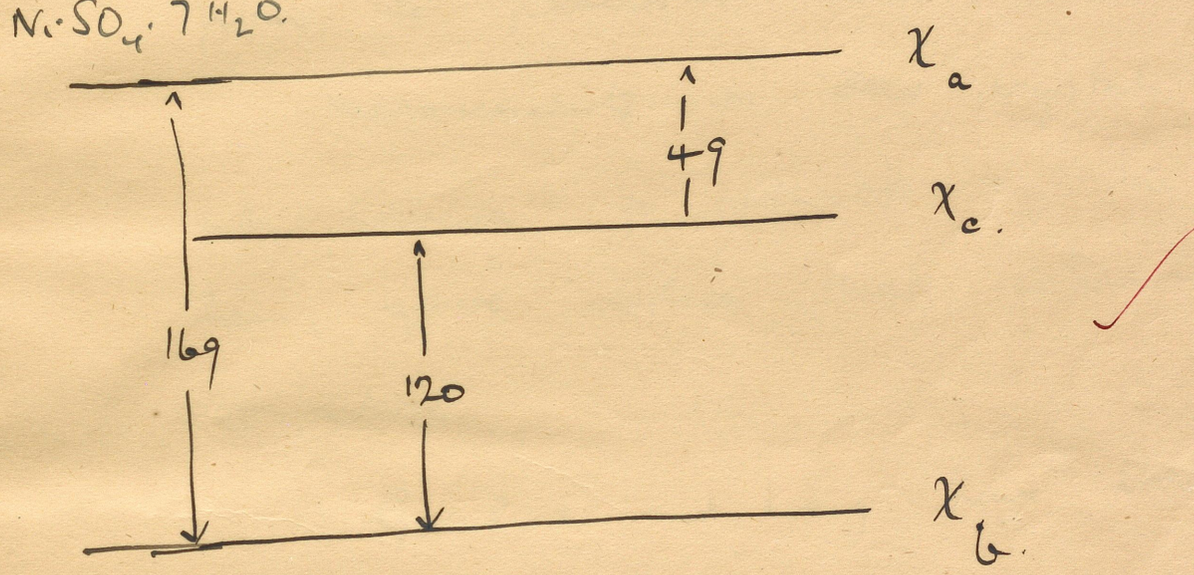
Same crystal gave with the same suspension but with higher field viz 1827 gauss the values $T = 2.32$ secs. $T' = 5.89$ secs.

$$\therefore \Delta\chi = \frac{8.21 \times 3.57}{2.32^2} \times \frac{280.9}{.1071} \times \frac{.00859}{1827^2} = 37 \times 10^{-6}$$

exactly the same value as before.

Using the results of (1) and ~~(2)~~ we have

$$\left.\begin{aligned} \chi_a - \chi_b &= 169 \\ \chi_c + \chi_b &= 120. \\ \chi_a - \chi_c &= 49. \end{aligned}\right\} \times 10^{-6}.$$



3) As a check on these values the crystal was next suspended with its 'c' axis vertical [actually (110) plane at 0.7° to vertical and intersection of (110) with (001) ~~at~~ exactly horizontal] 'a' axis sets itself along the field.

$T = 1.39$ secs. $T' = 2.72$ secs. ~~$m = 0.1071$ gms~~

$m = 0.1071$ gms $H = 613.4$ gauss.

$NiSO_4 \cdot 7H_2O$

$$\therefore \chi_a - \chi_b = \frac{4{\cdot}11 \times 1{\cdot}33}{1{\cdot}39^2} \times \frac{280{\cdot}9}{{\cdot}1071} \times \frac{{\cdot}00859}{613{\cdot}4^2}$$

$$= 169 \times 10^{-6}$$

in agreement with the value deduced from the previous oscillations.

Measurements on other crystals, which are not however so reliable as the ones given here, gave values not inconsistent with the above.

Grailich and Lang have investigated the deportment of this crystal in a magnetic field: Their results are however quoted differently by different authors. For example Graetz in his Handbuch IV p. 835 quotes their results as

$$\chi_c > \chi_a > \chi_b.$$

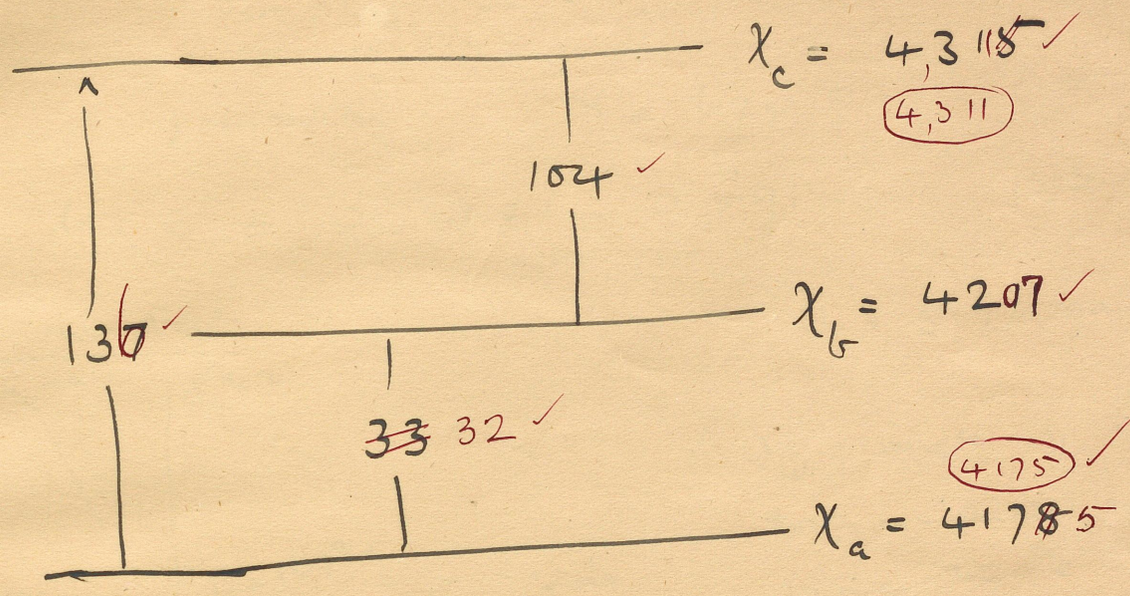
and Groth also ~~gives the~~ quotes the same order. On the other hand Finke quotes their order as

$$\chi_c > \chi_b > \chi_a$$

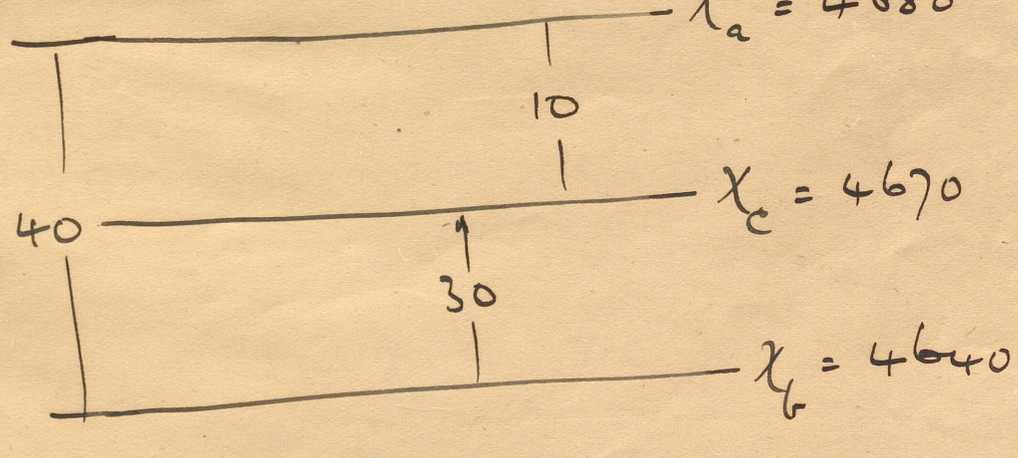
which supports his own results, viz.

Finke quotes Gr. & L. correctly as also Auerbach in Graetz's Handbuch where the notation adopted regarding the cryst. axes is $a > b > c$. Groth is incorrect.

$NiSO_4 \cdot 7H_2O$



Jackson's values for this crystal are [here his assumption that $\chi_a - \chi_b > 0$ as also $\chi_c - (\chi_a \sin^2 44^\circ 28' + \chi_b \cos^2 44^\circ 28') > 0$ happen to be correct-]



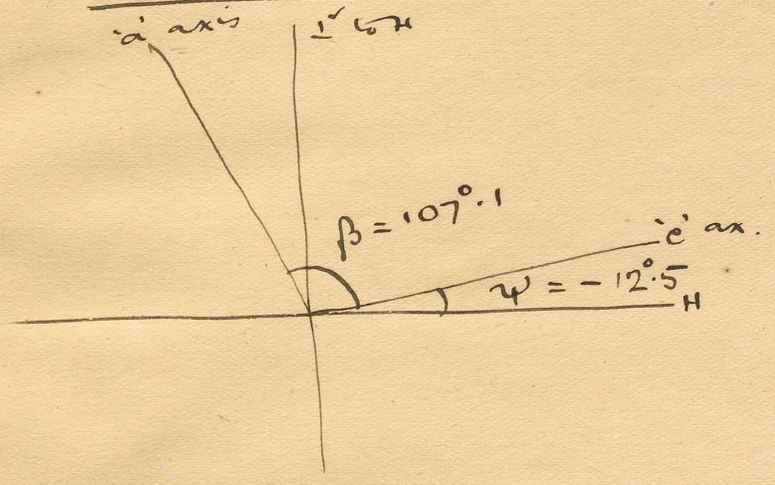
at 15° C.

$MnSO_4 \cdot Cs_2SO_4 \cdot 6H_2O$

monocl. prismatic $M = 620.8$ $\rho = 2.74$

$a : b : c = 0.727 : 1 : 0.491$; $\beta = 107° 7'$.

'b' ax. vert



$H = 5177$ gauss.

α_ψ = angle of rotation of torsion-head necessary to bring the 'c' ax. along field.
$(\alpha - 45°)$ = torsion corresponding to max couple.

1st expt.	$m = 0.330$ gm.	$c = .002113$	$\alpha_\psi = 540°$	$\alpha - 45 = 135.5°$	$\therefore \chi_1 - \chi_2 = 7.0$
				$\psi = -11°.5$	
2nd	.295 gm.	"	$\alpha_\psi = 527°$	$\alpha - 45 = 122.0$	
				$\therefore \psi = -12°.5$	$\chi_1 - \chi_2 = 7.1$
3rd	.345 "	"	$\alpha_\psi = 600°$	$\alpha - 45 = 134.5$	
				$\psi = -12°.9$	$\chi_1 - \chi_2 = 6.7$
4th	.265	$c = .001214$	$\alpha_\psi = 840°$	$\alpha - 45 = 192.0°$	
				$\psi = -12°.8$	$\chi_1 - \chi_2 = 7.0$

Aexpt $\chi_1 - \chi_2 = 7.0$ ✓
$\psi = -12°.5$. $\theta = +29°.6$. (1)

'a' ax. vert 'b' ax normal to field

$m = .360$ gm. $c = .002113$ $\alpha - 45 = 64.7°$

$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 3.1$ - - - (2)

From (1) and (2)

$$\chi_1 - \chi_2 = 7\cdot0$$
$$\chi_1 - \chi_3 = 5\cdot0$$
$$\psi = -12°\cdot5$$

c(001) fol. hori 2 'b' ax. along field

$m = \cdot215$ gm. $c = \cdot000381$ $\alpha - 45° = 205°$

$\therefore \chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = 0\cdot3$ ... (2)

3) 'a' ax. vert 'b' ax. set normal to field.

$m = \cdot360$ gm $c = \cdot002113$ $\alpha - 45 = 64°$

$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 3\cdot1$ ... (3)

as against- 3·3 calculated from (1) and (2).

Cobalt Sulphate Heptahydrate ($CoSO_4 \cdot 7H_2O$)

Monoclinic prismatic

$a : b : c = 1.1815 : 1 : 1.5325$, $\beta = 104° 40'$

The crystals used had a number of faces very well developed, especially (001), (110), (103), (101), (013), (010) and $(\bar{1}01)$, the general form of the crystal being as shown in Fig 677 on p. 432 of Groth II.

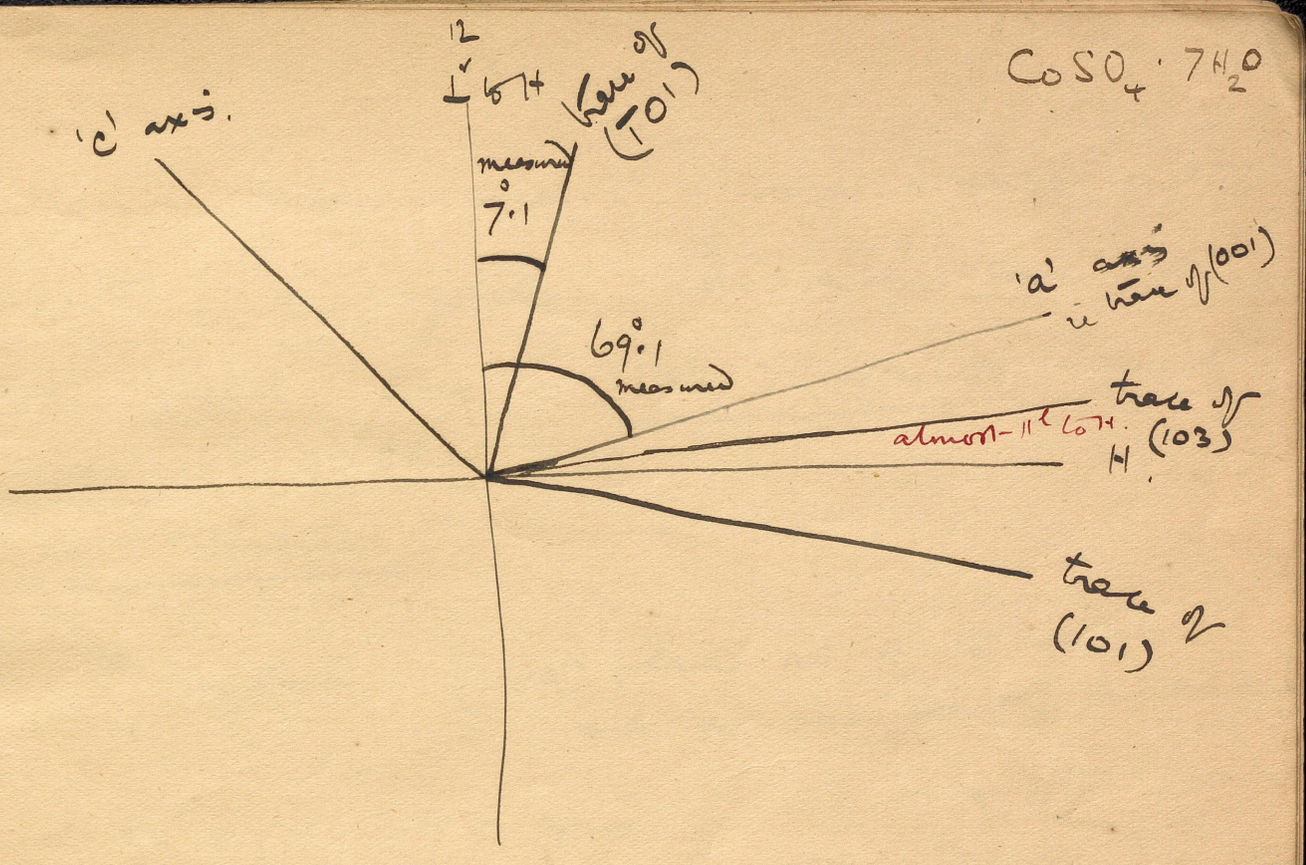
When the crystal is suspended with its 'b' axis vertical, the inclination between (001) face and (103), (101) and $(\bar{1}01)$ can be readily measured, and in an actual measurement the values obtained were

	Observed.	Calcd. Groth.
(001) ∧ (103)	21°	20° 39'
(001) ∧ (101)	44°	43° 22'
(001) ∧ $(\bar{1}01)$	62°	61° 51'

thus confirming our identification of the different faces. Also the angle on the (001) face between the 'b' axis (intersection of (001) and (103)) and the edge of intersection of (001) and (110) was measured and found to be 130° as against the calculated value of 130° 15'. ✓ Again when the crystal was suspended with its 'a' axis vertical, the $\angle^{le}$ between (001) and (011) was measured and was 54°.5', whereas the theoretical value given by Groth is 56°. ✓

Coming back to the suspension with the 'b' axis vertical, the setting of the crystal in the magnetic field was as follows:-

$CoSO_4 \cdot 7H_2O$



The inclination of the (001) face to the normal to the field was measured and found to be 69°·1 i.e. $\theta = +69°\cdot1$. Also the inclination of the (T01) face (which is known to make an angle of 61°·9 with the (001) face) to the normal to the field was 7°·1 which would correspond to $\theta = +69°\cdot0$.

