

Fleming of the Department of Terrestrial Magnetism for supplying the apparatus, and to Dr. H. V. Neher for carefully rechecking the quartz electroscope.

¹ Paul F. Gast and D. H. Loughridge, Phys. Rev. **59**, 127 (1941).

² R. A. Millikan and H. V. Neher, Phys. Rev. **50**, 15 (1936).

³ A. H. Compton, E. O. Woldan and R. D. Bennett, Rev. Sci. Inst. **5**, 415 (1934).

⁴ V. F. Hess, Phys. Rev. **57**, 781 (1940).

⁵ A. H. Compton and R. N. Turner, Phys. Rev. **52**, 799 (1937).

⁶ D. H. Loughridge and Paul F. Gast, Phys. Rev. **58**, 583 (1940).

The Magnetic Anisotropy of Gadolinium Sulphate Octahydrate

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March 11, 1941

IN a previous publication¹ we reported preliminary measurements on the magnetic anisotropy of gadolinium sulphate octahydrate, $Gd_2(SO_4)_3 \cdot 8 H_2O$, made with a moderately pure specimen. The difference between the two extreme principal susceptibilities of the crystal was found to be about 1.4 percent of its mean susceptibility. This value for the magnetic anisotropy, though small, is much larger than should be expected from the narrow separation of the 8S levels of Gd^{+++} that would occur under the crystalline electric fields in the neighborhood of the Gd^{+++} ions in the crystal.

Recently we have made measurements with a specimen of known purity, kindly presented to us by Professor Trombe, of the Paris University. The specimen was quite free from both samarium and terbium, and its europium content was less than 0.1 percent. The main impurity present was the diamagnetic yttrium salt, about 1.4 percent, which will not affect the magnetic anisotropy appreciably. The results of the magnetic measurements are given below.

The crystal of $Gd_2(SO_4)_3 \cdot 8 H_2O$ is monoclinic, and has the axial elements $a : b : c = 3.009 : 1 : 2.007$, $\beta = 118^\circ.0$. Denoting the maximum and the minimum susceptibilities in the (010) plane, for the above formula weight (747 grams, containing 2 gram ions of Gd^{+++}), by χ_1 and χ_2 , respectively, and the susceptibility along the b axis by χ_3 , it is found that at room temperature (303°K): $\chi_1 - \chi_2 = 36 \times 10^{-6}$; $\chi_3 - \chi_1 = 16 \times 10^{-6}$; $\chi = (\chi_1 + \chi_2 + \chi_3)/3 = 52,000 \times 10^6$ e.m.u. The χ_1 axis makes an angle of about 17° with c and 45° with a . The difference between the extreme susceptibilities, namely $\chi_3 - \chi_2 = 52 \times 10^{-6}$, is only 0.1 percent of the mean susceptibility. This value of the anisotropy will correspond to a separation of the order of ϵ between the adjacent levels in the Stark pattern of the 8S state of Gd^{+++} , where

$$\frac{\epsilon}{k \times 303^\circ} \sim 10^{-3} \quad \text{or} \quad \epsilon \sim k \times 0.3^\circ, \quad \text{or} \quad 0.2 \text{ cm}^{-1},$$

which is of the same order as should be expected from the demagnetization and the specific heat measurements on the salt at very low temperatures.²

¹ Krishnan, Mookherji and Bose, Phil. Trans. Roy. Soc. **A238**, 133 (1939).

² See M. H. Hebb and E. M. Purcell, Phys. Rev. **51**, 384A (1937).

A Single Component for the Primary Cosmic Radiation

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April 17, 1941

WITH reference to the *Letter to the Editor* entitled "The nature of the primary cosmic radiation and the origin of the mesotron," by M. Schein, W. P. Jesse and E. O. Wollan,¹ I wish to point out that identical conclusions have been cited by the present writer from other considerations. These conclusions, which are covered in three published communications,² are as follows:

(1) There is *only one type of primary radiation*, a charged particle radiation—probably protons—comprising particles of heavy mass.

(2) By processes at present unknown, the *primary radiation gives birth, probably indirectly, in the upper atmosphere, to mesotrons*.

(3) Those mesotrons which are born approximately at rest will have such short lives that they will disintegrate before they have traveled more than 300 meters. *They will, in fact, disintegrate in the stratosphere, and in so disintegrating, will give rise to electrons which, on account of the disintegration occurring from mesotrons at rest, will emerge on the average equally in all directions*.

