# V. RADIO-FREQUENCY SPECTROSCOPY

## A. MOLECULAR-BEAM RESEARCH

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### 1. The Fourth Atomic-Beam Apparatus

Construction of the fourth atomic-beam apparatus is nearing completion. A vacuum has been obtained, and all components have been installed. High current capacity submarine batteries, which will supply the heavy currents to the deflecting magnets and mass spectrographs, have been installed.

As this apparatus is to be used primarily in the study of radioactive isotopes, available only in quite small concentrations, it is necessary to have a very high mass spectrograph enrichment factor. This enables one to detect the radioactive isotopes, without their being obscured by the more abundant isotopes. To achieve this high enrichment factor, it was decided to use two mass spectrographs in this apparatus. The two mass spectrographs are so positioned that the image from the first mass spectrograph, after passing through a collimating slit, serves as the object of the second mass spectrograph. With this arrangement, it was hoped that the resultant enrichment factor would be the product of the two individual enrichment factors.

The two mass spectrographs were constructed of Armco Magnet Iron, and annealed in an atmosphere of hydrogen. Water-cooled current windings were placed on the mass spectrographs; with these windings, it has been found possible to obtain magnetomotive forces of as high as 3500-amp turns.

In order to focus the ion beam through the first mass spectrograph, the collimating slit between the two mass spectrographs was coated with the phosphor, zinc orthosillicate. For a certain value of magnetic field in the first mass spectrograph, the energy of a mono-energetic beam of ions is varied until the image of the ion source is seen on the phosphor. Then the magnetic field in the second mass spectrograph is varied until the beam also is focussed through the second mass spectrograph.

An ion beam from the conventional hot tungsten wire source of alkali ions has been passed through the two mass spectrographs. Preliminary measurements indicate that the enrichment factor of the combination is better than $10^4$. For example, when using a beam of potassium ions, it has been possible to see the image due to $K^{40}$ ions separated out from the $K^{39}$ and $K^{41}$ ions in the beam. The natural abundance of $K^{40}$ in potassium is

only 1 part in $10^4$. Complete mass spectrograph curves will be published in the next progress report.                     T. M. Hahn, Jr.

## B. NUCLEAR MAGNETIC RESONANCE

Prof. F. Bitter          W. Dickinson

N. I. Adams III          P. Sagalyn

J. Brossel              T. Wimett

### 1. The Magnetic Moment of $Rb^{87}$

The frequency ratio of the nuclear resonance of $Rb^{87}$ to that of the proton has been more precisely determined in a field of about 3000 gauss using a single sample consisting of a solution of Rb Cl and water. The ratio is found to be

$$\frac{\upsilon\ Rb^{87}}{\upsilon\ H^1} = 0.327228 \pm 0.000014 \ .$$

This error includes all of 21 separate determinations. The limit on precision was the width of the signals. As both lines were of the same approximate width (about 0.3 gauss) it seems probable that the line width was here limited by field inhomogeneity.          N. I. Adams III

### 2. The Magnetic Moment of $B^{11}$

As a preliminary check of the circuits used for the $Rb^{87}$ to proton measurement, seven determinations of the $B^{11}$ to proton frequency ratio were made at about 3000 gauss giving

$$\frac{\upsilon\ B^{11}}{\upsilon\ H^1} = 0.320834 \pm 0.000009 \ .$$

All seven determinations are included by this error. A single sample of $BF^3$ etherate was used. Both line widths were at most 0.5 gauss, but the limit of precision was line shapes. In particular, the proton signal was distorted by saturation effects. Further improvement in accuracy would probably be obtained by addition of paramagnetic ions to this solution.                     . N. I. Adams III, T. Wimett

### 3. The Magnetic Moment of $La^{139}$

The ratio of the frequency of the nuclear magnetic resonance of $La^{139}$ to that of the proton has been measured at 6700 gauss. Both resonances were observed in a single sample consisting of an aqueous solution of lanthanum chloride. In this measurement, although the two frequencies

correspond very closely to a 7:1 ratio as in the $Be^9$–$H^1$ measurement recently reported, advantage was not taken of the increased precision in frequency-ratio measurement made possible by heterodyning the seventh harmonic of the one frequency with the fundamental of the other. For $Be^9$ the observed line width was $\sim 1/2$ gauss and since it was possible to determine the center of this line to within 0.1 gauss in a field of 7000 gauss, a frequency ratio precision of at least 1 part in 70,000 could be utilized. However, the observed line width for $La^{139}$ was $\sim 3$ gauss and since the true line center could only be determined to within 1/2 gauss at best, the precision given by a Zenith BC-221-T frequency meter was sufficient.