We may therefore adopt the value

$$\theta = +69°\cdot1 \checkmark$$

and $\therefore \psi = -54°\cdot4 \checkmark$

$CoSO_4 \cdot 7H_2O$

Oscillation measurements were made with altogether 3 crystals. In all cases the field used was 182.3 gauss. and c was 0.00881.

1) 'b' axis vertical

(i) 1st crystal. ((001) plane at $\frac{1}{2}°$ to vertical and 'a' axis exactly horizontal.)

$m = 0.1687$ gms. $M = 281.1$

$T' = 5.03$ secs. $T = 2.17_5$ secs.

$$\therefore \chi_1 - \chi_2 = \frac{7.205 \times 2.855}{2.175^2} \times \frac{281.1}{.1687} \times \frac{.00881}{182.3^2}$$

$$= 1921 \times 10^{-6}$$

(ii) 2nd crystal. [(001) plane at $\frac{1}{2}°$ to vertl and 'a' axis at $\frac{1}{2}°$ to horizl.]

$m = 0.1348$ gms.

$T = 2.08_5$ secs. $T' = 4.42_5$ secs.

$$\therefore \chi_1 - \chi_2 = \frac{6.51 \times 2.34}{2.085^2} \times \frac{281.1}{.1348} \times \frac{.00881}{182.3^2}$$

$$= 1936 \times 10^{-6}$$

$CoSO_4 \cdot 7H_2O$

We may therefore accept of the mean of the two values, viz.,

$$\chi_1 - \chi_2 = \underline{1928} \times 10^{-6} \quad \checkmark \quad \ldots(1)$$

2) 'a' axis vertical.

(i) 1st crystal. [(001) plane at $\cdot 3^\circ$ to vertical and 'b' axis exactly horizontal.]

$m = 0.1687$ gms. ✓

$T = 3.23$ ✓ secs. $T' = 4.93$ ✓ secs.

'b' axis sets along the field. ✓

$$\therefore \chi_3 - \chi_1 \cos^2\theta - \chi_2 \sin^2\theta = \frac{8.16 \times 1.70}{3.23^2} \times \frac{281.1}{.1687} \times \frac{.00881}{182.3^2}$$

$$= 587 \times 10^{-6} \quad \checkmark$$

(ii) 3rd crystal. [(001) plane at 0.7° to vertical and 'b' axis at 0.7° to horizl. ✓]

$m = 0.1360$ gms. ✓ 'b' axis sets along field ✓

$T = 2.75$ secs. ✓ $T' = 3.98$ ✓ secs.

$$\Delta\chi = \frac{6.73 \times 1.23}{2.75^2} \times \frac{281.1}{.1360} \times \frac{.00881}{182.3^2} \quad \checkmark$$

$$= 600 \times 10^{-6} \quad \checkmark$$

$CoSO_4 \cdot 7H_2O$

For this suspension we adopt the mean value

$$\chi_3 - \chi_1 \cos^2\theta - \chi_2 \sin^2\theta = \underline{593 \times 10^{-6}} \quad \text{--(2)}$$

3) (001) plane horizontal.

(i) 1st crystal. ['a' axis at $\cdot 7^\circ$ to horiz. and 'b' axis exactly horizl.]

The crystal sets with 'a' axis $\parallel$ to field

$m = \cdot 1687$ gms. $T = 3 \cdot 60$ secs. $T' = 6 \cdot 20$ secs.

$$\therefore \chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = \frac{9 \cdot 80 \times 3 \cdot 60}{3 \cdot 60^2} \times \frac{281 \cdot 1}{\cdot 1687} \times \frac{\cdot 00881}{182 \cdot 3^2}$$

$$= 869 \times 10^{-6}$$

(ii) 3rd crystal. [(001) plane at $\frac{1}{2}^\circ$ to horizl.]

$m = 0 \cdot 1360$ gms. $T = 3 \cdot 00$ secs. $T' = 4 \cdot 77$ secs.

$$\therefore \Delta\chi = \frac{7 \cdot 77 \times 1 \cdot 77}{3 \cdot 00^2} \times \frac{281 \cdot 1}{\cdot 1360} \times \frac{\cdot 00881}{182 \cdot 3^2}$$

$$= 838 \times 10^{-6}$$

Adopting the mean we have

$$\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = \underline{854 \times 10^{-6}} \quad \text{--(3)}$$

From (1), (2) and (3) we obtain

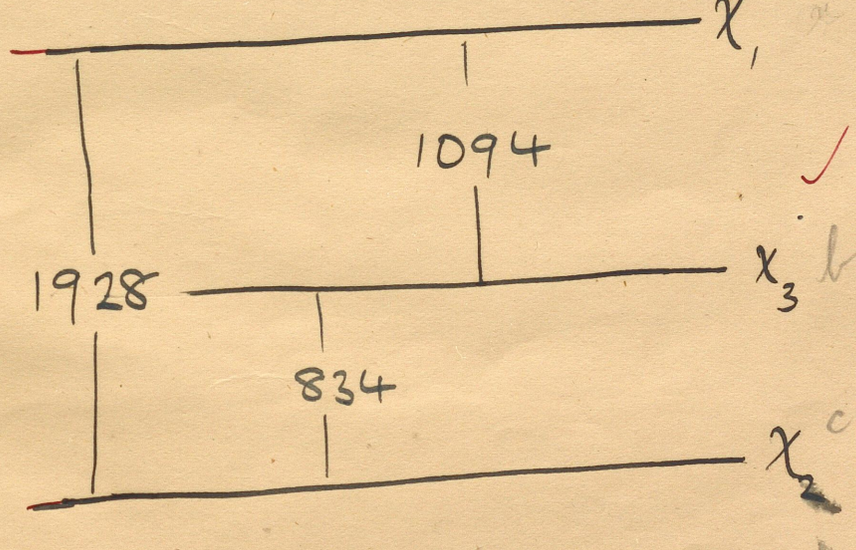
$$\left.\begin{aligned} \chi_1 - \chi_2 &= 1928 \\ \chi_1 - \chi_3 &= 1094 \end{aligned}\right\} \times 10^{-6} \checkmark$$

and $\theta = +69°.3$ ✓ which corresponds to

$\psi = -54°.6$ ✓

as against $\psi = -54°.4$ ✓ observed.

Thus we have finally for $\underline{CoSO_4 \cdot 7H_2O}$

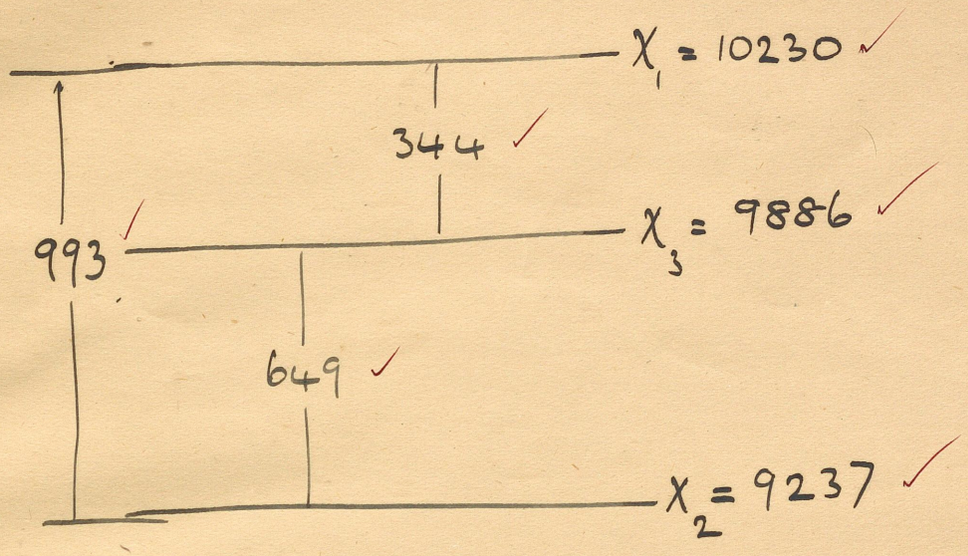


✓ $\psi = -54°.4$ obs. ✓

$-52°.6$ cal.

With these may be compared the following values obtained by Finke:

$CoSO_4 \cdot 7H_2O$



$\psi = -39^\circ 40'$

Ferrous sulphate heptahydrate ($FeSO_4 \cdot 7H_2O$)

Monoclinic prismatic

$a : b : c = 1.1828 : 1 : 1.5427$; $\beta = 104^\circ 15\frac{1}{2}'$

The form of the crystal was exactly the same as that of $CoSO_4 \cdot 7H_2O$ with its (001), (110), (103), (101), (013), (011) and ($\bar{1}$01) very well developed [see p. 10, as also Fig. 677, p. 432 of Groth II]

Suspending the crystal with its 'b' axis vertical the following angle measurements were made :-

	measured.	Cal. Groth.
(001) ∧ (103)	20°·5	20° 53'
(001) ∧ (101)	44°	43° 44'

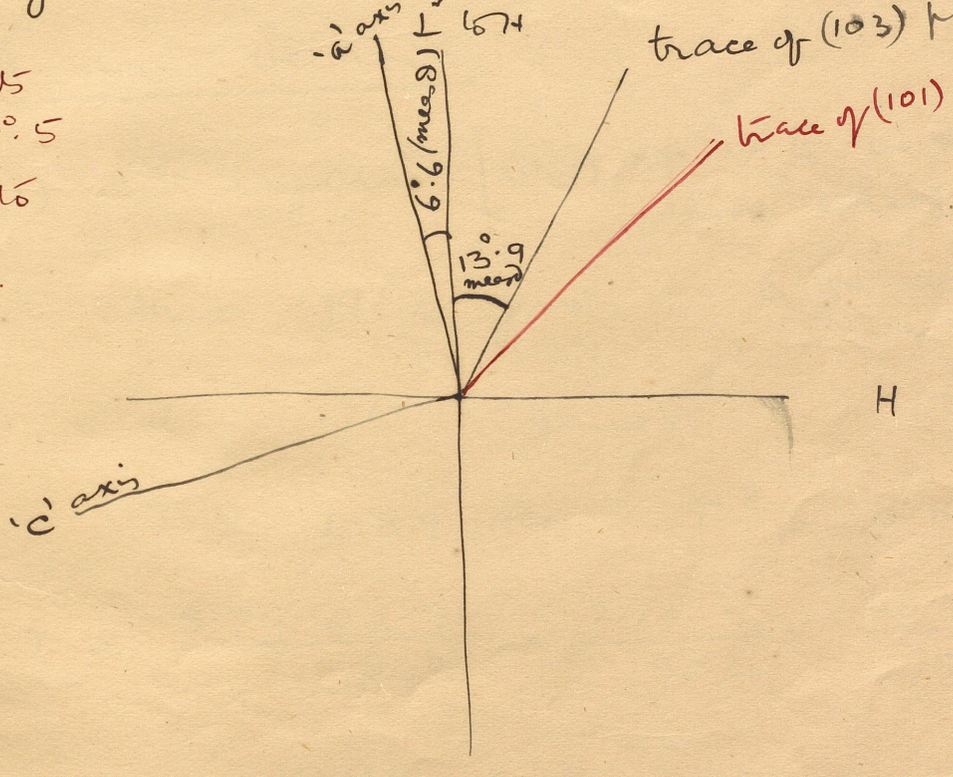
and similarly with the 'a' axis vertical

∠(001) ∧ (010)	90°	90°
(001) ∧ (011)	55°·5	56°

Also the angle (on the (001) face) between the 'b' axis and the edge of intersection of c(001) and m(110)

was measured and found to be 131°, as against the calculated value 130° 13'. ✓ thus confirming our identification of the different faces of the crystal.

Coming back to the suspension with the 'b' axis vertical, the setting of the crystal in the magnetic field was as follows:



new measurements gave $\theta = -7°.5$ corresponding to $\psi = +22°$.

θ directly measured from the inclination of the c(001) face was ~~-6°.6~~ -6°.6. On the other hand the (103) face (which is inclined at 20°.9 to the (001) face) was at 13°.9

to the normal to the field, thus giving for θ the value $-7^\circ \cdot 0$.

We may therefore adopt for θ the mean value $\theta = -\underline{6^\circ \cdot 8}$ ✓ which would correspond to

$$\psi = +21^\circ \cdot 1 \text{.} \checkmark$$

The oscillation measurements were as follows :-

1) 'b' axis vertical

(i) 1st crystal. [(001) at $\cdot 7^\circ$ to vertical and 'a' axis almost exactly horizontal.]

$m = \cdot 1904$ gms ✓. C for all the measurements below was 0·00881 ✓

$H = 175 \cdot 6$ ✓ gauss. $M = 278 \cdot 0$ ✓

$T = 2 \cdot 89$ ✓ secs. $T' = 5 \cdot 85$ ✓ secs.

$$\therefore \chi_1 - \chi_2 = \frac{8 \cdot 74 \times 2 \cdot 96}{2 \cdot 89^2} \times \frac{278 \cdot 0}{\cdot 1904} \times \frac{\cdot 00881}{175 \cdot 6^2}$$

$$= 1292 \times 10^{-6} \checkmark$$

(ii) 2nd crystal. [(001) at $0 \cdot 5^\circ$ to vert and 'a' axis at $\cdot 7^\circ$ to horizl.]

$m = \cdot 2266$ ✓ gms. $H = 175 \cdot 6$ gauss ✓

$T = 3 \cdot 60$ secs. ✓ $T' = 7 \cdot 78$ ✓ secs.

(7·78)

$FeSO_4 \cdot 7H_2O$

$$\therefore \chi_1 - \chi_2 = \frac{11.38 \times 4.18}{3.60^2} \times \frac{278.0}{.2266} \times \frac{.00881}{175.6^2}$$

$$= 1286 \times 10^{-6} \checkmark$$

We may adopt the mean of the two values viz.,

$$\chi_1 - \chi_2 = \underline{1289 \times 10^{-6}} \checkmark \quad \text{----(1).}$$

2) 'a' axis of the crystal vertical.

(i) 1st crystal. [(001) plane at 17° to vertl. and 'b' axis at 1.3° to horiz]

'b' axis set normal to field. ✓

$m = .1904$ gms. ✓ $H = 175.6$ ✓ gauss.

$T = 2.84$ ✓ secs. $T' = \cancel{2.84}$ 5.69 ✓ secs.

$$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \frac{8.53 \times 2.85}{2.84^2} \times \frac{278.0}{.1904} \times \frac{.00881}{175.6^2}$$

$$= 1257 \times 10^{-6} \checkmark$$

(ii) 2nd crystal $m = .2266$ ✓ gms. $H = 175.6$ ✓

$T = 2.68$ ✓ secs. $T' = 5.73$ ✓ secs.

$$\therefore \Delta\chi = 1252 \times 10^{-6} \checkmark$$

$FeSO_4 \cdot 7H_2O$

For this suspension we can adopt the mean value

$$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \underline{1254 \times 10^{-6}} \quad \cdots (2)$$

3) <u>(001) plane horizontal.</u>

<u>2nd crystal.</u> ['a' axis at ·7° and 'b' axis at ·3° to horizontal.]

'b' axis sets along field.

$m = \cdot 2266$ gms. $\quad H = 873$ gauss.

$T = 7\cdot 29$ secs. $\quad T' = 8\cdot 00$ secs.

$$\therefore \chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \frac{15\cdot 29 \times \cdot 71}{7\cdot 29^2} \times \frac{278\cdot 0}{\cdot 2266} \times \frac{\cdot 00881}{873^2}$$

$$= \underline{3 \times 10^{-6}}. \quad \cdots (3)$$

From (1), (2) and (3) we obtain

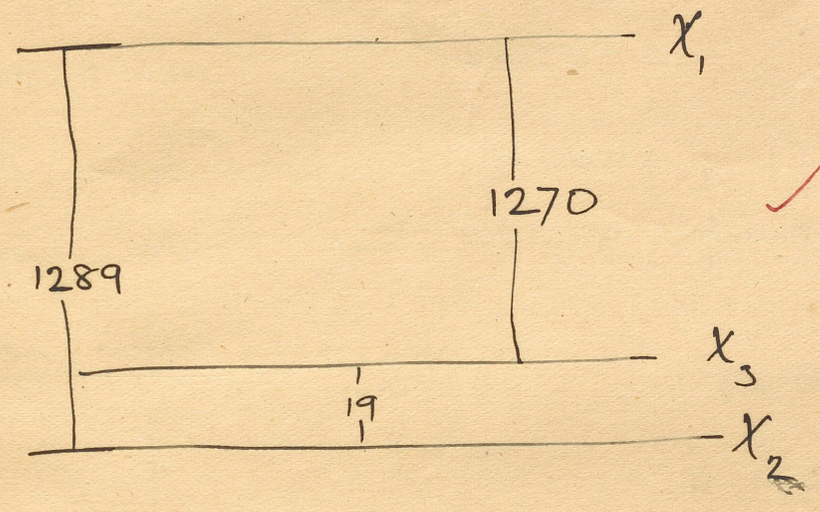
$$\chi_1 - \chi_2 = 1289$$
$$\chi_1 - \chi_3 = 1270$$

and $|\theta| = 6^\circ\cdot 4$, which corresponds to

$\psi = \cancel{+19^\circ\cdot 9}$ $+20^\circ\cdot 7$ $(+20^\circ\cdot 7)$ as against the observed

value of $\cancel{+20^\circ\cdot 1}$. $+21^\circ\cdot 1$

We thus have for $FeSO_4 \cdot 7H_2O$.