(4) The mesotrons formed with higher energy will disintegrate at lower altitudes, because of their longer lives, and *because they disintegrate at high energy, will give rise to electrons which possess on the average a forward component at these lower altitudes*.

(5) The assumptions (1) and (2) lead, through the logical consequences (3) and (4), to an explanation of the following facts: (a) As shown by the Bartol Foundation's observations in the two National Geographic—U. S. Army Air Corps Stratosphere Flights^{3,4} and in the Jean Piccard Flight,⁵ *the curve of intensity versus zenith angle flattens out with increasing altitude* to a condition in which, at a depth of 0.5 meter in the water equivalent atmosphere, there is only a 20 percent change from vertical intensity to horizontal intensity. (b) As shown by our stratosphere observations in *Explorer II*⁴ and independently by the observations of T. H. Johnson and J. G. Barry,⁶ *there is no appreciable azimuthal asymmetry at high altitudes*. It was, of course, to provide for the experimental facts cited under (a) and (b), that the hypotheses (1) and (2), with the consequences (3) and (4), were formulated.

(6) Any incoming electrons of primary origin and of one sign would necessitate azimuthal asymmetry and primary electrons of one sign or of both signs would cause strong dependence of intensity upon zenith angle. The absence of such effects prohibits assumption of the existence of any primary electrons and *necessitates that all the cosmic-ray electrons be born from the mesotrons in accordance with (2)*.⁷ *In other words, there can be no primary electrons*.

That the primary cosmic rays are *in part protons* has been suggested by A. H. Compton and H. Bethe,⁸ and also by T. H. Johnson.⁹ A single primary radiation of protonic nature giving rise to mesotrons and through them to the

cosmic-ray electrons was suggested by the present writer¹⁰ prior to his more detailed development of these ideas in papers cited.² T. H. Johnson¹¹ also suggested protons as the parents of the mesotrons but invoked a primary electronic radiation in addition.

¹ M. Schein, W. P. Jesse, and E. O. Wollan, *Phys. Rev.* **59**, 615 (1941).

² W. F. G. Swann, *Phys. Rev.* **56**, 209 (1939); *Rev. Mod. Phys.* **11**, 242 (1939). (See, in particular, pp. 251-254.) *Phys. Rev.* **58**, 200 (1940).

³ W. F. G. Swann and G. L. Locher, *Nat. Geog. Soc. Contr. Tech. Pap., Stratosphere Series No. 1*, pp. 7-14 (1935).

⁴ W. F. G. Swann, G. L. Locher, and W. E. Danforth, *Nat. Geog. Soc. Contr. Tech. Pap., Stratosphere Series No. 2*, pp. 16-25 (1936).

⁵ W. F. G. Swann, *J. Frank. Inst.* **222**, 1 (1936). (See, in particular, pp. 45-58.)

⁶ W. F. G. Swann, *Phys. Rev.* **56**, 209 (1939).

⁷ And to a negligible extent by shower production, which phenomenon, however, becomes relatively more important in the lower atmosphere.

⁸ A. H. Compton and H. Bethe, *Nature* **134**, 734 (1934); also A. H. Compton, *Rev. Sci. Inst.* **7**, 71 (1936).

⁹ T. H. Johnson, *Phys. Rev.* **45**, 569 (1934).

¹⁰ W. F. G. Swann, *J. Frank. Inst.* **226**, 757 (1938). (See, in particular, pp. 780 and 792.)

¹¹ T. H. Johnson, *Rev. Mod. Phys.* **11**, 208 (1939).

Vibrational Structure of the $4\Sigma_g^-(O_2^+) \leftarrow 3\Sigma_g^-$ Rydberg Series of O_2

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March 24, 1941

THE far ultraviolet absorption spectrum of molecular oxygen was studied by Price and Collins¹ in 1935. Our recent study in Berkeley, while confirming most of their observations, leads us to propose certain changes in their classification. The experimental arrangement was the same as in the case of N_2 reported recently,² except that the pressure of oxygen in the spectrograph was 0.001 mm.

Especially significant are the features we find in the region between $\lambda 740A$ and $660A$. Stated briefly, it appears that the bands designated as the Q progression, by Price and Collins together with some of their V and W bands,³ can be arranged into three different progressions, each forming a Rydberg series and converging respectively to the normal ($v=0$), $v=1$, and $v=2$ vibrational states of an excited O_2^+ electronic state which Mulliken⁴ tentatively called $b\ 4\Sigma_g^-$, thus constituting the (0,0) (1,0) and (2,0) bands of a $4\Sigma_g^- \leftarrow 3\Sigma_g^-$ Rydberg series of O_2 .

