GENERAL PHYSICS

I. MOLECULAR BEAMS

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A. NEUTRALITY OF ATOMS (ATOMIC BEAM METHOD)

To provide an experimental determination of an upper limit of possible charge residing on an un-ionized atom, a cesium beam experiment is in progress. In it, a beam of atoms is passed through a uniform electric field directed perpendicular to the beam's path. Hence a Cs atom would be deflected if it bore a net charge, q. The present experimental arrangement is such that a deflection of 2 Å would be expected if $q = 10^{-18}$ $e = 1.6 \times 10^{-37}$ coulomb.

Orginally the experiment was performed with a DC electric field in the deflecting region. This resulted in a value $q = (8.4 \pm 8.0) \times 10^{-16}$ e. Further improvements, including the rejection, to a large extent, of beam deflections that result from field gradients, vibration of the apparatus, and similar effects, have been made by modulating the deflecting field and looking for the signal appropriate to a true Cs charge with a lock-in detector. A method for in situ calibration of the apparatus sensitivity, so essential in any null experiment, by electrically deflecting the beam a known number of angstroms at frequent intervals during data accumulation, has also been incorporated. The most recent determinations have resulted in a value $q = (-2.0 \pm 1.0) \times 10^{-18}$ e. This result should be compared with the value $q = (1.3 \pm 5.6) \times 10^{-17}$ e obtained by Zorn, and his co-workers.[1]

The present result can be interpreted in terms of possible neutron, q_n, and electron-proton pair, q_{ep}, charges that give for the cesium atom $q = 55\, q_{ep} + 78\, q_n$. Assuming $q_n = q_p$ yields $q_{ep} = q_n = (-1.5 \pm 0.75) \times 10^{-20}$ e. The precision of this result approaches that obtained by gas efflux methods.[2]

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References

1. J. C. Zorn, G. E. Chamberlain, and V. W. Hughes, Phys. Rev. 129, 6 (1963).

2. J. G. King, Quarterly Progress Report No. 76, Research Laboratory of Electronics, M.I.T., January 15, 1965, pp. 9-13.

B. LOW TEMPERATURE HELIUM BEAM EXPERIMENT

1. Detector Operation

The following changes have been made in the detector assembly (see Quarterly Progress Report No. 76 (pages 13-15).

1. The P-16 phosphor screen has been replaced with Willemite. This is slower (decay time, microseconds) but has several hundred times higher luminous efficiency for 12-kv ions.

2. The needle holder has been adapted to point the needle directly at the phosphor screen. A study of the field electron emission pattern from the needle tip has shown that almost all field lines from the sharp tip region emerge within a 15° half-angle cone of divergence from the needle shaft axis.

3. The method of mounting the Pyrex disc on which the phosphor screen is deposited has been modified. In the old design an aluminum capture ring and a 0.020-inch gold wire gasket were used under the 1/2 inch thick glass disc. This resulted in fracture of the glass disc under temperature cycling when cooling the photomultiplier tube with dry ice. In the new configuration a stainless-steel capture ring and a 0.028-inch neoprene flat gasket which are used under the glass have thus far proved completely reliable. Also, 3/4 inch thick glass discs are now being used. The use of the neoprene seal has not resulted in poorer vacuum conditions, as a detector chamber pressure of 2×10^{-10} torr is still obtained, with or without dry-ice cooling of the photomultiplier-glass disc assembly.

Initial performance data of the detector were taken by reading the photomultiplier output current with a Keithley Model 600 electrometer, and by varying the partial pressures of N_2, A, and He in the detector chamber through the range 1×10^{-7} -2×10^{-10} torr. Pressure was monitored by a Bayard-Alpert gauge, with the correction factor appropriate for the various gases applied.[1] An over-all detection conversion efficiency (number of electrons from photomultiplier photocathode divided by number of atoms incident on needle tip, per unit time) of from 5% to 30% was calculated.

The sensitivity for He is approximately 4 times that for N_2, which is approximately 3/2 that for A. This is to be expected, as the phosphor yield should go as the momentum of the exciting ions, hence as the square root of the mass ratios. There is a further slight enhancement, since the helium, with a higher ionization potential, must approach the tip more closely to be ionized, the He^+ ions are formed in a higher potential region than, say, N_2^+, and hence have more energy when striking the phosphor.

The signal intensity now goes as the square of the needle tip voltage. The elimination of the electroluminescent effect (intensity exponential with tip voltage) noted previously is attributed to using Willemite rather than P-16, and is consistent with the observation that zinc-silicate base phosphors are, as a class, much less electroluminescent than zinc-sulfide base phosphors, or other common phosphor types.[2]

2. Beam Investigations

The room-temperature beam source must be operated at an excessive pressure to produce a signal visible on the Keithley electrometer, and a well-defined beam could not be obtained in this way. At a proper source pressure of the order of 10^{-4} torr one would expect approximately 500 atoms per second detected beam. Accordingly, pulse-counting electronic equipment has been incorporated. The arrangement, at present, consists of an emitter follower preamplifier, a Franklin Model 348 linear amplifier with internal pulse-height selector, and an R. L. E. Model 210 pulse counter (scale of 2^{15}). The overall resolution time is 5 μsec, and is judged appropriate for the Willemite phosphor.