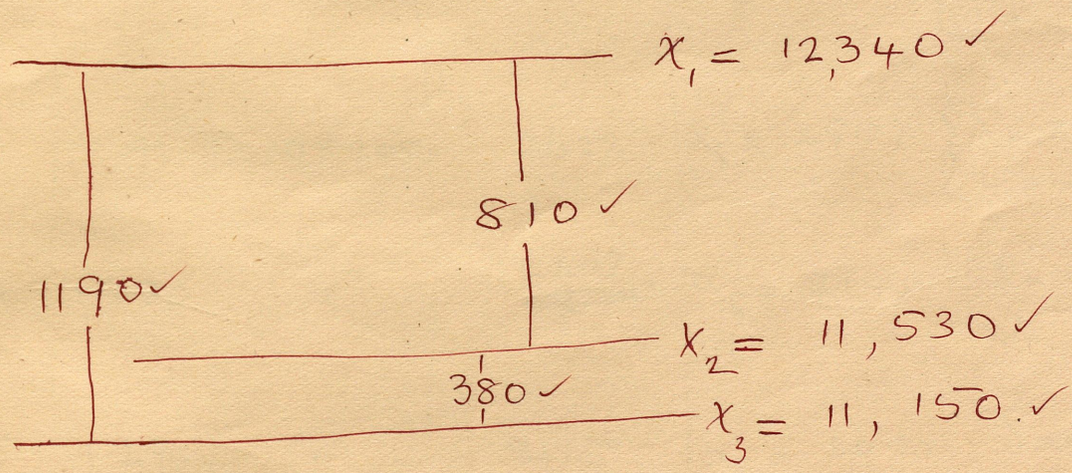


$\psi = +21^\circ \cdot 1$ obs.
$21^\circ \cdot 1$

~~$+19^\circ \cdot 9$ cal.~~
$+20^\circ \cdot 7$ cal.

The χ_1-axis is almost an axis of magnetic symmetry.

With these may be compared the following values obtained by Finke.



$\psi = +30^\circ 10'$

Manganous Thallous Selenate hexahydrate

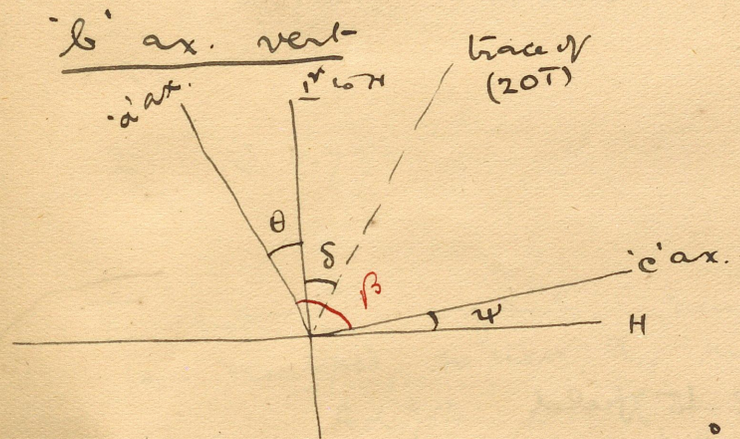
$MnSeO_4 \cdot Tl_2SeO_4 \cdot 6H_2O$

Monoc prismc. $M = 858.2$ $\rho = 3.833$

$a : b : c = 0.7463 : 1 : 0.4993$; $\beta = 105^\circ 29'$

Crystals white and almost opaque.

'b' ax. vert



$\delta + \theta = 63^\circ 31'$ (Groth)

H through out was 5177 gauss.

α = $\angle^{le}$ of rotation for just turning round the crystal

α_θ ; α_δ , α_ψ : angles for bringing (001) or (20T) to normality, or (100) along field

No.	m	c	$\alpha - 45^\circ$	α	ψ	$\chi_1 - \chi_2$
I 1	1.831	.00499	2750	$\alpha_\delta = 2557$	$\delta = 33^\circ.3$, $-14^\circ.7$	8.4
2			2685	$\alpha_\delta = 2600$	$\delta = 36^\circ.4$, ~~+20°.9~~, $-11^\circ.6$	
~~3~~						
3	1.693	.005205	2622	$\alpha_\delta = 2507$	$\delta = 35^\circ.3$, $\psi = -12^\circ.7$	9.0
4	1.450	"	2207 ~~2240~~	$\alpha_\delta = 2140$	$\delta = 36^\circ.2$, $\psi = -11^\circ.8$	8.9
5.	1.290	"	2115	$\alpha_\delta = 2050$	$\delta = 36^\circ.1$, $\psi = -11^\circ.9$	9.5

(001) pl. horiz 'b' ax. normal to field

m	c	$\alpha - 45°$	$\Delta\chi$
·830	·000175	330°	·8
·40	·000916	370°	·9
·37	"	385°	1·0

Appl- $\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = 0.9$ - - - (2)

From (1) and (2)

$\chi_1 - \chi_2 = 10.5$

$\chi_1 - \chi_3 = 8.9$

$\psi = -14°$

Mn Tl selenate

	No.	m	c	$\alpha - 45°$	α	ψ	$\chi_1 - \chi_2$
II cryst.	1	1·305	·00533	2310°	$\alpha_\psi = 1010°$	−12°·8	10·5
	2.	1·156	"	2040			10·5
III cryst.	1.	0·941	·005608	1575	$\alpha_\theta = 1300$	$\theta = +27°·0$, $\psi = -11°·5$	10·5
	2.	0·673	"	1150	$\alpha_\psi = 580$	$\psi = -14°·7$	10·7

III and II crystals much better than I, and (100) face best developed, so that α_ψ more accurate than either α_δ or α_θ.

Adopt ∴ $\chi_1 - \chi_2 = 10·5$

and $\psi = -14°$. — — — (1)

'a' ax. vert. 'b' ax. ⊥ to field

$$\therefore \Delta\chi = \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3.$$

m = ·574 gm. c = ·00320 $\alpha - 45° = 985°$ $\Delta\chi = 6·14$

·676 " " 1155° 6·12

Adopt $\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 6·1$ . . . (3)

as against 6·4 from (1) and (2)

~~from (1) and (2)~~ $\chi_1 - \chi_2 = 10·5$

$\chi_1 - \chi_3 = 8·6$

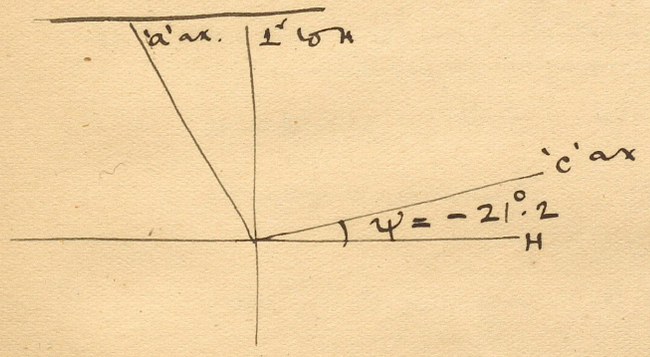
$\psi = -14°$.

$MnSeO_4 \cdot (NH_4)_2 SeO_4 \cdot 6H_2O$

monocl. prisme. $M = 485.5$ $\rho = 2.16$

$a : b : c = 0.743 : 1 : 0.499$ $\beta = 106° 16'$

'b' ax. vert-



Cryst no.

$H = 5177$ gauss.

$C_1 = \frac{\overline{2}.6718}{4.73^2} = .00210$

$C_2 = .000916$.

α_ψ = angle of rotation of torsion-head necessary to bring the 'c' ax. along field

Cryst no.	m	c	α_ψ	$\alpha - 45°$	$\chi_1 - \chi_2$	ψ
1.	0.475 0.240	C_1	2215°	3250°	9.1	$-21°.2$
2.	0.390	C_1	1815°	2665°	9.1	$-21°.2$

Adopt- $\chi_1 - \chi_2 = 9.1$

$\psi = -21°.2$

2) 'a' ax. vert 'b' ax. normal to field $\therefore \Delta\chi = \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3$

1. cryst $m = 0.400$gm. $c = C_1$ $\alpha - 45° = 990°$ $\therefore \Delta\chi = 3.3$

$= 0.405$ gm " $\alpha - 45° = 1010$ " 3.3

Adopt- $\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 3.3$ ---(2)

From (1) and (2)

$$\chi_1 - \chi_2 = 9.1$$
$$\chi_1 - \chi_3 = 6.7$$
$$\psi = -21^\circ$$

3) c(001) plan. horiz. Its ax. normal to field when set at a small angle, so that the measurements are not quite accurate.

1st exp. $m = 0.300$ gm. $c = c_2$ $\alpha - 45 = 630^\circ$ $\therefore \Delta\chi = 1.2$.

2nd " $= 0.320$ gm. " $= 350^\circ$ $\Delta\chi = 0.6$.

adopting the mean value, we have

$$\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = 0.9 \quad \text{---} \quad (3)$$

as compared with 1.0 calculated.

Manganese Ammonium Sulphate Hexahydrate

$MnSO_4 \cdot (NH_4)_2 SO_4 \cdot 6H_2O$.

Monoclinic prismatic.

$$a : b : c = 0.7360 : 1 : 0.4972 \; ; \; \beta = 107^\circ 2'.$$

The form of the crystal was the same as in the case of the other double-sulphates.

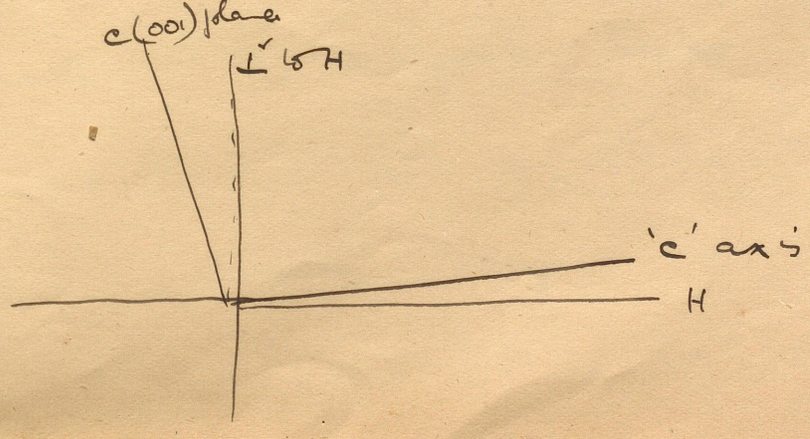
Since the magnetic anisotropy of the crystal is very small a different method of measurement was adopted. The crystal was suitably suspended by a calibrated quartz fibre in a bath of the same volume susceptibility as the mean volume susc. of the crystal, in the uniform magnetic field. The couple acting on the crystal was measured. The couple is evidently $= \frac{1}{2} H^2 \frac{m}{M} (\chi_I - \chi_{II}) \sin 2\varphi$ where χ_I and χ_{II} are the max. and min values of the gm. mol. susc. in the plane

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

of oscillation and φ is the angle which the χ_I axis makes with the direction of the field. The max. value of the couple is when $\varphi = 45^\circ$.

I 'b' axis vertical

The crystal was first adjusted, when the pole-pieces are very far apart, so that the c(001) plane may be $\perp^r$ to the direction of the field & be put on. The reading on the torsion head is noted. The poles ~~pieces~~ are brought near and clamped. A uniform field is put on, when the crystal rotates away from the



position of normality so that the normal to the field lies in the obtuse ∠le B. ~~b a and c~~. the 'c' axis being at a small ∠le to the field. in the position marked in the diagram. The ~~actual~~ exact setting ∠le could not be measured since the rotating couple is very feeble for a considerable range of ∠s from the equilibrium. ~~when the t. of inclination from the equili.~~ position. Hence it had to be indirectly measured as follows: -

The torsion head is rotated in the opposite direction to that in which the c(001) plane ~~rotates~~ from the position of normality to the field, until the c(001) plane is brought back to normality as viewed ~~from~~ through the telescope. The ∠le of rotation of torsion head is usually very large (considerably over 2π). Let α_1 be the ∠le of above

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

rotation of torsion head. Then

$$\alpha_1 \text{ (in degrees)} = \frac{180}{2\pi C} \cdot \frac{m}{M} H^2 (\chi_1 - \chi_2) \sin 2\theta \quad (1)$$

where θ is the inclination of the χ_2 axis to 'a' axis (our usual notation)

i.e., $\alpha_1 = K \sin 2\theta$, eq

where $K = \frac{180}{2\pi C} \frac{m}{M} \cdot H^2 (\chi_1 - \chi_2)$ ---(2)

If now the torsion head be further rotated in the same direction as before the inclination of the χ_1 axis to the field increases beyond θ, and when it reaches just above 45° the ~~equilibrium of the~~ ~~crystal~~ torsion on the crystal is just more than sufficient to compensated ~~by~~ the anisotropic couple. Hence the crystal rotates quickly round over a large angle, slightly less than 180°, so that χ_1 axis makes an $\angle$ of about 25° or so with the direction of the field,

on the opposite side. This critical angle of orientation of the crystal when it suddenly turns round is measurable accurately and hence the max. value of the couple. If α_2 is the total rotation of the torsion head from the initial position when the C(001) plane was normal to the direction of H and H was zero, the position when the crystal just turns round, then (if α_2 and θ are expressed in degrees)

$$\alpha_2 - (45^\circ - \theta) = K. \quad \text{---(3)}$$

Hence from (1) and (3)

$$\sin 2\theta = \frac{\alpha_{ak1}}{\alpha_2 - (45^\circ - \theta)}$$

where θ is known, as also K and hence $\chi_1 - \chi_2$.

A number of crystals were measured in this manner. The results are given below. The masses of the crystals were measured

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

immediately after the ~~balance~~ measurements in the field were made.

1st crystal. $m = \cdot 220$ gms. $M = 391 \cdot 2$.

$H = (14 \cdot 0$ amps.$)\ 4119$ gauss

$C = (23 \cdot 2$ secs.$)\ \cdot 00487$.

$\alpha_1 = 5^\circ 64'$ $\alpha_2 = 6^\circ 52'$.

$\therefore \sin 2\theta = \dfrac{5 \cdot 64}{6 \cdot 07 + \theta}$ $\therefore \underline{\theta = 31^\circ \cdot 1}$

$K = 5 \cdot 61 \times 10^7 (\chi_1 - \chi_2) = 6 \cdot 07 + \theta$

$\therefore \chi_1 - \chi_2 = \underline{11 \cdot 4 \times 10^{-6}}$

2nd crystal. In this case in addition to measuring α_1 and α_2, after the crystal had turned round, the torsion head was rotated ~~backwards to its original position so as to~~ further in the same direction so that the total torsion ~~opposite direction over an~~ be say α_3. $= \alpha_3$, such that C(001) is again normal to the field (i.e. 180° to its original orientation.)

$MnSO_4.(NH_4)_2SO_4.6H_2O$

The ~~section of the crystal~~ torsion head ~~is~~ is now rotated back in the opposite direction, ~~continued~~ till the crystal turned round again towards its original direction. Let α_4 be the total rotation from the original position when c(001) plane was normal to field and H was zero. Then.

$$\alpha_3 - 180^\circ = K \sin 2\theta \checkmark$$

$$\alpha_4 + 90^\circ + 45^\circ - \theta = K. \checkmark$$

~~$\alpha_4 - (\alpha_3 - 180^\circ) - (45^\circ + \theta) = K$.~~

For this crystal, $m = 0.420$ gms. ✓

$c = .00487$ ✓

$H = (9.0 \text{ ampss.})\ 3107$ gauss ✓

$\alpha_1 = 633^\circ$ ✓

$\alpha_2 = 719^\circ$ ✓

$\therefore \sin 2\theta = \dfrac{633^\circ}{674 + \theta}$ $\therefore$ $\underline{\theta = 31^\circ.8}$ ✓

$K = 6.09 \times 10^7 (\chi_1 - \chi_2) = 674 + \theta$ ✓

$\therefore \chi_1 - \chi_2 = \underline{11.6 \times 10^{-6}}$ ✓

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

For the same crystal

$\alpha_3 = 796^\circ$ ✓

$\alpha_4 = 591^\circ$ ✓

$\therefore \sin 2\theta = \frac{616}{726-\theta}$; $\theta = 31^\circ \cdot 2$ ✓

$\chi_1 - \chi_2 = \frac{726-\theta}{6.09 \times 10^7} = 11.4 \times 10^{-6}$ ✓

3rd crystal.

