Paramagnetic Resonance in Trivalent Molybdenum

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IT is well known that molybdenum in its lower valencies exhibits paramagnetism. Bose[1] has measured the susceptibilities of trivalent molybdenum compounds such as $K_3MoCl_6 \cdot 12H_2O$ and $Mo(SCN)_6(NH_3)_4 \cdot 4H_2O$ and found that the effective Bohr magneton number is near the spin-only value. As the study of paramagnetic resonance absorption spectra affords a very reliable method for the determination of the ionic g values, experiments have been undertaken on compounds of Mo^{+++}. A double salt of Mo^{+++} was prepared by the reduction of a solution of molybdic acid in concentrated HCl by potassium amalgam. The green crystals so obtained are unstable in air but are easily preserved in paraffin wax. The salt is believed to be K_2MoCl_5 which is known to exist in two isomeric forms, one green and the other red.[2] Paramagnetic resonance experiments in this compound have been performed with the familiar experimental set-up at 3 cm. A sharp resonance was obtained. The experimental g value is 1.76 ± 0.02 and the half-breadth $2\Delta H_{\frac{1}{2}} = 190$ oersteds. g values calculated from susceptibility data for Mo^{+++} in $K_3MoCl_6 \cdot 12H_2O$ and $Mo(SCN)_6(NH_3)_4 \cdot 4H_2O$ are, respectively, 1.86 and 1.92. It is interesting to note that Mo^{+++} shows a sharp resonance spectrum even in the polycrystalline state similar to those in Cr^{+++} and V^{++} compounds. All these three ions are in the same electronic state $^4F_{\frac{3}{2}}$.

Similar sharp resonances occur in Cu^{++} salts, and the sharpness has been attributed to exchange interaction. It is probable that the same explanation may hold in the case of Mo^{+++}. Further investigations are in progress.

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[1] D. M. Bose and H. G. Bhar, Z. Physik **48**, 716 (1928).
[2] J. W. Mellor, *Treatise on Inorganic Chemistry* (Longmans, Green and Company, London, 1931), Vol. XI.

Multiple Events Produced in Hydrogen by Very High Energy Cosmic-Ray Particles at an Altitude of 90,000 Feet*

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A COUNTER experiment has been performed in order to study the production of mesons in the interactions of cosmic-ray particles with hydrogen nuclei. The apparatus used was flown from Chicago on September 6, 1950, by means of a General Mills constant level balloon. The balloon reached an altitude of 90,000 feet and floated at that height for $4\frac{1}{2}$ hours. The proton target consisted of a spherical metal Dewar, 30 cm in diameter, filled with hydrogen. The experimental arrangement is shown in Fig. 1. Four crossed counter trays (A, B, E, and F) determined the direction of the incoming particle; two counter trays (T and $H-G$) detected multiple events. A master pulse was triggered by the coincidence $ABCD$ or $EFGH$. The pulses from each counter were in coincidence with the master pulse and were registered individually on a moving photographic film (hodoscope). Towards the middle of the flight the hydrogen was ejected from the Dewar. The remaining time at altitude was used as a control experiment without hydrogen.

Of all the coincidences recorded by the equipment, only those will be discussed in which not more than one counter was activated in any one of the four trays A, B, E, or F (see Fig. 1). Coincidences of this type are assumed to be due to a single incident particle interacting in the liquid hydrogen or in the walls of the Dewar. Table I gives the frequency of events obtained during 130 minutes of flight at 90,000 feet with an average of 1.4 g/cm² of liquid hydrogen interposed between the counter trays, and during 110

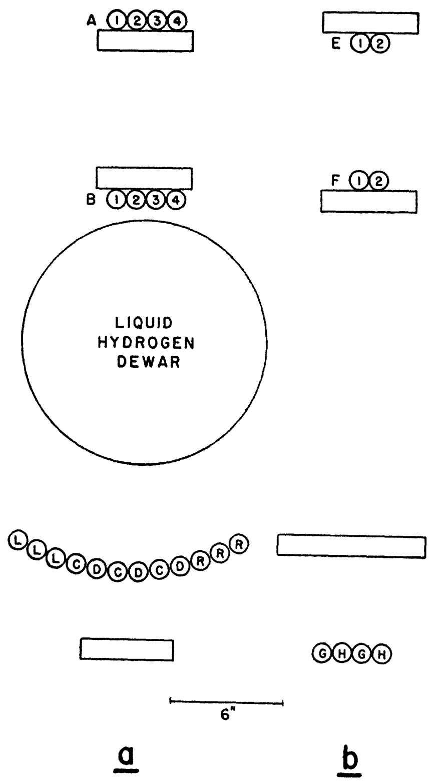

FIG. 1. Schematic diagram of apparatus used for the study of multiple events originating in liquid hydrogen. a, front view; b, side view.

minutes after the ejection of the hydrogen. The frequency of events in which 2 or 3 counters were activated in tray T decreases noticeably after the ejection of the hydrogen.

A selection of those coincidences in which at least three counters were activated in tray T eliminates the possibility that some of the events recorded may have been the result of knock-on electrons, the break-up of α-particles, elastic collisions, and other interactions giving rise to events consisting of two secondary particles only. Figures 2a and b are histograms of the frequency of events in which 3 or more counters were activated in tray T, originating in the walls of the Dewar and of the liquid hydrogen, respectively, plotted as a function of their total angular width. This width is assumed to correspond to the angular separation, as seen from the geometrical center of the Dewar, of the two farthest counters activated in tray T. Figure 2a shows that events originating in the walls of the Dewar are distributed almost isotropically over the area of these counters. The absence of events of an angular width of less than 4° results from the requirement that three counters be discharged in counter tray T. The finite size of the counters places a lower limit on the minimum angular separation observed. Figure 2b shows that events originating in hydrogen have a spread of only 15°, indicating that low energy interactions cannot have contributed significantly to the counting rate. This is in agreement with the fact that real stars cannot be produced in proton-proton collisions. The fact that the number of events in

TABLE I. Frequency of multiple events observed with the hydrogen equipment.

Number of counters activated in tray T	Frequency of events with hydrogen (counts/hr)	Frequency of events without hydrogen (counts/hr)
≥ 2	43	33
≥ 3	24	12