A total of six determinations was made. From these the following value for the ratio of the resonant frequencies in the same magnetic field was obtained:

$$\frac{\upsilon\ (La^{139})}{\upsilon\ (H^1)} = 0.141251 \pm 0.000014 \quad .$$

The uncertainty given represents limit of error, all six values falling within the above limits.

The broadness of the $La^{139}$ resonance line may be due to a nuclear quadrupole Q which, however, has never been measured. Similar broad lines have been observed for $I^{127}$, $Cs^{133}$, and the two Br isotopes, all of which are known to have quadrupole moments.                                          W. Dickinson

### 4. Deuteron-Proton Moment Ratio

A different kind of r-f bridge circuit has been devised in an effort toward better control of line shape for this precision measurement. One such has been constructed for 4.5 Mc and it appears to be a definite improvement with regard to stability and line shape, but a preliminary rough check revealed a lower signal-to-noise ratio as compared to the older bridge. This factor will be investigated further but is not very important for this particular experiment because the proton resonance signal amplitude at 4.5 Mc is many times noise. The Helmholtz coils to be used in this experiment are being adjusted.                                          T. Wimett

### 5. Faraday Effect

An apparatus is being set up for observing the Faraday effect of optical resonance radiation in very weak magnetic fields.

J. Brossel, P. Sagalyn

### 6. New Magnet

An electromagnet for measuring small nuclear g-factors is being constructed.

                                                              F. Bitter

## C. MICROWAVE SPECTROSCOPY

| Prof. M. W. P. Strandberg | B. V. Gokhale | G. W. King |
| Prof. G. G. Harvey | R. E. Hillger | R. B. Lawrance |
| Prof. A. G. Hill | J. G. Ingersoll | C. C. Loomis |
| J. R. Eshbach | H. R. Johnson | M. T. Weiss |

### 1. Ketene

Work on this molecule has been suspended for the summer. An improved precision Stark cell has been built to facilitate further millimeter work on this molecule. Deutero acetone has been made available to us by R. Lord (M.I.T. Chemistry Department) and a study of deuterated ketene will be next attempted.

                                                              H. R. Johnson

### 2. Formaldehyde
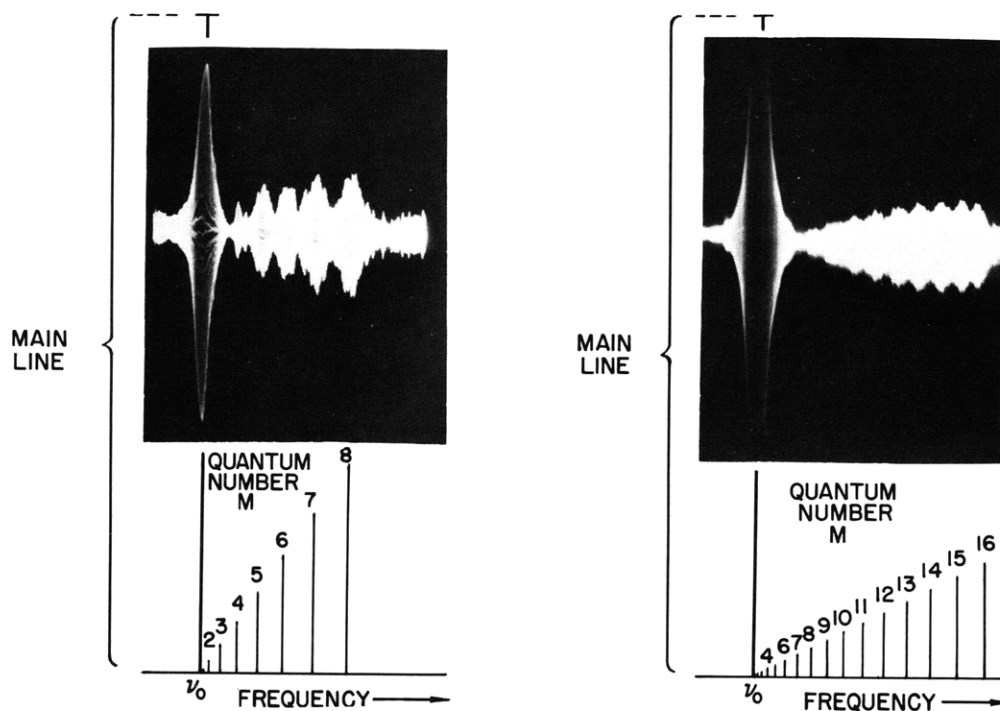
The study of this molecule is nearly completed. Calcium formate