$m = .392$ gms. $H = (7.0 \text{ amps.})$ 2581 gms ✓

$c = .00487$ ✓

only α_1 was measured and was $= 394^\circ$ ✓

$\sin 2\theta = \frac{394}{K} = \frac{394}{448}$; $\therefore$

assuming $\chi_1 - \chi_2 = 11.4 \times 10^{-6}$; $\theta = 30^\circ \cdot 8$ ✓

4th Crystal.

$m = 0.555$ gms. ✓ $H = (9.0 \text{ amps})$ 3107 gms ✓

$c = (22.1 \text{ secs.}) \quad .00537$ ✓

$\alpha_1 = 720^\circ$ ✓ $\alpha_2 = 816^\circ$ ✓

the reference plane being now the $\chi'(20\bar{1})$ plane and not the $c(001)$ plane.

$MnSO_4.(NH_4)_2SO_4.6H_2O$

If β is the inclination of the X_2 axis to the $x'(20\bar{1})$ plane, then

$$\sin 2\beta = \frac{720^\circ}{771+\beta} \quad \therefore \beta = 31^\circ.8$$

Since x' plane is inclined at $64^\circ 57'$ to the $c(001)$ plane, this value would correspond to $64^\circ 57' - 31^\circ.8 = 33^\circ.2$

Also $\chi_1 - \chi_2 = \frac{803}{7.31\times10^7} = 11.0 \times 10^{-6}$

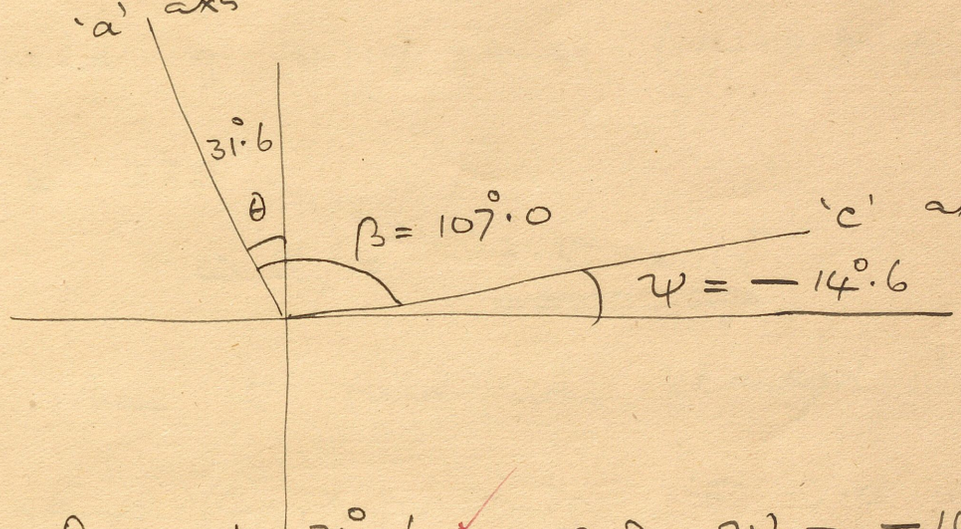
Collecting the values we have

Crystal & mass.	$(\chi_1-\chi_2)\times10^6$	θ
I .220 gm	11.4	$31^\circ.1$
II .420 "	11.6	$31^\circ.8$
	11.4	$31^\circ.2$
III .392 "	11.4	$30^\circ.8$
IV .555 "	11.0	$33^\circ.2$
mean	11.4	$31^\circ.6$ adopted.

Rejected. Then mean $\theta = 31^\circ.2$

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

Thus the actual positions of the axes are given by



Thus $\theta = +31°\cdot6$ ✓ and $\psi = -14\cdot6$. ✓

II Next the crystals were suspended with their 'a' axes vertical. The crystal was initially adjusted so as to have the c(001) plane at 45° to the field. When the field is put on, the c(001) plane tends to rotate towards normality to field. ; ie 'b' axis sets ⊥ to field.

The couple was measured by taking the torsion head in the opposite direction

till the crystal turned round.

$m = \cdot 420$ $c = \cdot 00487$

In a field of 4119 gauss (14·0 amps.)

$\alpha = 375^\circ$

$\Delta\chi = \frac{375}{1.071 \times 10^{-8}}$ $\therefore$ $= \cancel{\Delta\chi} = \underline{\underline{3.5 \times 10^{-6}}}$

Again when the field was changed to 2581 gauss (corresponding to 7·0 amps.)

$\alpha = 158^\circ$

$\therefore$ $\Delta\chi = \frac{158}{4.21 \times 10^{7}} = \underline{\underline{3.8 \times 10^{-6}}}$ 3.8×10^{-6}

Adopting the mean value we have

$$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 3.7 \times 10^{-6}$$

III Finally the crystal was suspended with its c(001) plane horizontal.

'b' axis was 1st adjusted to be at 45° to field. When the field is put on, it rotates towards parallelism with field.

$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

The couple reqd to turn round the crystal corresponds to

$\alpha = 335^\circ$. ✓ $m = 0.401$ ✓ gms.

$H = (14.0 \text{ amps})\ 4119$ gms ✓

$C = (36.1 \text{ secs}) \cdot 00201$ ✓

$\therefore \chi_3 - (\chi_1 \sin^2\theta + \chi_2 \cos^2\theta) = \frac{335}{2.47 \times 10^8} = 1.4 \times 10^{-6}$ ✓

Collecting all the results for $MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ we have

$$\chi_1 - \chi_2 = 11.4$$ ✓

$$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 3.67$$ ✓

$$\chi_3 - (\chi_1 \sin^2\theta + \chi_2 \sin^2\theta) = 1.4.$$

whence $\left.\begin{aligned} \chi_1 - \chi_2 &= 11.4 \\ \chi_1 - \chi_3 &= 6.8 \end{aligned}\right\} \times 10^{-6}$ ✓

$\cos 2\theta = \frac{5.1}{11.4}$ and $\cos 2\theta = \frac{5.01}{11.4}$ ✓ $\therefore \theta = 31^\circ.7$ ✓ $\psi = -14^\circ.1$

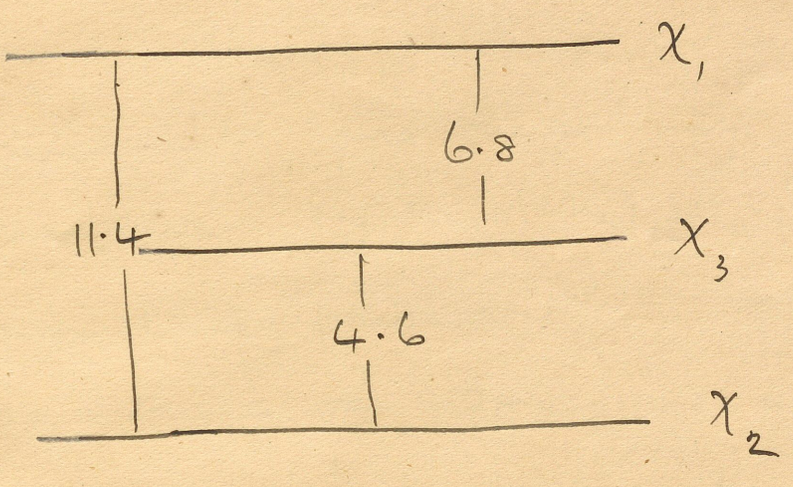
$\therefore |\theta| = 31^\circ.7$ ✓ $\theta = 31^\circ.6$ directly calculated.

corresponding to $\psi = -14^\circ.7$ ✓ against $\psi = -14^\circ.6$ ✓ directly calculated.

as compared with $\psi = -14^\circ.6$ ✓ directly Calculated.

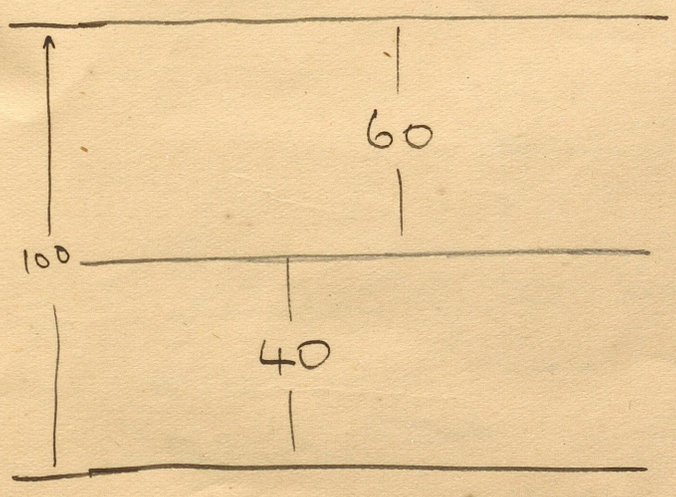
$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

Thus we have for $MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$



$\psi = -14.6$ direct
-14.7 cal.
~~[illegible]~~

With these may be compared Rabi's values



$\psi = +14^\circ$

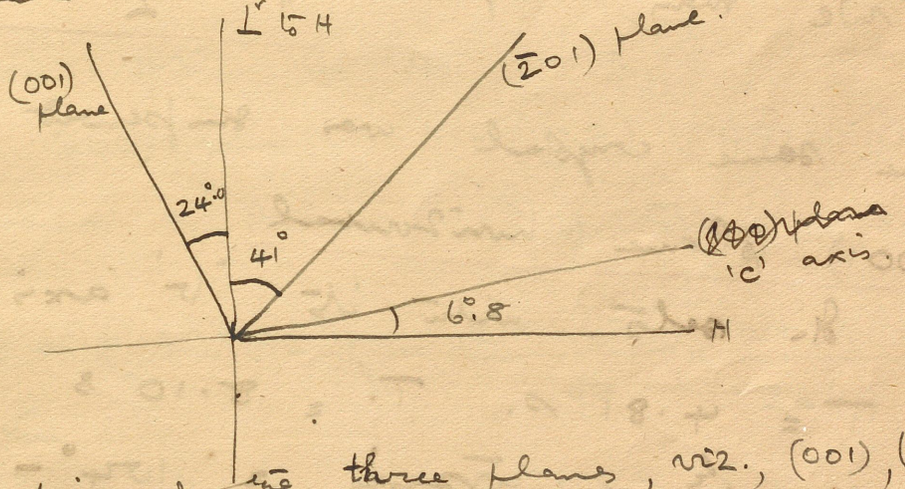
$MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

For comparison with the values for $MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ measurements were made with a diamagnetic alum, viz. $MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

monoclinic prismatic,

$a : b : c = 0.7400 : 1 : 4918$; $\beta = 107^\circ.1$.

when suspended with its 'b' axis vert. the setting of the crystal was as below:



The inclinations of the three planes, viz., (001), (2̄01) and (100) to the field were measured and the ⊥les are as marked as ~~bel~~ in the figure.

$\therefore \theta = \underline{24^\circ.0}$; $64^\circ.5 - 41^\circ = \underline{23^\circ.5}$; and $107^\circ.1 + 6^\circ.8 - 90^\circ$ $= \underline{23^\circ.9}$ respectively; giving the mean value

$$\theta = +23^\circ.8 \quad \text{or} \quad \psi = -6^\circ.7 \quad (-6^\circ.7)$$

$\Delta\chi$'s were measured not by the oscillational method but by measuring the max. couple by the static method described for the manganese salt. For the above

'b' axis vertical

2nd crystal $m = \cdot 1740$ gm. $H = 6632$ gauss.

$T = 3.54$ secs. $T' = 10.35$ s. $C = \cdot 00330$.

$\angle^{le}$ of torsion corresponding to max. compl.

was $269^\circ - 45^\circ = 224^\circ$.

$$\therefore \chi_1 - \chi_2 = \frac{13.89 \times 6.81}{3.54^2} \times \frac{360.6}{\cdot 1740} \times \frac{\cdot 00330}{6632^2} = 1.17 \times 10^{-6}$$

$$\text{or} = \frac{\pi \times 224}{90} \times \quad " \quad " \quad = 1.22 \times 10^{-6}$$

We may adopt $\chi_1 - \chi_2 = 1.20 \times 10^{-6}$ . . . (1)

as a check

The same crystal was suspended with its

c(001) plane horizontal.

It sets with its 'b' axis along field

$T = 4.81$ s. $T' = 8.10$ s

max $\angle^{le}$ of torsion $= 104^\circ - 45^\circ = 59^\circ$.

$$\therefore \chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \frac{12.91 \times 3.29}{4.81^2} \times \frac{360.6}{\cdot 1740} \times \frac{\cdot 00330}{6632^2} = 0.29 \times 10^{-6}$$

$$\text{also} = \frac{\pi \times 59}{90} \times \quad " \quad " \quad = 0.32 \times 10^{-6}.$$

adopt $\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = 0.30 \times 10^{-6}$

as against 0.31×10^{-6} calculated from (1) and (2)

$MgSO_4.(NH_4)_2SO_4.6H_2O$

suspension, $(M = 360.6)$

$m = 0.2195$ gms. $\quad c = .000761$ (16.2 secs. smaller disc)

$H = (6.00 \text{ amps})\ 2560$ gauss. $\quad$ L.C. of torsion $= 189° - 45°$.

$$\therefore \chi_1 - \chi_2 = \frac{2 \times 144 \times \pi}{180} \times \frac{.000761 \times 360.6}{.2195 \times 2560^2}$$

$$= 0.96 \times 10^{-6} \text{ per gm. molec.} \qquad (1)$$

2) Secondly the crystal was suspended with its 'a' axis vertical.

'b' axis set $\perp^r$ to field.

$m = .2669$ gms. $\quad H = (15.0 \text{ amp})\ 4710$ gauss

c same as before; L.C. of torsion $= 347° - 45°$

$$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \frac{2 \times 302 \pi}{180} \times \frac{.000761 \times 360.6}{.2669 \times 4710^2}$$

$$= 0.49 \times 10^{-6} \qquad (2)$$

Note another crystal gave for this suspension, i.e., 'a' axis vert. $\Delta\chi = .71$ & $.73$ by oscln. & rotn. respy. These values were rejected.

From (1) and (2) using $\theta = 23°.8$,

$$\left.\begin{aligned} \chi_1 - \chi_2 &= 1.20 \\ \chi_1 - \chi_3 &= 0.69 \end{aligned}\right\} \quad \psi = -6°.97$$

The field should be 6870 gauss instead of 6632

$\chi_1 -$

Ferrous potassium sulphate hexahydrate

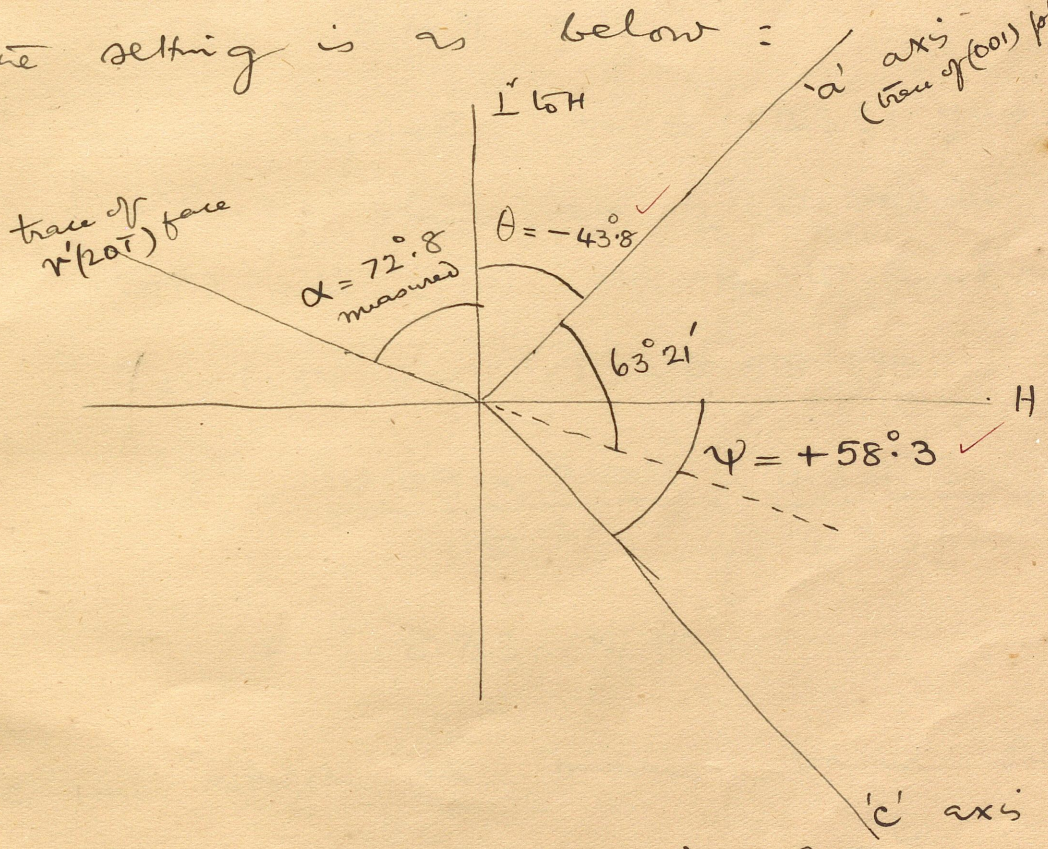
$FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$.

monoclinic prismatic

$a : b : c = 0.7377 : 1 : 0.5020$; $\beta = 104^\circ 32'$.

