

## IX. MOLECULAR BEAMS\*

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### A. HYPERFINE STRUCTURE OF BROMINE

A new detector assembly has been built in order to reduce the large extraneous bromine background. It consists of a box containing a thoriated tungsten ribbon that is used as a surface ionization detector for bromine atoms. The atoms are admitted to the box through an opening that is filled with crinkly foil.

An electrometer, utilizing an FP54 tube, was used to look at the ionized atoms from the tungsten ribbon. This background of bromine from the wire, as well as the electron emission from the wire, was very unsteady. The unsteadiness was much greater than shot effect and was assumed to be flicker noise from the wire. Also, the electron emission and bromine background decreased after the accelerating voltage had been on for a while. This was probably the result of ion bombardment. As a consequence, the ribbon never became fully thoriated. R. Weiss suggested carburizing the filament. This was done by heating the ribbon for 3 minutes in 0.1 mm of methane. This changes some of the tungsten into tungsten carbide, which, for reasons that are not understood, helps keep the thorium on the surface of the ribbon; that is, it slows down the evaporation of the thorium. After this treatment, the ribbon readily became thoriated. It was then found that by running the wire at 1800°K, at which temperature it was space-charge-limited for the mass spectrometer voltage required for bromine, the unsteadiness in the background was greatly reduced.

A beam was observed, and the thoriated tungsten ribbon gave a much higher detection efficiency than the tungsten had formerly given. Part of this gain was lost by the formation of space charge in front of the ribbon. The beam had two types of noise. One was a cyclic variation, with a period of several minutes, which was the result of variations in the source temperature. The other was characterized by irregular decreases in the beam, which were finally correlated with small pressure increases. A small irregular leak exists in the vacuum envelope. An intensive search has failed to locate it. A modulated detection system is now being tried, which may smooth out this noise.

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### B. EFFECTS OF PHASE SHIFTS IN THE RAMSEY METHOD OF MOLECULAR BEAM MAGNETIC RESONANCE

An experiment was begun to investigate the effects of phase shifts in the Ramsey method of molecular beam magnetic resonance with separated oscillating fields. An apparatus built by R. D. Haun (1) and modified by R. F. C. Vessot is being used. The apparatus is constructed to permit the passage of two cesium beams through the oscillating fields in opposite directions (1).

The different components of the modified apparatus were checked and necessary repairs were made. The alignment of deflecting magnets, sources, and detectors was checked. Secondary-emission multipliers were installed, the apparatus was then assembled and pumped.

The downward traveling beam was turned on and low-frequency  $F = 4$ ,  $m_F = -4 \rightarrow F = 4$ ,  $m_F = -3$  transitions were observed. High-frequency  $F = 4$ ,  $m_F = 0 \rightarrow F = 3$ ,  $m_F = 0$  transitions were then observed. The signal-to-noise ratio of the Ramsey pattern was poor (2:1, at best). The source of the noise has been traced to the large background of unflopped atoms that reach the detector, and work is proceeding to correct this defect.

R. Golub

#### References

1. A Study of Electric Polarization Effects on Cesium<sup>133</sup> Hyperfine Structure, R. D. Haun, Jr., Ph.D. Thesis, Department of Physics, M.I.T., Jan. 7, 1957; Technical Report 322, Research Laboratory of Electronics, M.I.T., Jan. 18, 1957.

### C. HYPERFINE STRUCTURE OF Be<sup>7</sup>

Present experimentation is being carried out with the stable isotope Be<sup>9</sup>. A beam has been produced by heating the metal above the melting point, 1551°K. The Be<sup>9</sup> is contained in a beryllium oxide crucible, which is set in a resistance-heated graphite oven. The vaporization occurs in a chamber whose pressure is approximately  $10^{-6}$  mm Hg, as measured by a General Electric ion gauge.