Fig. V-1 Stark effect

(left) of $8_{2,7} \rightarrow 8_{2,6}$ line    (right) of $16_{3,14} \rightarrow 16_{3,13}$ line.

samples (B. P. Dailey) containing carbon 13 have allowed the isotopic molecule, $H_2C^{13}O^{16}$, to be studied.

As had been suspected by us, the unidentified line of Bragg and Sharbaugh has been proven to be due to the naturally occurring carbon 13 molecule. Data are being reduced at present to yield the structure of the molecule, the variations of dipole moment with rotational state and an empirical equation for the centrifugal distortion of the molecule. A sample of deuterated formaldehyde is also available, so work will start on this molecule to check the information derived from our present data.

Figures V-1 and V-2 show the observed Stark effect on two lines, and the measured and computed frequencies for the carbon 12 molecule, $H_2C^{12}O^{16}$.

R. B. Lawrance



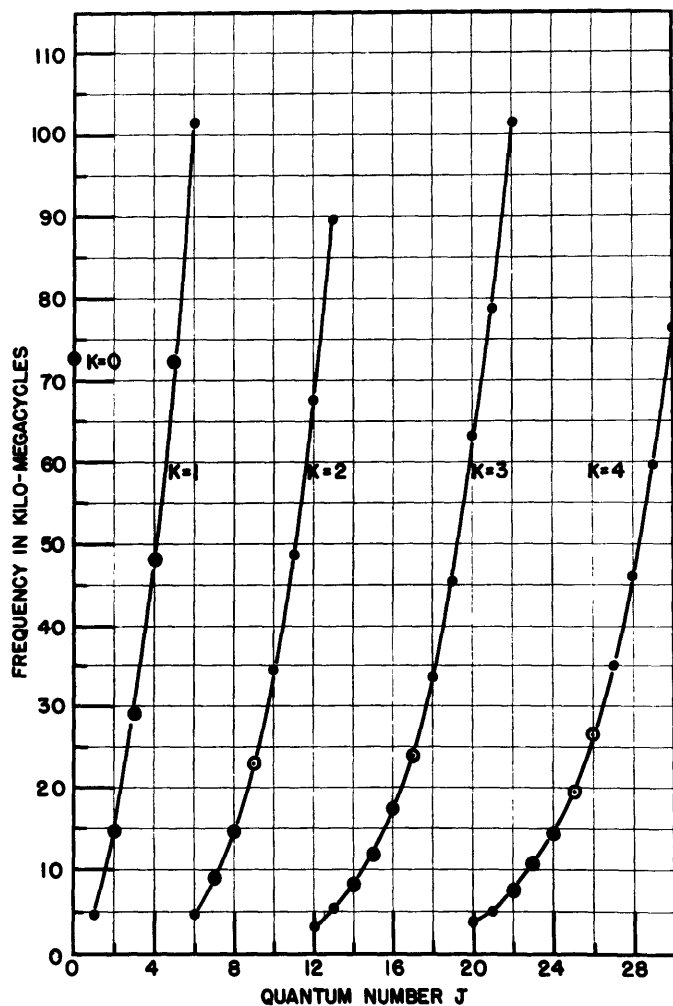Fig. V-2 Measured and computed frequencies for the carbon 12 molecule, $H_2C^{12}O^{16}$.