The form of the crystal was the same as that of the other monoclinic sulphates.

When suspended with its 'b' axis vertical the setting is as below :



The inclination of r' (20$\bar{1}$) plane to X_2 axis was found to be $72^\circ.8$, corresponding to $\theta = -43^\circ.8$ and

$$\psi = +58^\circ.3.$$

$FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$

I The oscillation measurements with 'b' axis vertical gave the following results: [C through out- = ·00542 (corresp. to 21·99 secs)]

(i) (C(001) plane at 1° to vert. and 'a' axis at- 1° to horiz.) m = ·1186 gms. M = 434·3

T = 1·175 secs. T' = 4·86 secs. H = 415·9 gms

$$\therefore \chi_1 - \chi_2 = \frac{6.035 \times 3.685}{1.175^2} \times \frac{434.3}{.1186} \times \frac{.00542}{415.9^2}$$

$$= 1849 \times 10^{-6}.$$

(ii) another crystal m = ·2331 gms.

[r'(20T) plane at ½° to vertical. Intersection of (20T) with (010) at ½° to horiz.]

T = 1·51 secs. T' = 8·58 secs. H = 415·2 ~~secs~~ gms

$$\therefore \chi_1 - \chi_2 = \frac{10.09 \times 7.07}{1.51^2} \times \frac{434.3}{.2331} \times \frac{.00542}{415.2^2}$$

$$= 1833 \times 10^{-6}.$$

We can adopt the mean value for $\chi_1 - \chi_2$, viz.,

$$\chi_1 - \chi_2 = \underline{1841 \times 10^{-6}} \quad ---(1)$$

$FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$

II 'a' axis vert. $H = 415.9$ gauss

'b' axis sets along field.

(i) $m = .14355$ gms. 'a' axis exactly vert.

$T = 1.64$ secs. $T' = 6.16$ secs.

$$\therefore \chi_3 - (\chi_1 \cos^2\theta + \chi_2 \sin^2\theta) = \frac{7.80 \times 4.52}{1.64^2} \times \frac{434.3}{.14355} \times \frac{.00542}{415.9^2}$$

$$= 1245 \times 10^{-6}.$$

(ii) $m = .2746$ gms.

((001) plane at .7° to vert & 'b' axis at .7° to horiz)

$T = 2.28$ secs. $T' = 11.48$ secs.

$$\therefore \Delta\chi = \frac{13.76 \times 9.20}{2.28^2} \times \frac{434.3}{.2746} \times \frac{.00542}{415.9^2}$$

$$= 1208 \times 10^{-6}$$

For this suspension ~~aqui~~ also adopting the mean value we have

$$\chi_3 - (\chi_1 \cos^2\theta + \chi_2 \sin^2\theta) = 1227 \times 10^{-6} \quad \ldots (2$$

$FeSO_4 . K_2SO_4 . 6H_2O$

III (001) plane horiz. H = 415.9 gms

Here also 'b' axis lies along field.

(i) m = .1436 gms.

T = 1.77 secs. T' = 6.59 secs.

$$\therefore \chi_3 - (\chi_1 \sin^2\theta + \chi_2 \cos^2\theta) = \frac{8.36 \times 4.82}{1.77^2} \times \frac{434.3}{.1436} \times \frac{.00542}{415.9^2}$$

$$= 1220 \times 10^{-6}$$

(ii) m = .1186 gms.

'a' axis at .5° to horiz. and 'b' axis at .5° to horiz.

T = 1.573 secs. T' = 5.44 secs.

$$\therefore \Delta\chi = \frac{7.013 \times 3.867}{1.573^2} \times \frac{434.3}{.1186} \times \frac{.00542}{415.9^2}$$

$$= 1261 \times 10^{-6}$$

Adopting the mean we have

$$\chi_3 - (\chi_1 \sin^2\theta + \chi_2 \cos^2\theta) = 1241 \times 10^{-6} \quad \ldots (3)$$

$FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$

From (1) (2) and (3) we obtain

$$\chi_1 - \chi_2 = 1841$$

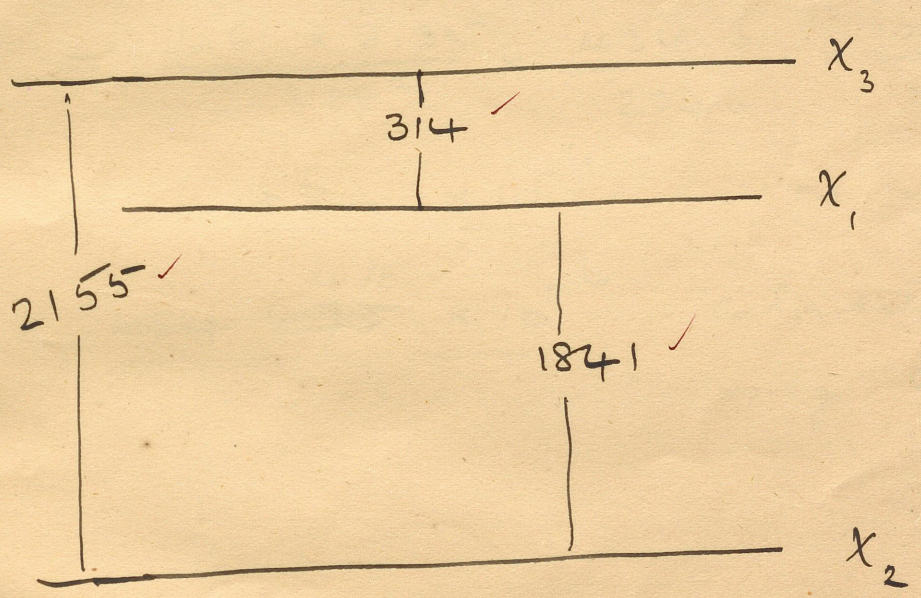
$$\chi_3 - \chi_1 = 314$$

and $\theta = 44^\circ \cdot 8$ which corresponds to

$$\psi = +59^\circ \cdot 3$$

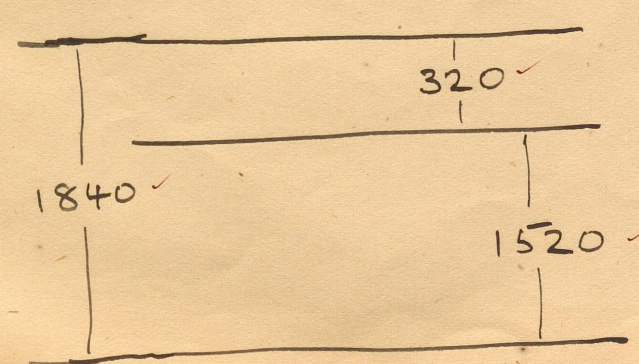
as compared with $\psi = +58^\circ \cdot 3$ as observed.

Thus for $FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$ we have



$\psi = +58^\circ \cdot 3$ obs.
$+59^\circ \cdot 3$ cal.

We may compare with this Rabi's values



$\chi_3 = 12160$

$\chi_1 = 11840$

$\psi = +55^\circ$

$\chi_2 = 10320$

$FeSO_4 \cdot K_2SO_4 \cdot 6H_2O$

As a further check one crystal was suspended with its r' (20$\bar{1}$) face horiz.

('b' axis ~~at~~ 0.8° to horiz. and the intersection of r'(20$\bar{1}$) and (010) planes exactly horiz.)

'b' axis set along field

$m = .2746$ gms. $H = 415.9$ gauss

$T = 3.88$ secs. $T' = 12.73$ secs.

$\chi_3 - (\chi_1 \sin^2\alpha + \chi_2 \cos^2\alpha)$ where α is the inclination of r'(20$\bar{1}$) face to χ_2 axis

$$= \frac{16.61 \times 8.85}{3.88^2} \times \frac{434.3}{.2746} \times \frac{.00542}{415.9^2}$$

$$= 484 \times 10^{-6}$$ as compared with

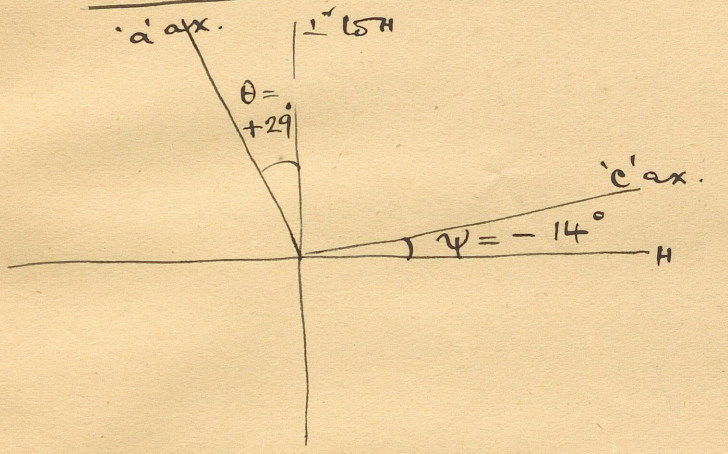
$$475 \times 10^{-6}$$ calculated from previous results using $\alpha = 72°.3$. $72°.8$.

Manganous Rubidium Selenate Hexahydrate

Monocl. prisms. $M = 620.3$ $\rho = 2.763$

$a : b : c = .7422 : 1 : .5008$; $\beta = 105°9'$.

'b' ax. vert.



H throughout was 5102 gauss

α_θ = angle of rotation of torsion-head from eqm. posn. reqd. to bring the 'a' ax. ⊥r to field

α_ψ to bring 'c' ax. along field

$\alpha - 45°$ is the torsion ∠le ~~for complete~~ corresponding to max. couple.

Cryst no.	m	c	α_θ or α_ψ	$\alpha - 45°$	ψ	$\chi_1 - \chi_2$
1.	0.760	.002172	$\alpha_\theta = 3550°$	3855°	~~18~~ −18°	9.2
2.	.73	"	$\alpha_\theta = 3460$	3720	−18°	9.2
3.	.535	"	$\alpha_\psi = 1270$	2700 H = 5036 gauss.	−14°	9.3
4.	.72	"	$\alpha_\theta = 3248$	3850	−13½°	9.7

Adopt $\psi = -14°$ $(\theta = +29°)$

$\chi_1 - \chi_2 = 9.2$ . . . . . (1)

~~'a' ax. vert. 'b' axis sets normal to field, so max-~~

Mn Rb selenate.

c(001) pl. horiz. 'b' ax. ⊥ to field

No.	m	c	$\alpha - 45^\circ$	$\Delta\chi$
1.	·58	·00555	440°	·35
2	·60	"	600	·46

adopt $\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = 0.4$ - - - (2)

From (1) and (2)

$$\chi_1 - \chi_2 = 9.2$$
$$\chi_1 - \chi_3 = 7.4$$
$$\psi = -14^\circ$$

'a' ax. vert. 'b' ax. ⊥ to field

no.	m	c	$\alpha - 45^\circ$	$\Delta\chi$
1.	·43	·00214	2070°	4·9
2.	·64	·00217	1930°	5·4
3.	·46	"	1355°	5·3
4.	·63	"	1840°	5·3

Adopt $\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 5.3$ - - - (3)

This agrees well with 5·2 calculated from (1) and (2).

Manganous potassium sulphate tetrahydrate

$MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$.

Monoclinic prismatic. $M = 397.3$

$a : b : c = 1.0324 : 1 : 1.2485$ $\beta = 95^\circ 0'$

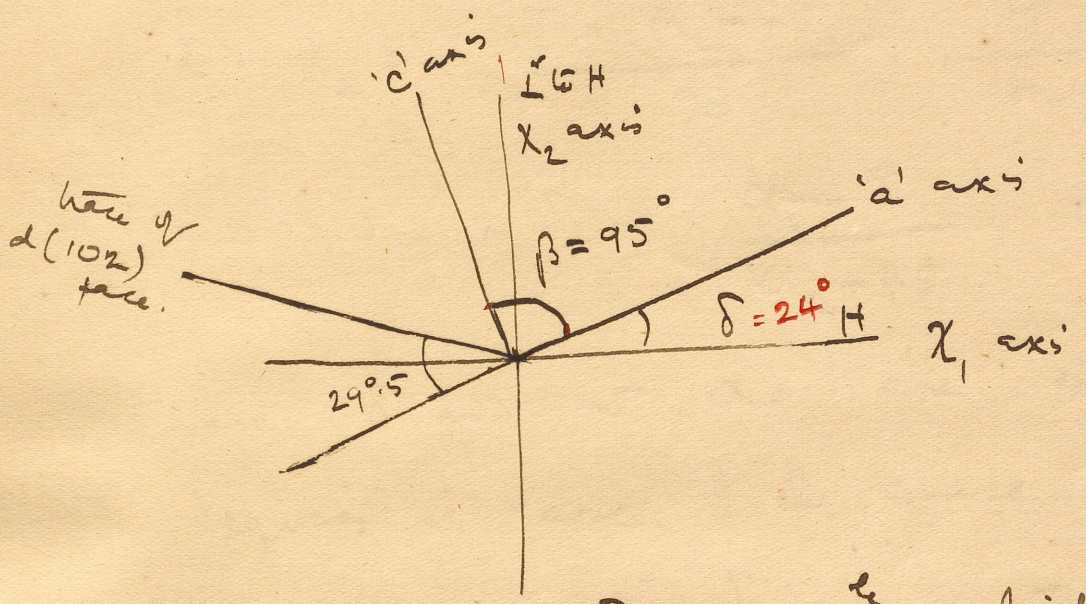
The following were the L^le measurements made:

	obs.	cal. (given by Groth 2, 508.)
a(100) : c(001)	84°.5	85° 0′
d(102) : c(001)	29°.5	29° 47′
δ′(T02) : c(001)	32°.0	32° 27′
n(011) : c(001)	51°.3	51° 12′ Marignac obs.
o(013) : c(001)	22°.5	22° 31′.

The anisotropic measurements were made with the crystal suspended in a liquid bath ($MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$ saturated soln + suitable ~~Mn~~ concentration of $MnCl_2$) having the same vol. suscep. as crystal.

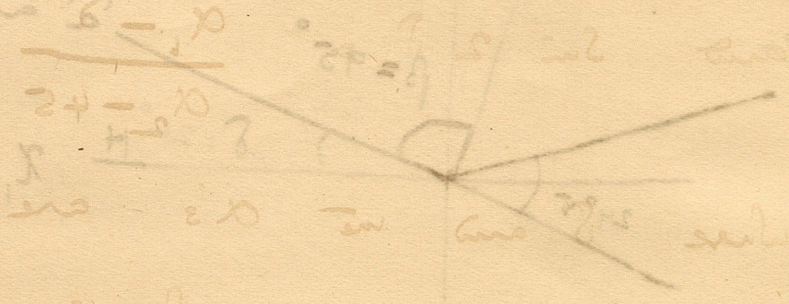
$MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$

'b' axis vertical



Let us denote by δ the $\angle^{le}$ which the χ_1 axis makes with the 'a' axis.

δ was measured by finding the $\angle^{le}$ α_2 by which the torsion head has to be rotated from the position for zero torsion in the presence of the field in order to bring the 'a' axis of the crystal (i.e. 'c(001) planes') exactly parallel to the field. If α_2 is the $\angle^{le}$ through which the torsion head has to be rotated from the above equilibrium position (corresponding to zero torsion in field) in order that the crystal



The field is now 6632 but ~~6830~~ 6870 gauss which will lower all the $\Delta\chi$ values in the ratio $(6632/6870)^2 = .93$. Corrected values are given in red in K.

$MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$

may just turn round, we have

$$\chi_1 - \chi_2 = \frac{\pi \times (\alpha_2 - 45^-)}{90} \times \frac{M}{m} \times \frac{c}{H^2}$$

and $$\sin 2\delta = \frac{\alpha_1 - \delta}{\alpha_2 - 45}$$

where δ and the α's are expressed in degrees of arc. Of course in our usual notation

$$\psi = 95^\circ + \delta. \quad (\text{or } -180^\circ + 95^\circ + \delta.)$$

The measurements were made on a large no. of crystals and the results are tabulated below.* (See next page)

Throughout H was 6632 gauss.

---

* δ was separately measured by measuring α_1 and α_2 for a number of crystals at different fields. The values were

25°.2	22°.4
23°.0	22°.3
23°.5	24°.9
23°.5	

$MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$

'b' axis vertical. $H = 6632$ gauss.