This equipment has just been adjusted for optimum operation, and only preliminary results are now available. The counting statistics for the background gas fit the assumption of a random distribution, that is, the standard deviation of the means agrees within 5% of the $\sqrt{N}$ expected, when allowance is made for the counter inefficiency resulting from the 5-μsec resolution time and the 0.3% random timing error of the electromechanical counter timing gate.

There are preliminary indications consistent with a beam of 50 counts per second, with a source pressure of 4×10^{-2} torr; however, this has not been confirmed by scanning the needle across the beam.

An electronic gate is to be added between the Franklin and the counter for use with the beam chopper in taking velocity distributions. It is to be noted that the detected beam intensity goes _inversely_ as the 3/2 power of the source temperature, so that at 0.9° K, with the vapor pressure of He^4 is 4×10^{-2} torr, the detected beam would be 2500 counts per second, even after a 0.1% duty cycle in the chopper. Thus, from a signal-to-noise point of view, this experiment will be substantially easier with low-temperature sources.

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References

1. S. Dushman, _Scientific Foundation of Vacuum Technique_ (John Wiley and Sons, Inc., New York, 2d edition, 1962), p. 324.
2. H. F. Ivey, _Electroluminescence and Related Effects_, _Advances in Electronics and Electron Physics_, _Suppl. I_ (Academic Press, New York, 1963).

C. HIGH-RESOLUTION MEASUREMENTS OF THE 3-3 INVERSION TRANSITION IN AMMONIA

The two-cavity maser spectrometer described in previous reports[1] is now being used to study the hyperfine structure of the J = 3, K = 3, inversion line of NH_3. A resonance linewidth of 350 cps is obtained with a cavity separation of 115 cm. This constitutes improvement in resolution by a factor of 20 over previous measurements,[2] and many more lines are now resolvable.

The main line ($\Delta F = \Delta F_1 = 0$) at zero magnetic field is split as shown in Fig. I-1. The calculations of Gordon[2] indicate that the main line will be split into three components if the quadrupole coupling constant eqQ is different in the two inversion states. The separation between the $F_1 = 4$ and $F_1 = 2$ components ($\vec{F}_1 = \vec{J} + \vec{I}_N$, I_N = nitrogen spin) is small (<500 cps), and the $F_1 = 2$ component should be much weaker because the degeneracy is smaller and the focussing is weaker for this state. Therefore we see primarily the $F_1 = 3$ and $F_1 = 4$ $\Delta F_1 = 0$ transitions, and the contribution from $F_1 = 2$ is much smaller. Seven of the nine components of the magnetic satellites have been observed. These magnetic satellites result when one hydrogen spin is "flipped" simultaneously with the inversion.

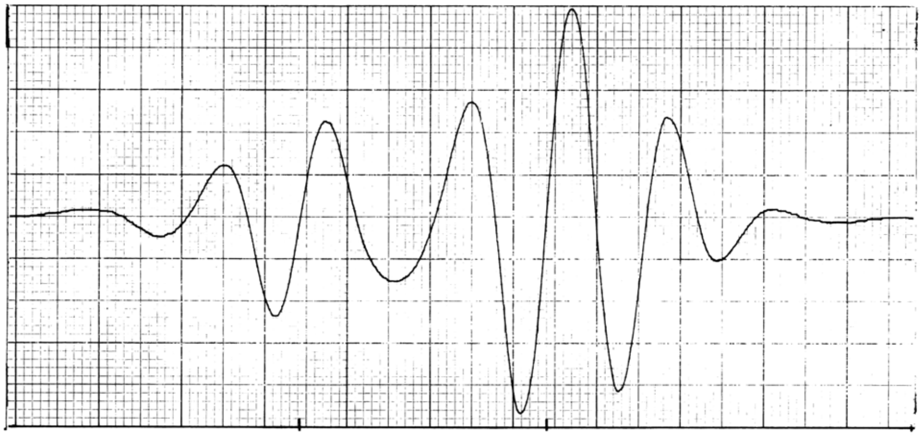

Fig. I-1. J = 3, K = 3 main-line ($\Delta F = \Delta F_1 = 0$) components at 23,870,127.95 kc and 23,870,129.62 kc (first derivative of resonance).

The main-line measurements indicate that the quadrupole coupling constant eqQ is larger in the lower inversion state by 3.6 ± 0.1 kc.

We have also observed three of the four components of one of the upper quadrupole satellites. More data will be necessary to identify each of the satellite components, but if we average over magnetic interactions we obtain agreement with Gordon's value of eqQ, 4094.8 ± 1.5 kc for the 3-3 state. When these magnetic components are identified we should obtain at least an order of magnitude improvement in accuracy for the magnetic and quadrupole coupling constants. These results provide better data on electronic wave functions and geometrical parameters for the NH_3 molecule.

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References

1. S. G. Kukolich, Quarterly Progress Report No. 72, Research Laboratory of Electronics, M. I. T., January 15, 1964, pp. 1-11; No. 73, April 15, 1964, pp. 1-2; No. 74, July 15, 1964, pp. 4-7.

2. J. P. Gordon, Phys. Rev. 99, 1253 (1955).