## 3. Oxygen

The method of detection and measurement briefly mentioned in the last

report has given distinctly encouraging results.

Radiation of a fixed frequency from a stabilized oscillator is passed through the absorption cell. A 30-cycle square wave magnetic field (0 to about 50 gauss) is applied at right angles to the direction of propagation of the wave. This causes the signal to be square-wave modulated on account of the difference in the magnitude and shape of absorption with and without a Zeemann field. The signal is detected and amplified at an intermediate frequency of 24 Mc/sec. This amplifier is followed by a 30-cycle lock-in amplifier, and the absorption variation is shown as a deflection on a d-c meter. The shape of the absorption line can be plotted from measurements at a number of frequencies differing by a few megacycles.

In this manner a number of absorption lines have been detected. Detailed but rough measurements on one of these lines gave the center frequency as about 59,162 Mc/sec and a line width of about 10 Mc/sec at 11 mm pressure. However the measurement was not accurate enough either to identify the transition or to estimate the line width as accurately as it is hoped eventually to do. (The accepted value of the line width seems to be about 600 Mc/sec at atmospheric pressure. Assuming the line width to be proportional to pressure, we should expect it to be about 9 Mc/sec at 11 mm.)

In order to save the labor of point-by-point plotting of the lines we are setting up a slow-sweep arrangement so as to vary the frequency of the stabilized oscillator continuously over a small range.

J. Ingersoll, B. V. Gokhale

### 4. Tellurium

The search for the molecular, rotational absorption spectrum of HDTe continues. A considerable portion of the microwave frequency range has been covered without much success. It is difficult to predict exactly where the lines may be located on a rigid rotor basis, because the molecule is quite asymmetric and zero-point vibration corrections to the mounts of inertia are large. However, two lines have been found that are attributed to the molecule HDS. Impurities of selenium and sulphur are always present in samples of tellurium and the lines as interpreted are believed to be due to these impurities. The lack of isotopic lines in the near vicinity of these lines seems to rule out selenium and tellurium. Verification was obtained with a chemically pure mixture of HDS, $H_2S$ and $D_2S$. One line was found at 27,566.31 Mc/sec and identified by its Stark pattern to be the transition $J = 7_{4,4} \rightarrow J = 7_{4,3}$. The very fact that the transition seems to

be $\triangle J = 0$ rules out the possibility of the line being due to $D_2S$ since by symmetry conditions this line is forbidden in $D_2S$. The other line was found at approximately 17,200 Mc/sec and has not been positively identified at this date. Dipole moment calculations agree with HDS data found in the literature.

Search will continue for the HDTe absorption line and work on HDS will be carried as far as possible.                                    R. E. Hillger

### 5. Methyl Stannane

The search for the $J = 1 \rightarrow J = 2$ rotational transition of methyl stannane ($CH_3S_nH_3$) has been temporarily delayed by the discovery of a rich spectrum of acetone lying in the same region of the frequency spectrum (27,000 − 29,000 Mc/sec) as the calculated transition frequencies of methyl stannane. These lines will be catalogued for reference and to tune up the spectroscope in the region of the methyl stannane spectrum. The acetone was inadvertently introduced into the waveguide when it was used to thin glyptol which was painted on a small leak. The waveguide cell is being altered to make unnecessary the use of glyptol seals, before continuing the search for methyl stannane.

The chemistry of methyl stannane has been done by Dr. B. P. Dailey. The sample now in hand appears from such physical characteristics as vapor pressure, boiling point etc. to be reasonably certain to contain a large percentage of methyl stannane.                                    C. C. Loomis

### 6. Apparatus

The slow-sweep system is now ready to operate, so tests of the scheme will be made in conjunction with already progressing work.

The hot-guide system to study absorption at elevated temperatures ($< 250°C$) has been operating satisfactorily for the past month. No successful studies have been made so far, but the lack of results has been due to the substances rather than the system operation.