No.	m (gm)	c	α_1	$\alpha_2 - 45°$	~~ϕ~~ δ	$(\chi_1 - \chi_2) \times 10^6$
1.	0·328	·00259 (10·75 secs. new small disc)	1260°	18 45°	21°·1	4·59
2.	0·304	"	1270	1690	23°·8	4·54
3	0·290	"	1160	1570	23°·2	4·42
4	0·273	"	1140	1495	24°·1	4·47
5	0·480	·00319 (9·37 secs. same disc)	1857	2290	26°·5	4·80
6.	0·458	"	1784	2260	25°·5	4·96
7.	0·444	"	1598	1995	26°·0	4·52
8.	0·380	"	1563	1970	25°·6	Rejd. 5·22
9.	0·375	"	1356	1705	25°·6	4·57
10.	0·342	"	1225	1535	25°·7	4·52
11	0·240	·00326			25°·8	4·80
				mean	24°·3 (24°) after taking into consideration values given at ft of last page.	~~4·62~~ ~~4·57~~ (4·6) ~~4·2~~ 4·3 after correction

(2) 'a' axis vertical

'b' axis sets along field, so that

$$\Delta\chi = \chi_3 - (\chi_2 \cos^2\phi + \chi_1 \sin^2\phi)$$

with the same H = 6632 gauss as above the results were

No	m gms.	C	$\alpha - 45^\circ$	$\Delta\chi \times 10^6$	
1.	·557	·00243 (10·75 secs new small disc)	1740°	2·39	
2.	·537	"	1510	2·16	
3.	·500	"	1284	1·97	
4.	·451	"	1215	2·07	
5.	·386	"	1010	2·00	
6.	·328	"	850	1·99	
7.	·312	·00319	550	1·77	Rejected
8.	·274	"	575	2·11	
9.	·261	·00326	570	2·25	
			mean	2·12 ~~2·08~~ (2·1)	Corrected 2·0.

Thus

$$\chi_1 - \chi_2 = 4.6 \times 10^{-6} \quad \text{(4.2)} \quad \text{---(1)}$$

$$\chi_3 - (\chi_1 \sin^2 \delta + \chi_2 \cos^2 \delta) = 2.1 \times 10^{-6} \quad \text{(2.0)} \quad \text{---(2)}$$

$$\delta = 24^\circ \quad \text{---(3)}$$

Whence

$$\chi_1 - \chi_2 = 4.6 \times 10^{-6} \quad \text{(4.2)}$$

$$\chi_1 - \chi_3 = 1.7 \times 10^{-6} \quad \text{(1.6)}$$

$$\psi = -61^\circ$$

As a check the crystal was suspended with c(001) plane horizontal. 'a' axis set along field.

No	m gm.	c	H gauss	$\alpha - 45^\circ$	$\Delta\chi \times 10^6$
1.	·283	·00243	6632	295°	0·8
2	·220	·00326	"	218°	1·0
3.	·284	"	"	228°	0·8

$$\therefore \chi_1 \cos^2 \delta + \chi_2 \sin^2 \delta - \chi_3 = 0.9 \ (0.8) \times 10^{-6}$$

as compared with 0.9 (0.8) calculated from above constants.

The field was 6870 gauss instead of 6632 and all the $\Delta\alpha$'s have to be decreased in the ratio $(6632/6870)^2$ = 0.93. The corrected values are given in red ink.

Magnesium potassium sulphate hexahydrate

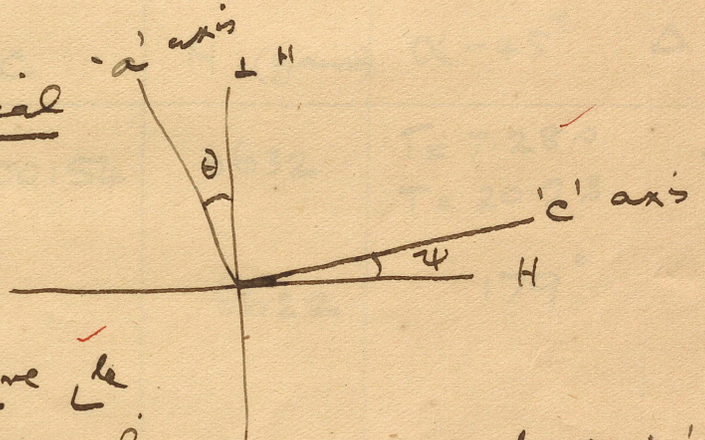
$MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$.

$M = 402.7$.

Monoclinic prismatic

$a : b : c = 0.7413 : 1 : 0.4993$. $\beta = 104^\circ.8$.

1.) 'b' axis vertical



θ small +ve Lt

and ψ small −ve Lt

α_1 is the Lt by which torsion head is rotated to bring 'c' axis ∥ to H.

No.	m gms.	c	H gauss	α_1	$\alpha_2 - 45^\circ$	ψ	$(\chi_1 - \chi_2) \times 10^6$
1	·2382	·00154	6632	T = 2·92 s.	T' = 13·72 s		1·25
2.	"	"	"	43°	615°	−1°·9	1·27
3.	"	"	6562	43°	610°	−1°·9	1·29
4.	"	"	6602	45°	614°	−2°·0	1·28
5	·4117	"	6632	T = 4·38 s.	T' = 26·4 s		1·21
6	"	"	6577	82°	1053°	−2°·2	1·28
7	"	"	6598	92°	1049	−2°·4	1·27
8	"	·0103	6632	T = 4·03 s.	T' = 10·08 s	−2°·5	1·21
9	"	"	"		164°		1·31
					mean	−2°·2	1·26

2) (001) face horizontal

'b' axis sets itself along field, so that

$$\Delta\chi = \chi_3 - (\chi_1 \sin^2\theta + \chi_2 \cos^2\theta)$$

The results of the measurements were

No.	m gms	C	H (gauss)	$\alpha - 45^\circ$	$\Delta\chi \times 10^6$
1.	·2382	·00154	6632	T = 7.28 s. T' = 20.28.	·40
2	"	"	6622	179°	·37
3.	·4117	"	6632	T = 7.02 s T' = 26.48.	·45
4	"	"	6620	383°	·46
				mean =	0.42

From the above data

$$\psi = -2^\circ.2$$

$$\chi_1 - \chi_2 = 1.26 \times 10^{-6}$$

$$\chi_1 - \chi_3 = 0.73 \times 10^{-6}$$

b4 $MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$

As a check on the above measurements, $\Delta\chi$ was measured finally with

a(100) plane horizontal

'c' axis sets along field, so that

$$\Delta\chi = \chi_1 \cos^2\psi + \chi_2 \sin^2\psi - \chi_3.$$

No	m gms	c	H gauss.	$\alpha - 45°$	$\Delta\chi \times 10^6$
1	·2382	·00154	6632	T = 5·12 s T' = 18·35 s	0·70
2	"	"	6622	345°	0·71
3	·4117	"	6632	T = 6·80 s T' = 32·3 s	0·74
4	"	"	6626	635°	0·76
5	"	·0103	6632	91°·5	0·73
				mean	0·73

The value of $\chi_1 \cos^2\psi + \chi_2 \sin^2\psi - \chi_3$, calculated from the constants given at the top of last page = 0·73

Austin measurement gave

$$\sin 2\psi = -\frac{493^\circ - |\psi|}{865^\circ}$$

i.e. $\psi = -16^\circ \cdot 7$

agreeing with the value given here.

The field was 6870 gauss instead of 6632. The values corrected accordingly are given in red ink.

Another measurement gave

$$\sin 2\psi = -\frac{493^\circ - |\psi|}{865^\circ}$$

i.e. $\psi = -16^\circ \cdot 7$

agreeing with the value given here.

The field was 6870 gauss instead of 6632. The values corrected accordingly are given in red ink.

Manganous Thallous sulphate hexahydrate

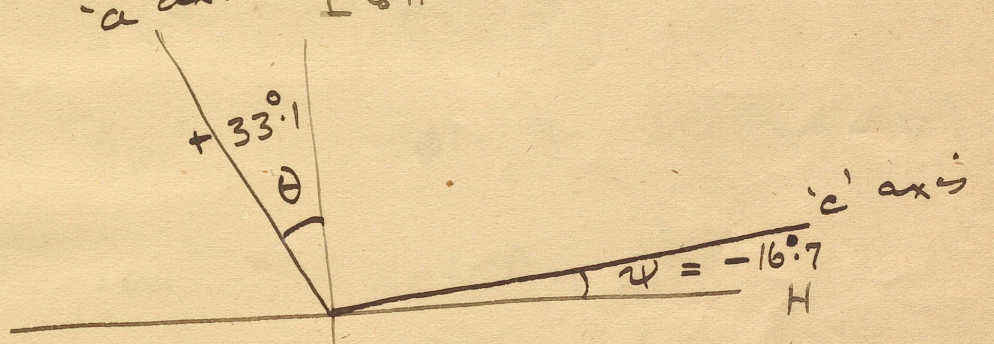
$$Mn SO_4 . Tl_2 SO_4 . 6H_2O.$$

M = 763·9.

Monoclinic prismatic

$a : b : c = 0.7454 : 1 : 0.4964$; $\beta = 106^\circ 22'$

With 'b' axis vertical the setting is as below.



α_1 is the ∠ by which the torsion head had to be rotated in order to bring the 'c' axis along field

No.	m gms	c	H gauss	α_1	$\alpha_2 - 45^\circ$	ψ	$(\chi_1 - \chi_2) \times 10^6$
1	·3105	·00572	6632	512°	865°	−17°·4	9·66
2	·379	"	"	569	1052	−15°·9	9·63
3	·1065	·00154	——	493°	865°	−16°·7	——
4.	·234	·00572	"	360°	625°	−16°·7	9·26
					Mean	−16°·7	9·5₂

8·989

$MnSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$.

2) c(001) plane horizontal

'b' axis sets normal to field so that

$$\Delta\chi = \chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 .$$

H = 6632 gauss c = ·00572

m	$\alpha - 45^\circ$	$\Delta\chi \times 10^6$
·228	56°	0·85
·286	98°	1·19
·337	101°	1·04
·216	55°	0·88

mean $\Delta\chi = 0.99$

·9

∴ From the results of (1) and (2)

$$\psi = -16^\circ\cdot7$$

i.e. $\theta = +33^\circ\cdot1$

$$\chi_1 - \chi_2 = 9\cdot5_2$$

$$\chi_1 - \chi_3 = 7\cdot6_7$$

8·9

7·1

$MnSO_4 \cdot K_2SO_4 \cdot 6H_2O$.

3) As a check the measurements were finally made with 'a' axis vertical

'b' axis set normal to the field.

$\therefore \Delta\chi = \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3$

H and C same as in (2)

m	$\alpha - 45^\circ$	$\Delta\chi \times 10^6$
0.276	398°	5.00
0.259	365°	4.89
0.246	365°	5.15

mean = $5.0_1 \times 10^{-6}$

4.7 4.7

as compared with $\Delta\chi = 4.8_3 \times 10^{-6}$

4.5

calculated from the values given at the top of p. 67.

The field was 6870 gauss instead of 6632, and the corrected values are given in red in R.

$MgSO_4 . Tl_2SO_4 . 6H_2O$

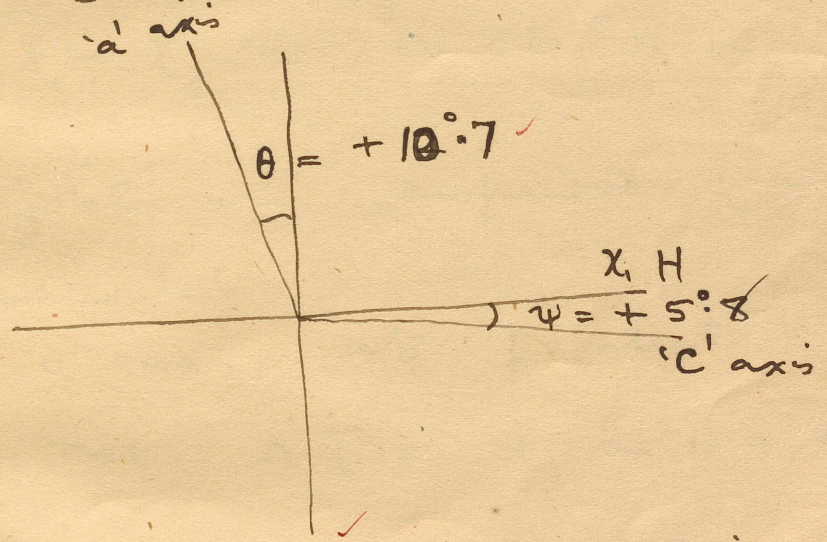
Monoclinic prismatic $\rho = 3.573$.

$a : b : c = .7422 : 1 : 0.5002$; $\beta = 106° 24'$

Tutton " $= 0.7442 : 1 : 0.5000$ $\beta = 106° 30'$.

1) 'b' axis vertical

Setting of crystal is as follows:-



$\theta = +10°.7$ corresponding to $\psi = +5°.8$

$c = .00326$ (9.27 secs. with new disc)

H for all the measurements = 6632 gauss

$m = .3577$ gm. $M = 733.3$

$T = 5.82$ ". $T' = 14.8$ secs.

L^{le} of rotation of torsion head necessary to

$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$

$\alpha_F = 45^\circ$

just turn round the crystal $= 214^\circ - 45^\circ$

$= 169^\circ$.

From the above data

$$\chi_1 - \chi_2 = \frac{20.62 \times 8.98}{5.82^2} \times \frac{733.3}{.3577} \times \frac{.00326}{6632^2} = 0.83$$

$$\text{also} = \frac{\pi \times 169}{90} \times \qquad = 0.89$$

Adopt mean of the two values

$$\chi_1 - \chi_2 = 0.86 \times 10^{-6} \quad \text{---} \quad (1)$$

0.8

2) Crystal was suspended with its c(001) plane horizontal.

'a' axis set parallel to field.

so that $\Delta\chi = \chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3$.

1st cryst $m = .3577$ $c = .00326$

$T' = 12.0$ secs. $T^* = 6.02$ secs.

$\alpha - 45^\circ = 138^\circ.5 - 45^\circ = 93^\circ.5$

$$\therefore \Delta\chi = \frac{18.02 \times 5.98}{6.02^2} \times \frac{733.3}{.3577} \times \frac{.00326}{6632^2} = 0.45 \times 10^{-6}$$

$$\text{also} = \frac{\pi \times 93.5}{90} \times \text{" " } = 0.50 \times 10^{-6}$$

$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$

so that $\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = 0.48 \times 10^{-6}$ ... (2)

0.5

(viz., 10°.7

From (1) and (2) and the measured value of θ

$\chi_1 - \chi_3 = 1.301 \times 10^{-6}$.

1.2

A second crystal of mass .2349 gm. gave

with $c = .00154$

when suspended with 'c' axis vertical

'b' axis ⊥r to field

$T' = 14.98$ secs. $T' = 6.30$ secs.

$\alpha - 45° = 127°$

$\therefore \chi_1 \sin^2\psi + \chi_2 \cos^2\psi - \chi_3$

$= \frac{21.28 \times 8.68}{6.30^2} \times \frac{.00154}{6632^2} \times \frac{733.3}{.2349} = 0.51 \times 10^{-6}$

also $= \frac{\pi \times 127}{90} \times$ " " " $= 0.48 \times 10^{-6}$

mean $= 0.50 \times 10^{-6}$.

Hence using (1) and $\psi = 5°.8$

$\chi_1 - \chi_3 =$ ~~1.35 × 10⁻⁶~~ 1.35×10^{-6}

1.2

$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$

Axes for the crystal

$$\chi_1 - \chi_2 = 0.86 \times 10^{-6}$$

$$\chi_1 - \chi_3 = 1.33 \times 10^{-6} \quad (1.33)$$

$$\psi = +5^\circ.8$$

As a check measurements were made with 'a' axis vertical.

'b' axis normal to field.

$m = .3577$ gms. $c = .00326$

$T = 5.08$ s. $T' = 15.4$ s.

$\alpha - 45^\circ = 214^\circ.5$.

$$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3$$

$$= \frac{20.48 \times 10.32}{5.08^2} \times \frac{733.3}{.3577} \times \frac{.00326}{6632^2} = 1.25 \times 10^{-6}$$

or $= \frac{\pi \times 214.5}{90} \times$ " " $= 1.28 \times 10^{-6}$.

A second crystal of mass .2349 gms. $c = .00154$

$T = 5.52$ s. $T' = 20.1$ s. $\alpha - 45^\circ = 320^\circ$.

$$\Delta\chi = \frac{25.62 \times 14.58}{5.52^2} \times \frac{733.3}{.2349} \times \frac{.00154}{6632^2} = 1.34 \times 10^{-6}$$

or $= \frac{\pi \times 320}{90} \times$ " " $= 1.22 \times 10^{-6}$

$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$

The mean of the above four values

$= 1{\cdot}27 \times 10^{-6}$ ✓

as compared with ~~1·28 × 10⁻⁶~~ $1{\cdot}30 \times 10^{-6}$ ✓ calculated from the constants given at the top of last page.

20th Mar. 1934.