Current work is concerned with electronic detection of the beam by using the photons emitted when excited atoms in the metastable  $^3P_2$  state (produced by electron bombardment) decay to the ground state upon striking a graphite target. This target is viewed by a photomultiplier tube whose function is detection of the photons. No satisfactory evidence of detection has been obtained, although a deposit of beryllium was seen after the dismantling of the apparatus.

A preliminary measurement of the hyperfine structure of Be<sup>9</sup> has just been completed by Dr. A. Lurio, of the IBM Watson Laboratory. In his detection method the

atoms in the metastable state are de-excited by ejecting electrons from a cesium-coated surface. Dr. Lurio is being approached, in order to learn whether or not his work will include a measurement of the hyperfine structure of Be<sup>7</sup>. Until Dr. Lurio's plans are definitely known, we plan to make a final test of the photon-detection method.

E. L. Kamen

#### D. ELECTRIC RESONANCE CLOCK

Since the last report (1) on this research, the carbon monoxide (CO) background has been reduced by a factor of 50 by means of a helium trap, a mercury pump, and an elaborate liquid air-cooled baffle. A directional entrance to the detecting chamber was introduced to reduce the effects of the scattered beam in the main chamber and to make it easier to keep the pressure in the detector independent of the rest of the apparatus. The beam strength has been increased by a factor of 5. However, even with the best attainable pressure in the detecting chamber –  $5 \times 10^{-10}$  mm Hg – the CO background at both the CO and the C positions of the mass spectrometer is 10 times larger than the maximum attainable total beam. The experiment is going to be tried with C<sup>12</sup>O<sup>18</sup>, which is now being synthesized. The mass spectrometer resolution seems to be adequate to resolve mass 28 from mass 30. There is still the problem of whether or not the scattered beam in the main chamber will allow a 100/1 signal-to-noise ratio, which is necessary to observe the transition. (I may have to build another buffer chamber between the main can and the detector.)

At present, I am lining up the apparatus with a beam of sulphur dioxide (SO<sub>2</sub>) with a detection efficiency of 1/40 for the beam and 1/30 for the background. The signal-to-noise ratio is 200/1 for a beam of 10<sup>6</sup> ions/sec of SO<sub>2</sub>. Sulphur dioxide has the nice properties that it condenses on liquid nitrogen and that there is negligible noise at its mass number.

If the experiment with CO becomes too difficult, CS could be an alternative molecule. In spite of the necessity for generating it in a discharge of CS<sub>2</sub>, CS has many of the desirable properties of CO. It is also a strictly electric molecule with a large rotation constant – about 23 kmc. It has a larger dipole moment than CO, 2 debye units rather than 0.1 debye unit, and it has approximately one-hundredth of the molecules in the two rotation states that are involved in this experiment. The major advantages are that it condenses on liquid air and decomposes in so doing and that at mass number 44 there is 50 times less noise than at the CO mass position. The discharge poses the main problem.

An interesting, as well as annoying, problem occurred when it appeared that the thoriated tungsten filaments used in the detector did not emit electrons more copiously than ordinary tungsten. It appeared that in this exceptionally clean apparatus, free of hydrocarbons, the wires failed to produce a stable thorium surface. An auxiliary

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experiment showed that carburizing a thoriated tungsten filament reduced the thorium evaporation rate, and made the adsorbed thorium surface less susceptible to oxidation and positive ion bombardment. I tried forming tungsten silicide and tungsten boride surfaces as alternative schemes so that I would not have to introduce any carbonaceous material into the detector – but to no avail. The tungsten boride surface appeared to serve the same function as the tungsten carbide, but it was not refractory enough. Tungsten silicate showed no increase in electron emission. Carburizing thoriated tungsten seems to be an established procedure in industry; the problem has never arisen in this laboratory because the pump oils in vacuum systems perform the carburization automatically.

R. Weiss

References

1. R. Weiss, A carbon monoxide clock, Quarterly Progress Report No. 53, Research Laboratory of Electronics, M. I. T., April 15, 1959, pp. 66-67.