A precision Stark cell has been constructed and measured, so that we should know the dimensions of the guide to $\pm$ 0.0001 inch under evacuated conditions. The accuracy of the guide will greatly enhance the accuracy of our dipole measurements. The guide has no dielectric material in the region of radio-frequency field, and transmits frequencies above 30,000 Mc vastly better than a conventional Stark guide with central system and polystyrene side supports.

Three standard spectroscopes have been constructed this summer. The

systems are convenient, standard, portable, and have a sensitivity of
$\alpha \simeq 10^{-8}$ cm$^{-1}$ with two meters of guide, and oscilloscope presentation.

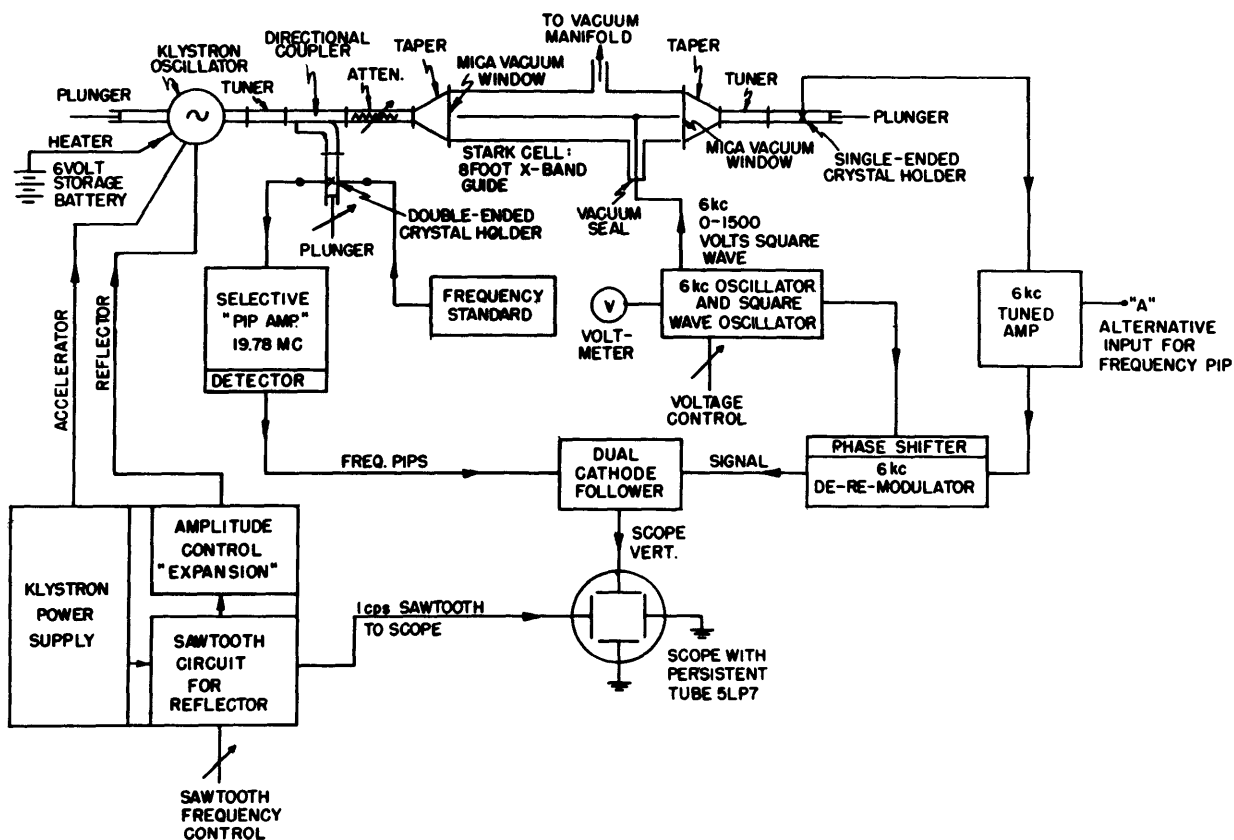Figure V-3 shows a block diagram of this standard apparatus.

J. R. Eshbach, M. T. Weiss

Fig. V-3  Microwave spectroscope.

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