$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$ (Bloedite)

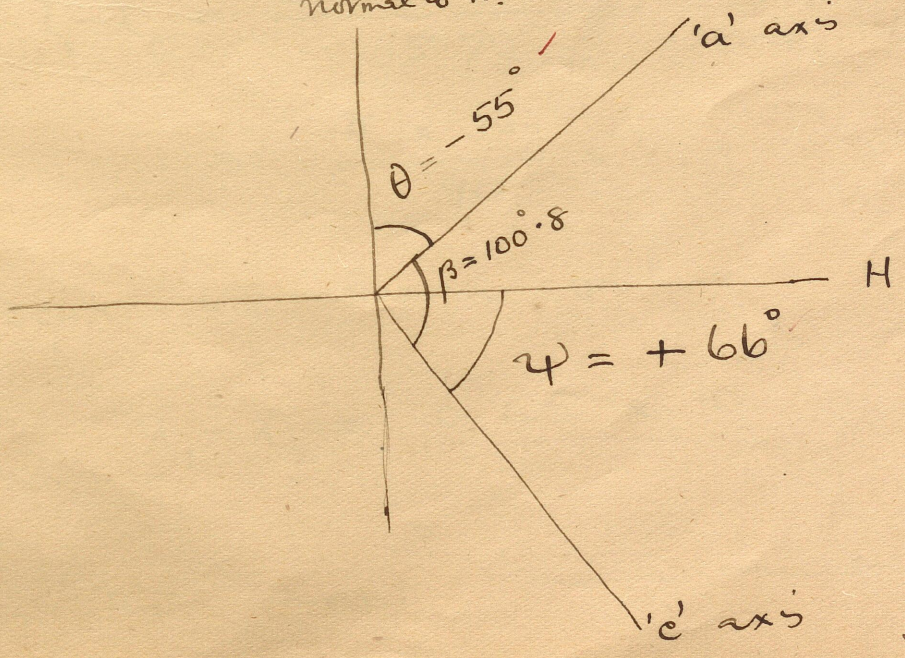
Monoclinic prismatic.

$a : b : c = 1.3492 : 1 : 0.6717$; $\beta = 100^\circ\ 48\frac{1}{2}'$.

Very well developed natural crystals were used.

	observed	calculated from above axial ratios
(001) : (011)	33° 25′	33° 25′
(001) : (0$\bar{1}\bar{1}$)	33° 55′	"
(210) : (2$\bar{1}$0)	67° 30′	67° 4′
(110) : (210)	19° 35′	19° 26′.

1) 'b' axis vertical Setting is as follows:-



θ = − 55°
mean of results with 2 different crystals.

∴ ψ = + 66°.

$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$

For all the following measurements H and c were the same, viz., 6870 gauss and ·001325 respectively. $M = 334.5$

1st Cryst. $m = .2195$ gm. For above suspension

$T = 4.5$ s. $T' = 15.4$ s. $\alpha = 356^\circ - 45^\circ = 311^\circ$

$$\therefore \chi_1 - \chi_2 = \frac{19.9 \times 10.9}{4.5^2} \times \frac{Mc}{H^2} \times \frac{1}{.2195} = 0.46 \times 10^{-6}$$

$$= \frac{\pi \times 311}{90} \times \text{"} \quad \text{"} = 0.46 \times 10^{-6}$$

2nd Cryst. $m = 0.28044$ gm.

$T' = 21.6$ s. $T^* = 5.72$ s. $\alpha = 411^\circ - 45^\circ = 366^\circ$.

$$\therefore \chi_1 - \chi_2 = \frac{27.32 \times 15.88}{5.72^2} \times \frac{1}{.28044} \times \frac{Mc}{H^2} = 0.45 \times 10^{-6}$$

$$= \frac{\pi \times 366}{90} \times \text{"} \quad \text{"} = 0.43 \times 10^{-6}$$

Adopt the mean value

$$\chi_1 - \chi_2 = \underline{0.45 \times 10^{-6}} \quad \text{---} \quad (1)$$

For the second measurement the crystal was suspended with b-

$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$

'a' axis vertical

'b' axis sets itself normal to the field so that $\Delta\chi = \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3$.

1st crystal $m = 0.2195$ gms.

$T = 4.38$ s. $T' = 14.05$ s. $\alpha = 311^\circ - 45^\circ = 266^\circ$

$$\therefore \Delta\chi = \frac{18.43 \times 9.67}{4.38^2} \times \frac{1}{.2195} \times \frac{Mc^{11}}{H^2} = 0.40 \times 10^{-6}$$

$$= \frac{\pi \times 266}{90} \times \text{"} \quad \text{"} = 0.40 \times 10^{-6}$$

2nd Crystal $m = 0.2804$ gms.

$T = 4.46$ s. $T' = 15.8$ s. $\alpha = 395^\circ - 45^\circ = 350^\circ$

$$\therefore \Delta\chi = \frac{20.26 \times 11.34}{4.46^2} \times \frac{1}{.2804} \times \frac{Mc}{H^2} = 0.39 \times 10^{-6}$$

$$= \frac{\pi \times 350}{90} \times \text{"} \quad \text{"} = 0.41 \times 10^{-6}$$

Average $\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = 0.40 \times 10^{-6}$ (2)

From (1) and (2)

$$\chi_1 - \chi_2 = 0.45 \times 10^{-6}$$
$$\chi_1 - \chi_3 = 0.70 \times 10^{-6}$$
$$\psi = +66^\circ$$

For the check measurements the crystals were suspended with their C(001) planes horizontal the 'b' axis again set normal to the field such that $\Delta\chi = \chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3$.

1st Cryst. $m = 0.2195$ gm.

$T = 4.42$ s. $T' = 16.6$ s. $\alpha = 428^\circ - 45^\circ = 383^\circ$

$$\therefore \Delta\chi = \frac{21.02 \times 12.18}{4.42^2} \times \frac{1}{.2195} \times \frac{Mc}{H^2} = 0.56 \times 10^{-6}$$

$$= \frac{\pi \times 383}{90} \times \text{"} \quad \text{"} = 0.57 \times 10^{-6}$$

2nd Cryst. $m = .2804$ $\alpha = 511^\circ - 45^\circ = 466^\circ$

$$\Delta\chi = \frac{\pi \times 466}{90} \times \frac{1}{.2804} \times \frac{Mc}{H^2} = 0.54 \times 10^{-6}.$$

Taking the mean value

$$\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = 0.56 \times 10^{-6} \quad \text{--- (3)}$$

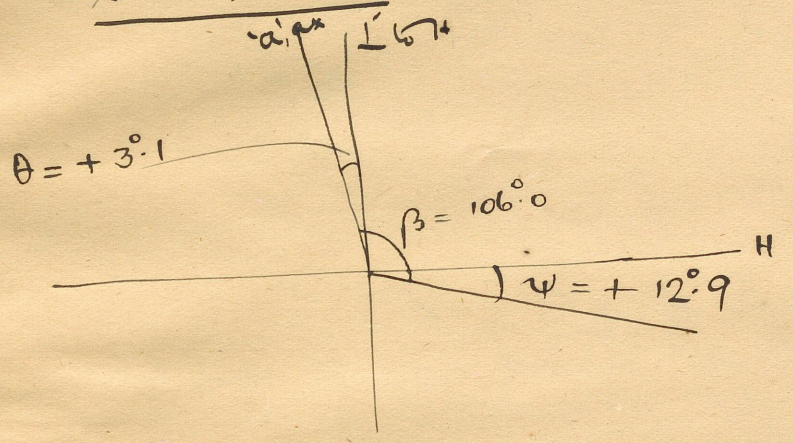
which agrees with the value 0.55×10^{-6} calculated from the constants given on the previous page.

$MgSO_4 \cdot Rb_2SO_4 \cdot 6H_2O$

Monocl. prisms. $\rho = 2.386$ $M = 495.4$

$a : b : c = 0.7400 : 1 : 0.4975$; $\beta = 105°\,59'$

'b' ax. vert.



$\theta = +3°.1$ $\therefore \psi = +12°.9$

In the following measurements $H = 5492$ gauss

$c = .001143$

$m = .3227$

$$\Phi = \frac{\pi}{90} \times \frac{M}{m} \times \frac{a}{H^2}$$

$$\chi_1 - \chi_2 = \Phi \times \frac{457+462}{2} = 0.93 \quad \text{---------- (1)}$$

'a' ax. vert. 'b' ax. normal to field

$$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi \times \frac{376+366}{2} = 0.75 \quad \text{------- (2)}$$

~~observed $\chi_1 \chi_2 \chi_3$~~

c(001) pl. horiz. 'b' ax. along field

$$\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \Phi \times \frac{104+106}{2} = 0.21 \quad \text{------- (3)}$$

From (1) and (3)

$$\chi_1 - \chi_2 = 0.93$$

$$\chi_1 - \chi_3 = 0.72$$

$$\psi = +12°.9$$

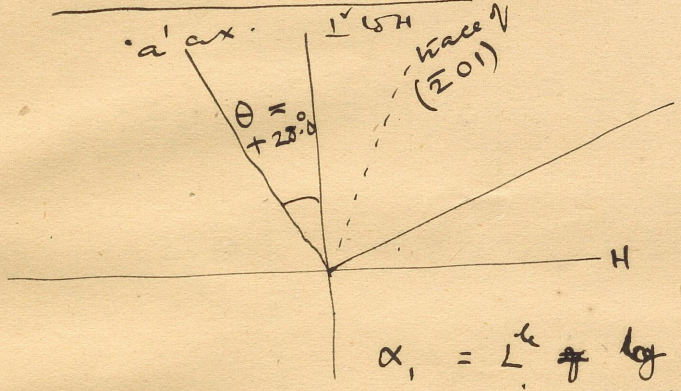
For (2) cal $\Delta\chi = 0.72$ as against 0.75 observed.

$MnSO_4 \cdot Rb_2SO_4 \cdot 6H_2O$

Monoclinic prismc. $\rho = 2.459$ $M = 526.0$

$a : b : c = 0.7382 : 1 : 0.4950$; $\beta = 105° 57'$.

With 'b' ax. vert. the setting is as below.



Field for this suspension was $6131 \cdot \sqrt{\frac{1178}{2437}} = 4264$

α_1 = L^k of log which the torsion head had to be rotated from its equm. position for bringing the (001) face normal to field

No	m gms.	c	H	α_1	$\alpha_2 - 45°$	θ	$\chi_1 - \chi_2$
1	0.866	·00411	4264	1640°	1925°	+28°.4	9.2₃
2	·728	"	"	1354°	1600°	+28°.0	9.1₂
3	1.010	·00422	"	1785°	< 2210°	> 26°.4	< 9.3
4	0.935	"	"	1653°	1995°	+27°.3	9.1₀

Accpt. $\theta = +28°.0$ which corresponds to

$\psi = -12°.0$

and $\chi_1 - \chi_2 = 9.1$ ..... (1)

Mn Rb sulphate

'a' ax. vert. 'b' ax. sets normal to field so that

$$\Delta\chi = \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 .$$

No.	m gms.	c	H	$\alpha - 45°$	$\Delta\chi$
1.	·544	·00411	4264	590°	$4{\cdot}5_0$
2	·301	·00170	5177	1143°	$4{\cdot}4_2$ best measurement
3	·270	"	"	< 1125°	$< 4{\cdot}8_5$
					adopt 4·4.

$$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \underline{4{\cdot}4} \quad \text{---} (2)$$

(001) plane horiz. 'b' axis sets $\parallel^l$ to field,

$$\therefore \Delta\chi = \chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta .$$

No	m	c	H	$\alpha - 45°$	$\Delta\chi$
1	0.516	·00533	5177	slightly less than 112°	$< 0{\cdot}7_9$
2	0.390	·00170	"	240°	$0{\cdot}7_2$
					adopt 0·7.

$$\therefore \chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \underline{0{\cdot}7} \quad \text{----} (3)$$

From (1), (2) and (3)

Mn Rb Sulphate

$\chi_1 - \chi_2 =$ ~~0.4~~ 9.1

$\chi_1 - \chi_3 =$ 6.4

and $\theta = +28^\circ$ / which corresponds to

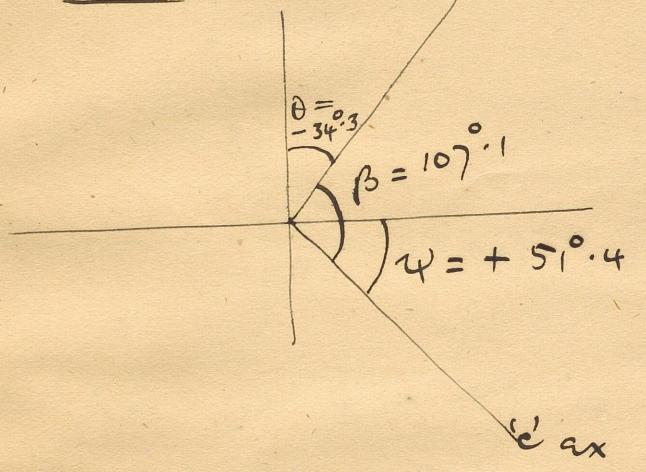
$\psi = -12^\circ$. in agreement with the directly measured value.

$MgSO_4 \cdot Cs_2SO_4 \cdot 6H_2O$

Monocl. prismatic $\rho = 2.676$; $M = 590.15$

$a : b : c = 0.7279 : 1 : 0.4946$; $\beta = 107^\circ 6'$

'b' ax. vert- 'a' ax



$\theta = -34^\circ.3$

$\therefore \psi = +51^\circ.4$

Thompson- $c = .001275$

$H = 6615$

$m = 0.1070$

$\Phi = \frac{\pi}{90} \times \frac{Mc}{mH^2}$

$\chi_1 - \chi_2 = \Phi \times 228 = 1.28$ ---- (1)

(001) pl. horiz. $T' = 9.07$ s. $T^* = 7.42$ s. 'b' ax. normal to field

$\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = \frac{16.49 \times 1.65}{7.42^2} \times \frac{Mc}{mH^2} = 0.08$ --- (2)

From (1) and (2)

$\chi_1 - \chi_2 = 1.28$

$\chi_1 - \chi_3 = 0.95$

$\psi = +51^\circ.4$

'a' ax. vert- 'b' ax. normal to field

$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi \times \frac{85^- + 91}{2} = 0.49$ --- (3)

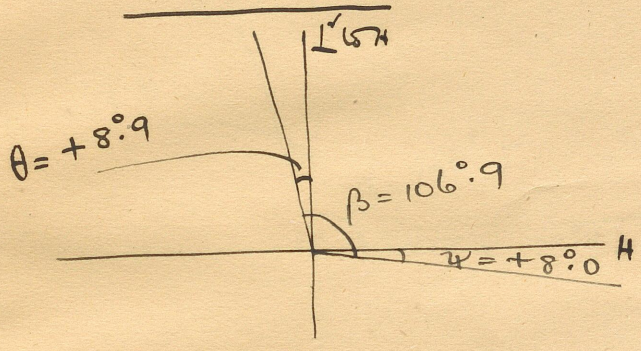
as compared with 0.54, Calculated.

$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

Monocl. prisms. $\rho = 1.932$. $M = 401.6$

$a : b : c = 0.7368 : 1 : 0.4997$; $\beta = 106^\circ 52'$.

'b' ax. vert.



$\theta = +8^\circ.9$ $\therefore \psi = +8^\circ.0$.

For the following measurements

$H = 6615$ gauss

$m = .0656$ gms

$c = .001275$.

$\Phi = \frac{\pi}{90} \times \frac{MC}{mH^2}$.

$\chi_1 - \chi_2 = \Phi \times 187 = 1.17$ . . . . . (1)

(001) pl. horiz. 'b' ax. along field.

$\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \Phi \times \frac{63 + 66}{2} = 0.40$ . . (2)

From (1) and (2)

$$\left.\begin{aligned} \chi_1 - \chi_2 &= 1.17 \\ \chi_1 - \chi_3 &= 0.74 \\ \psi &= +8^\circ.0 \end{aligned}\right|$$

'a' ax. vert 'b' ax. normal to field

$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi \times 116 = 0.72$, . . . (3)

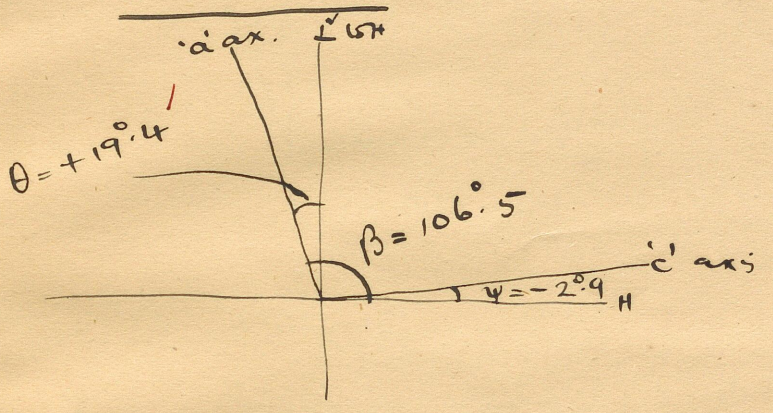
as against the calculated value of 0.71.

