

## Letters to the Editor.

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## Diamagnetism of the Trivalent Bismuth Ion.

THE diamagnetic susceptibilities of a number of ions have been calculated by Pauling,<sup>1</sup> Stoner,<sup>2</sup> Slater<sup>3</sup> and Angus.<sup>4</sup> These theoretical considerations have enhanced the interest in the experimental determinations of ionic susceptibilities.

We have determined the diamagnetic susceptibilities of a number of trivalent bismuth salts by the aid of the Bhatnagar-Mathur Magnetic Interference Balance.<sup>5</sup> The value for  $\chi_A$  for  $\text{Bi}^{+3}$  has been calculated by subtracting the value of the susceptibility of the negative ion from the experimentally determined value of the molecular susceptibilities of the salts.

Most of the values of  $\chi_A$  for the negative ions have been taken from Kido's careful investigations.<sup>6</sup> For  $\text{Cl}^-$ , the value 19.8 as experimentally determined in this laboratory<sup>7</sup> has been used. The  $\chi$  values for  $(\text{PO}_4)^{3-}$ ,  $\text{O}^{2-}$ , and  $\text{S}^{2-}$  have been taken from the International Critical Tables; the value of  $(\text{CrO}_4)^{2-}$  has been calculated from that of  $\text{H}_2\text{CrO}_4$  and the value for the citrate ion has been calculated from the values of  $\chi$  for carbon, hydrogen and oxygen atoms as given in the International Critical Tables.

The results obtained are shown in the table below.

Salt	$-\chi_a \times 10^6$	$-\chi_m \times 10^6$	$-\chi_A \times 10^6$ for $\text{Bi}^{+3}$
Bismuth oxide $\text{Bi}_2\text{O}_3$	0.170	79.22	42.20
Bismuth hydroxide $\text{Bi}(\text{OH})_3$ ..	0.253	65.78	40.28
Bismuth trichloride $\text{BiCl}_3$ ..	0.316	99.65	40.10
Bismuth tribromide $\text{BiBr}_3$ ..	0.328	146.94	42.84
Bismuth triiodide $\text{BiI}_3$	0.340	200.53	40.93
Bismuth sulphide $\text{Bi}_2\text{S}_3$ ..	0.240	123.40	38.45
Bismuth phosphate $\text{BiPO}_4$ ..	0.254	77.22	41.72
Bismuth sulphate $\text{Bi}_2(\text{SO}_4)_3$ ..	0.282	199.14	41.07
Bismuth chromate $\text{Bi}_2(\text{CrO}_4)_3$ ..	-0.202	-154.33	43.45
Bismuth citrate $\text{BiC}_6\text{H}_5\text{O}_7$ ..	0.302	120.20	41.38

The value of  $\chi$  for  $\text{Bi}^{+5}$  has been calculated by Angus. The value for  $\text{Bi}^{+3}$  which is the commonest bismuth ion does not seem to have been calculated by either the Slater or the Angus method. In view of the experimental data available, we have calculated

the theoretical value of  $\chi$  for  $\text{Bi}^{+3}$  by the Slater method, as a comparison of the theoretical and the experimental values should be of considerable interest.

The gram atomic susceptibility  $\chi_A$  is given by the expression :

$$\chi_A = - \frac{e^2 L}{6mc^2} \sum n r^{-2} \quad \dots \quad (1)$$

According to Slater, the values of  $r^{-2}$  are given by

$$r^{-2} = \frac{(n')^2 (n' + \frac{1}{2})(n' + 1)}{(z-s)^2} \quad \dots \quad (2)$$

The values of  $\chi_A$  can therefore be obtained according to equation (1) by summing over all the electrons remembering that  $r^{-2}$  in (2) is given as a multiple of  $a_0^2$  where  $a_0$  is the radius of the innermost orbit in hydrogen ( $a_0 = 0.528 \times 10^{-8}$ ). This gives

$$- \chi_A \times 10^6 = 0.790 \sum \frac{(n')^2 (n' + \frac{1}{2})(n' + 1)}{(z-s)^2} \quad (3)$$

Calculating the values of  $r^{-2}$  for different electronic groups in  $\text{Bi}^{+3}$  and summing up, the value of  $\sum r^{-2}$  is found to be 55.448. Substituting this value in (3) the atomic diamagnetic susceptibility of  $\text{Bi}^{+3}$  comes to be  $43.8 \times 10^{-6}$ .