If we assign the three strong bands at $\lambda 732.22A$ (int. 4) $725.98A$ (4) and $720.07A$ (3) as the (0,0) (1,0) and (2,0) bands for $n=3$,⁵ thirteen members ($n=3$ to 15) were observed for each series. The frequencies of the bands in each of the three series follow a Rydberg law closely, giving as the series limit $\nu_{00}=146,548\text{ cm}^{-1}$ for (0,0) band, $147,705\text{ cm}^{-1}$ for (1,0), and $148,831\text{ cm}^{-1}$ for (2,0). The successive differences between the above numbers, namely $\Delta G_1=1157\text{ cm}^{-1}$, and $\Delta G_{1+1}=1126\text{ cm}^{-1}$ agree closely with the values 1162 cm^{-1} , and 1127 cm^{-1} obtained from the known constants for the $b\ 4\Sigma_g^-$ state of O_2^+ .

The ionization potential corresponding to the O_2^+ $b\ 4\Sigma_g^-$ normal state comes out as 18.08 ± 0.01 volts, which is close to the value 18.1 ± 0.1 volts obtained by combining the data⁶ for the $b\ 4\Sigma_g^- \rightarrow a\ 4\Pi_u$ bands of O_2^+ with the ionization potential of the $a\ 4\Pi_u$ level given by Tate and

Smith and Hagstrum and Tate⁷ from electron impact experiments.

The value obtained by Price and Collins for the $b\ 4\Sigma_g^-$ state is 18.2 ± 0.1 volts, which would seem to correspond to the mean of our values for the heights of the normal, first, and second vibrational states of $b\ 4\Sigma_g^-$.

Since there has heretofore been no spectroscopic connection between the quartet and doublet states of O_2^+ , our result would be of significance in supplying the accurate spectroscopic data for the energy of the quartet levels.

Unlike the case of N_2 that we reported in these columns, the (1,0) and (2,0) bands in O_2 are even stronger than the (0,0) band. Those bands that lie just beyond the limits of the series appear very diffuse, likely because of auto-ionization.

A more detailed report will appear soon in the *Scientific Papers of the Institute of Physical and Chemical Research* (Tokyo).

We wish to express our sincere thanks to Professor F. A. Jenkins for his continued interest.

¹ W. C. Price and G. Collins, *Phys. Rev.* **48**, 714 (1935).

² Y. Tanaka and T. Takamine, *Phys. Rev.* **59**, 613 (1941).

³ In these groups Price and Collins mention that their classification is uncertain.

⁴ R. S. Mulliken, *Rev. Mod. Phys.* **4**, 56 (1932).

⁵ Our assignment is tentative.

⁶ R. Frerichs, *Zeits. f. Physik* **35**, 683 (1926); T. E. Nevin, *Trans. Roy. Soc.* **237**, 471 (1938).

⁷ J. T. Tate and P. T. Smith, *Phys. Rev.* **39**, 270 (1932); H. D. Hagstrum and J. T. Tate, *Phys. Rev.* **59**, 354 (1941).

Variations in the Relative Abundance of the Carbon Isotopes

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April 18, 1941

SEVERAL years ago it was shown¹ that variations are present in the C^{12}/C^{13} abundance ratio of carbon obtained from various natural sources. The results have now been confirmed and extended in a new investigation with the 60° mass spectrometer² of 57 specimens of widely different geological age and geographic origin.

The samples were all converted to CO_2 and the C^{12}/C^{13} ratio determined from the relative heights of the mass 44 and 45 peaks after correction had been made for $C^{12}O^{16}O^{17}$ molecules.³

As the measurements were made over a period of several months a control sample was included each time analyses were made. The difference between the control and the sample in question was then noted. All computed ratios are based on these differences and the assumed constancy of the control. Frequent interchecks were made. This method eliminates possible errors due to variations in the mass spectrometer.

In Table I are recorded the results obtained. Each sample was analyzed at two different times and the final number adopted was the average of the two separate determinations. In over ninety percent of the cases the two separate values found for the C^{12}/C^{13} ratio agreed within 0.4 percent. In only three cases was the agreement worse than 0.6 percent, the poorest being 0.9 percent. The differences