$MgSeO_4 \cdot (NH_4)_2SeO_4 \cdot 6H_2O$

Monocl. prismc. $\rho = 2.058$ $M = 454.89$

$a : b : c = 0.7420 : 1 : 0.4966$; $\beta = 106° 27'$

'b' ax. vert



$\theta = +19°.4$ $\therefore \psi = -2°.9$

for the following measurements

$H = 5492$ gauss

$c = .001275$

$m = .1065$ gm.

$$\Phi = \frac{\pi}{90} \times \frac{Mc}{mH^2}.$$

$\therefore \chi_1 - \chi_2 = \Phi \times 237 = 1.49$ - - - - - (1)

c(001) pl. horiz 'b' ax. sets along field.

$\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \Phi \times \frac{51+55}{2} = 0.33$ - - - (2)

From (1) and (2)

$$\left.\begin{aligned} \chi_1 - \chi_2 &= 1.49 \\ \chi_1 - \chi_3 &= 1.00 \\ \psi &= -2°.9 \end{aligned}\right|$$

'a' ax. vert 'b' ax. normal to field

$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi \times \frac{134+134}{2} = 0.84$ - - (3)

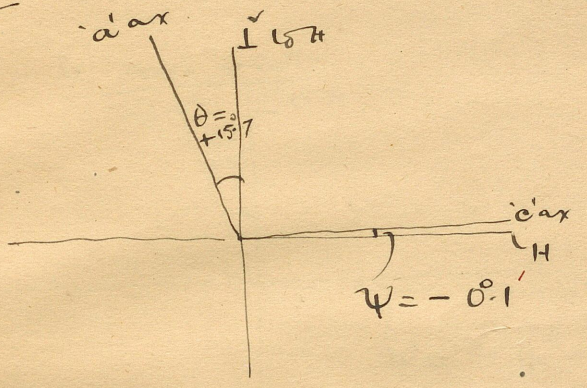
as against 0.84 calculated.

$MgSeO_4 \cdot Tl_2SeO_4 \cdot 6H_2O$

monocl. prisms. $\rho = 3.721$ $M = 827.59$

$a : b : c = 0.7485 : 1 : 0.4993$; $\beta = 105° 36'$.

'b' ax. vert



$\theta = 15°.7$ $\psi = -0°.1$.

$H = 5177$ gauss.

$C = .000846$

$m = .0919$ gm.

$\Phi = \frac{\pi}{90} \times \frac{MC}{mH^2}$

'b' $\chi_1 - \chi_2 = \Phi \times 205 = 2.03$ . . . (1)

'a' ax. vert 'b' ax. sets normal to field

$\therefore \chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi \times 241° = 2.39$ . . . (2)

$\therefore \chi_1 - \chi_2 = 2.03$

$\chi_1 - \chi_3 = 2.54$ $\psi = -0°.1$

For the 3rd direction the cryst was suspended with 'b'

(001) pol. horiz 'a' ax. sets along field

rough measurement $\chi_1 \sin^2\theta + \chi_2 \cos^2\theta - \chi_3 = \frac{\pi}{90} \times \frac{M \times .001143}{.2544 \times 5492^2} \times 185 = 0.8$

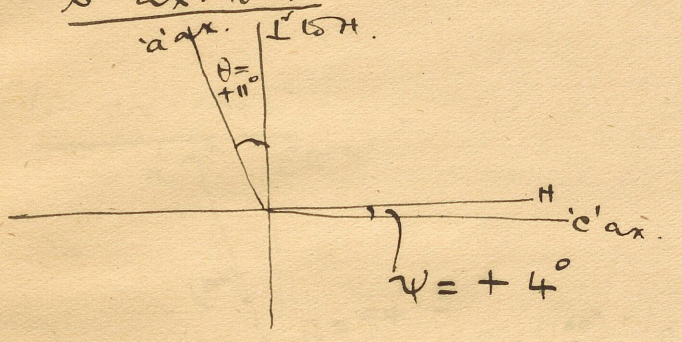
as against 0.7 calculated.

$MgSeO_4 \cdot Rb_2SeO_4 \cdot 6H_2O$

Monocl. prisms. $\rho =$ $M = 589.7$

$a : b : c = 0.7424 : 1 : 0.5011$; $\beta = 105^\circ 14'$

'b' ax. vert- 'a' ax. ⊥ to H.



$\theta = +11^\circ \quad \therefore \psi = +4^\circ$.

$H = 5177$ gauss.

$m_1 = .1948 \quad c_1 = .000846$

$m_2 = .2365 \quad c_2 = .000881$

$\Phi_1 = \frac{\pi}{90} \times \frac{Mc_1}{m_1 H^2} \qquad \Phi_2 = \frac{\pi}{90} \times \frac{Mc_2}{m_2 H^2}$

$\chi_1 - \chi_2 = \Phi_2 \times 454 = 1.30$ ..... (1)

2) 'a' ax. (001) pl. horiz 'b' ax. along H

$\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \Phi_1 \times 55 = 0.18$

also $= \frac{35.70 \times 8.20}{13.75^2} \times \frac{Mc_1}{m_1 H^2} = 0.15$

adopt- 0.18 ..(2)

From (1) and (2)

$\chi_1 - \chi_2 = 1.30$

$\chi_1 - \chi_3 = 1.07$

$\psi = +4^\circ$

3) 'a' ax. vert- 'b' ax. ⊥ to field

$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \Phi_1 \times 302 = 1.01$

$\Phi_2 \times 353 = 1.01$

as against- 1.02 calculated from above data.

Potassium ferri oxalate ~~hexahydrate~~

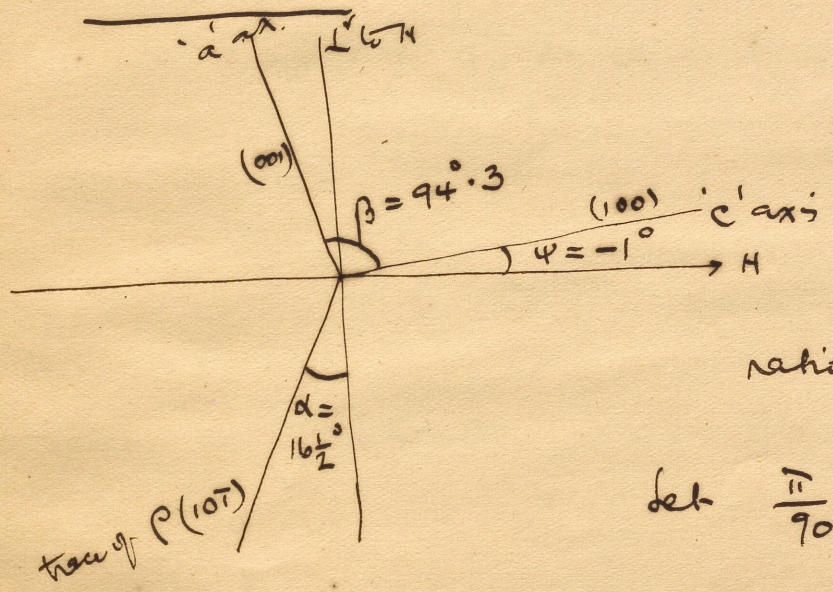
$M = \frac{1}{2} \times$

We shall adopt for the molecular formula $\frac{1}{2} \cdot K_6 Fe_2 (C_2O_4)_6 \cdot 6 H_2O$.

or $K_3 Fe (C_2O_4)_3 \cdot 3 H_2O$. $M = 491 \cdot 2$

Monocl. prismc. $a : b : c = 0.9918 : 1 : 0.3896$; $\beta = 94° 15'$.

'b' ax vert



The $\perp^{le}$ betn (10T) plane and the normal to H was measured and was $16\frac{1}{2}°$ (see below), (100) plane nearly $\parallel^{l}$ to field.

~~The~~ Since from the above axial ratios $(10T) \wedge (100) = 72° \cdot 3$

$\therefore \psi = -1°$

Let $\frac{\pi}{90} \cdot \frac{M}{H^2} = \varphi$ H throughout was 5102 gauss.

$$\chi_1 - \chi_2 = \varphi \times \frac{\cdot 002172}{\cdot 222} \times 4280 = \tfrac{1}{2} \times 55$$

$$\left(\text{also } \sin 2\alpha = \frac{2330 - \alpha}{4280} \qquad \alpha = 16\tfrac{1}{2}°.\right)$$

$$= \varphi \times \frac{\cdot 006146}{\cdot 339} \times 2385 = \tfrac{1}{2} \times 57.$$

Adopt $\chi_1 - \chi_2 = \frac{1}{2} 56 \times 10^{-6}$ - - - (1)

$= 28 \times 10^{-6}$

2) (10T) pl. horiz. 'b' ax. sets normal to field.

$$\left.\begin{aligned} \chi_1 \sin^2\alpha + \chi_2 \cos^2\alpha - \chi_3 &= \varphi \times \frac{\cdot 006146}{\cdot 415} \times 5340 = 104 \\ &= \varphi \times \frac{\cdot 006146}{\cdot 253} \times 3295 = 105 \end{aligned}\right\} \times \tfrac{1}{2} \text{ - - - (2)}$$

Former cryst. slightly better. ∴ adopt

$$\chi_1 \sin^2\alpha + \chi_2 \cos^2\alpha - \chi_3 = \tfrac{1}{2} \times 104 \times 10^{-6} \text{ - - - (2)}$$

$$= 52 \times 10^{-6}$$

Pot. ferri oxalate.

From (1) and (2)

$$\chi_1 - \chi_2 = 28 \times 10^{-6}$$
$$\chi_1 - \chi_3 = 78 \times \text{"}$$
$$\psi = -1^\circ.$$

3) Both (010) and (10T) planes vert. 'b' ax. ⊥ to field

$$\chi_1 \cos^2\alpha + \chi_2 \sin^2\alpha - \chi_3 = \varphi \times \frac{\cdot 006146}{\cdot 310} \times 5705 = 75$$

$$= \varphi \times \frac{\cdot 006146}{\cdot 330} \times 6140 = 75.$$

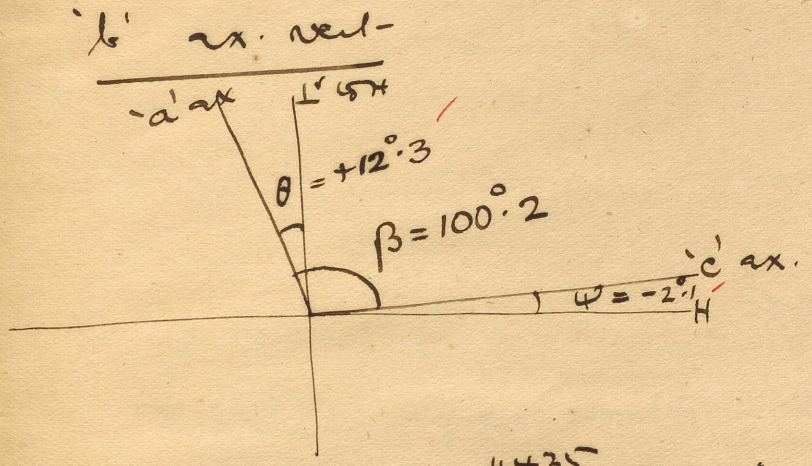
$$\therefore \chi_1 \cos^2\alpha + \chi_2 \sin^2\alpha - \chi_3 = 75 \times 10^{-6} \quad \text{----(3)}$$

as compared with 76×10^{-6} calculated from above values.

Sodium ferri oxalate $Na_3 Fe(C_2O_4)_3 \cdot 5H_2O$

$M = 478.9$

Monocl. prism. $a : b : c = 1.3692 : 1 : 1.2010$; $\beta = 100^\circ 15'$.



Throughout- $H = 5102$ gauss

$c = .00637$

(3.8042)

$$\varphi = \frac{\pi}{90} \times \frac{MC}{H}.$$

(i) $\chi_1 - \chi_2 = \varphi \cdot \frac{4435}{.594} = 30.6$

$\sin 2\theta = \frac{1820 - \theta}{4435}$; $\theta = +12^\circ.0$ or $\psi = -1^\circ.8$

(ii) another $\sin 2\psi = 215/2880$; $\psi = -2^\circ.1$

(iii) $\chi_1 - \chi_2 = \varphi \times \frac{2990}{.397} = 30.8$

$\sin 2\psi = 230/2990$; $\psi = -2^\circ.2$

∴ accepted- $\chi_1 - \chi_2 = 30.7 \times 10^{-6}$ - - (1)

$\psi = -2^\circ.1$ or $\theta = +12^\circ.3$

2) (001) pl. horiz. 'b' ax. along field.

$\chi_3 - \chi_1 \sin^2\theta - \chi_2 \cos^2\theta = \varphi \times \frac{1310}{.930} = 5.8 \times 10^{-6}$

$\therefore \chi_1 - \chi_3 = 23.5$

Sod. ferri oxalate.

3.) 'a' ax. vert: 'b' ax. normal to field

$$\chi_1 \cos^2\theta + \chi_2 \sin^2\theta - \chi_3 = \varphi \times \frac{3755}{.725} = 21.2$$

$$= \varphi \times \frac{4545}{.840} = 22.2$$

$$= \varphi \times \frac{2725}{.532} = 21.0$$

adopt mean $= 21.5 \times 10^{-6}$ -- (3)

~~This~~ ~~[illegible]~~ agrees with 22.1 calcd.

Some ions in the S-state

Cr 24 electrons $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

$^7S_3$

Cr^+ 23 elec. DO $3d^5$ ~~4s~~.

$^6S_{5/2}$

Mn 25 elec. DO. $3d^5\ 4s^2$ — $^6S_{5/2}$

Mn^+ 24 elec. Same as Cr $^7S_3$

Mn^{++} 23 elec. Same as Cr^+ $^6S_{5/2}$

Fe^{+++} 23 elec. "

Absol. Suscep.

	temp	k_1^t	ρ_1	χ_1^t	$\chi_1^{30°}$	mean χ
$MnSO_4 \cdot Na_2SO_4 \cdot 4H_2O$						
(2.333) Mn K_2 4 "	30°.2	$k_3 = 80.92$	2.333		$\chi_3 = 13790$ 13770 13810	13,790
" Am_2 6 "						13,830
(2.459) " Rb_2 "	30°.6	65.78	2.456	14,090	14,120 (14040)	14,030
	28°.4	66.00	2.473	14,040	13,960	
" Cs_2 "						
" Tl_2 "						13,720
$MnSeO_4 \cdot Am_2SeO_4 \cdot 6H_2O$	26°.4	$k_1 = 59.49$	2.138	13,510	13,350	13,360
	24°.7	" 59.68	2.129	13,600	13,370	
Rb_2						
Cs_2						
Tl_2						

Double Sulphates

Crystal	ψ	$\chi_1 - \chi_2$	$\chi_1 - \chi_3$	Crystal	ψ	$\chi_1 - \chi_2$	$\chi_1 - \chi_3$
$MnSO_4 \cdot Na_2SO_4 \cdot 4H_2O$							
$MnSO_4 \cdot K_2SO_4 \cdot 4H_2O$	$-61°$	4.6	1.7	$MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$	$-2°.2$	1.26	0.73
				$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$ (Bloedite)	$+66°$	~~0.48~~ 0.45	~~0.75~~ 0.70
$MnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	$-14°.6$	11.4	6.8	$MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	$-6°.7$	1.20	0.69
				$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	$+8°.0$	1.17	0.74
$MnSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$	$-16°.7$	9.5	7.7	$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$	$+5°.7$	0.86	1.33
$MnSO_4 \cdot Rb_2SO_4 \cdot 6H_2O$	$-12°.0$	9.1	6.4	$MgSO_4 \cdot Rb_2SO_4 \cdot 6H_2O$	$+12°.9$	0.93	0.72
$MnSO_4 \cdot Cs_2SO_4 \cdot 6H_2O$	$-12°.5$	7.0	5.0	$MgSO_4 \cdot Cs_2SO_4 \cdot 6H_2O$	$+51°.4$	1.28	0.95

Double Selenates

Crystal	ψ	$\chi_1 - \chi_2$	$\chi_1 - \chi_3$	Crystal	ψ	$\chi_1 - \chi_2$	$\chi_1 - \chi_3$
$MnSeO_4 \cdot (NH_4)_2SeO_4 \cdot 6H_2O$	$-21°$	9.1	6.7	$MgSeO_4 \cdot (NH_4)_2SeO_4 \cdot 6H_2O$	$-2°.9$	1.49	1.00
$MnSeO_4 \cdot Tl_2SeO_4 \cdot 6H_2O$	$-14°$	10.5	8.9	$MgSeO_4 \cdot Tl_2SeO_4 \cdot 6H_2O$	$-0°.1$	2.03	2.54
$MnSO_4 \cdot Rb_2SeO_4 \cdot 6H_2O$	$-14°$	9.2	7.4	$MgSeO_4 \cdot Rb_2SeO_4 \cdot 6H_2O$	$+4°$	1.30	1.07
$MnSO_4 \cdot Cs_2SeO_4 \cdot 6H_2O$				$MgSeO_4 \cdot Cs_2SeO_4 \cdot 6H_2O$			

1) Field = an log 2·6074 × $\frac{\text{known}}{\text{known for reversal of 1 amp turn solenoid.}}$

2) For small osc $c = \text{an log. } T \cdot 3004 / T^2$