The value of  $\chi_A$  for  $\text{Bi}^{+3}$  has been experimentally found to be 41.24 and is in close agreement with the theoretical value 43.8 calculated according to Slater's method. Angus has introduced a slight modification in Slater's formula for evaluating the effective nuclear charge. This modification has the effect of lowering the calculated value for susceptibility and would bring it in closer agreement with the experimental value.

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<sup>1</sup> Pauling, *Proc. Roy. Soc.*, 1927, A 114, 181.

<sup>2</sup> Stoner, *Proc. Leeds Phil. Soc.*, 1929, 1, 484.

<sup>3</sup> Slater, *Phys. Rev.*, 1930, 36, 57.

<sup>4</sup> Angus, *Proc. Roy. Soc.*, 1932, A 136, 569-578.

<sup>5</sup> Bhatnagar and Mathur, *Phil. Mag.*, 1929, 8, 1041.

<sup>6</sup> Kido, *Science Reports of the Tohoku Imperial University*, Series I, Vol. XXI, No. I.

<sup>7</sup> Cf. *Phil. Mag.*, 1934, 18, 449.

### The Emission of Fast Particles.

As a result of a series of experiments recently carried out by Rutherford and others,<sup>1,2</sup> it has been shown that from a number of radioactive elements groups of fast particles

are often emitted. Moreover the elements which are supposed to emit particles of given velocity really give out particles of velocities varying over a small range. Accordingly the wavestatistical formula deduced before<sup>3</sup> must be modified.

From a numerical computation of the energy of the disintegrated  $\alpha$ -particles, it can be shown that they become free at least at a distance  $10^{-13} \rightarrow 10^{-12}$  cm., from the centre of the core. On the other hand the wavestatistical formula of the radius of the hard core gives  $r_0 \sim 10^{-15}$  cm., for radioactive substances. So we have to suppose that the region between  $10^{-15}$  and  $10^{-13}$  cm. is filled with electrically neutral particles. Evidently it corresponds to the neutral shell of Rutherford. Since it is outside the charged core, the electrical force of repulsion is Coulombian in this region.

According to Rutherford the shell is filled with polarised helium atoms. But it appears a more general assumption would be to suppose that the shell is packed with large numbers of  $\alpha$ - and  $\beta$ -particles, such that the net charge is zero. The particles may possibly circulate in a number of orbits under a polarisation field. Thus the neutral shell may be supposed to consist of a number of thin shells of particles. Now as soon as an  $\alpha$ -particle comes out of the core and passes through the shell, it will naturally interact with the circulating  $\alpha$ -particles in the thin shells. And as a result of that an  $\alpha$ -particle which was originally present in the shell is ejected.

It is evident that the rate of disintegration is really the rate of ejection from the thin shells. The previous wavestatistical formula gives the rate at which the  $\alpha$ -particles enter the shell from the hard core within. Multiplying this rate by the number of  $\alpha$ -particles present in an excited state in a given thin shell, we find for the disintegration constant :

$$\lambda = \text{const.} \frac{\sqrt{U_0 E}}{\cot u_0} e^{-2k(2u_0 - \sin 2u_0)} \sin^2 \frac{2\pi m v r_1}{h}$$

where the symbols have been explained in the previous paper.<sup>4,5</sup>

If it is supposed that the  $\alpha$ -particles belonging to a particular group are all emitted with the mean velocity, then the factor  $\sin^2 \frac{2\pi m v}{r_1}$  becomes evidently unity,