Hydrogen chloride exhibits a transition of the first order at 98.4°K, which has been alternately interpreted either as a transition from hindered to free molecular rotation, or as a transition between ordered and disordered arrays of dipoles.[2] These experiments eliminate the former explanation in favor of the latter. Following the proton resonance from about 80°K to the melting point of hydrogen chloride at 159°K, a line width of roughly 10 gausses was observed. There was no appreciable change in this width at the transition point. A narrow line was observed only after the sample had melted.

In the case of natural rubber, samples of pale crepe, unloaded and unvulcanized, and a vulcanized sample, unloaded, gave proton resonance widths of 0.3 gauss at a resonant frequency of 30.5 Mc/sec. and at room temperature. Such narrow resonances have been identified with molecular rotation in liquids and in a few solids (e.g., CH_4). In view of the chain-like structure of the rubber molecule the interpretation of the narrow lines cannot be so direct. The effect is probably due to internal rotation of parts of the chain, i.e., hydrogen bonds, side methyl groups, or radicals.

The pale crepe natural rubber, unvulcanized and unloaded, was studied over a temperature range from 24°C to −75°C. Contrary to what might be expected, there was little or no apparent hindering of the internal free rotations at lower temperatures. That is, no change in the width or damping properties of the resonance was noted in the above temperature range. However, there was a drastic change in the amplitude of the resonance which decreased by about a factor of 10 over this range. The greatest change in amplitude occurred in the temperature interval from 24°C to 0°C. At liquid nitrogen temperature the narrow resonance was not visible. This behavior might indicate that at the lower temperatures there is a decrease in the number of atoms which are rotating, and as a result fewer nuclei find themselves in high frequency internuclear fields which essentially average out to zero.

The observation that this effect occurred gradually over the entire temperature range and was not yet complete at −75°C is surprising in view of dynamic Young's modulus measurements[3] on this same material by A. W. Nolle of the Acoustics Laboratory, M.I.T. Nolle found a relatively rapid transition in this quantity near −50°C. Also, the transition of rubber to its rigid form is generally assumed to be complete by −70°C.

A single sample of carbon-loaded natural rubber, unvulcanized, was investigated. The resulting resonance was more rapidly damped and slightly wider than for the unloaded sample, indicating the more hindered nature of the internal rotations in the loaded rubber. In addition, one unloaded sample and one carbon-loaded sample of Buna-N synthetic rubber showed broad resonances greater than 5 gausses in width. It may be remarked in this connection that the mechanical relaxation phenomena in Buna-N rubbers are appreciably slower than those in natural rubber.

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[1] F. Bitter, N. L. Alpert, H. L. Poss, C. G. Lehr, and S. T. Lin, Phys. Rev. **71**, 738 (1947).

[2] L. Tisza, Phys. Rev. **72**, 161A (1947).

[3] Private communication.

Saturation Effect in Microwave Spectrum of Ammonia*

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TOWNES[1] has reported the existence of a saturation effect in the microwave spectrum of ammonia. He observed that at low pressures the peak attenuation, γ, of the 3,3 line decreased with increase in power while the width of the line increased. Gordy and Kessler[2] have failed to confirm the broadening of the line. The present observations find no broadening of the line, but agree in magnitude of intensity saturation with Townes' results.

The total power absorbed at the center of the line was examined as a function of the power, P, fed into a 3.5-meter guide of 10.7×4.3-mm cross section. Starting with low powers, this peak absorbed power γP was observed first to increase linearly with input power (region of constant attenuation γ_0), then to increase more slowly (onset of saturation), and finally to approach a constant asymptote. At a line width of $2\Delta\nu=350$ kc, γP was observed to be constant within ±20 percent over a power range of 600 to 6000 microwatts, the high power limit of our observations. Similar plateaus were observed at other pressures, the low power end of the plateau varying in proportion to the pressure. Over each run at constant pressure the line width was observed to be independent of the input power within ±20 percent. The detectors were calibrated crystals, used in their approximately square-law range to minimize corrections.

If t is the average time between collisions, I the power in quanta per second per cm², and n_0 the number of molecules per cm³ in the ground state at thermal equilibrium, it may be shown that, if the line shape is constant,

$$I\gamma=(1-\gamma/\gamma_0)(n_0h\nu/2kTt).$$

At low powers γ approaches γ_0 while at high powers, where γ approaches zero, $I\gamma$ becomes constant in agreement with our observations. Our value of t measured near $\gamma/\gamma_0=\frac{1}{2}$ agrees with the value deduced from pressure broadening within 50 percent, the accuracy of the experiment. This observation is in agreement with Townes' conclusions.

In his theory, Townes apparently identified the rate, n_q, at which molecules make transitions because of the radiation present, with BI, where B is the Einstein coefficient of induced radiation, rather than with $BI(1-m/n)$, where m and n are the probabilities of the molecule in the upper and lower state, respectively. The latter identification leads to a time between radiative absorptions that approaches

a constant minimum value of the order of magnitude of $t(1+kT/h\nu)$, which is much greater than t and hence does not lead to a broadening of the line.

Irrespective of the details of the theory, it would seem that induced radiative transitions should not greatly broaden the line, as the time allowed for a measurement of the energy E of the system of (atom+radiation field of definite frequency) is the time t between molecular collisions and $\Delta E \cdot t = \hbar$, according to the Heisenberg uncertainty principle. At the time of measurement, the molecule may be in either an upper or lower state, differing by the definite amount $h\nu$, but either state uncertain in energy only to an amount $\hbar/t$. The line width, therefore, should not differ greatly from that given by theories of collision broadening.

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[1] C. H. Townes, Phys. Rev. **70**, 665 (1946).
[2] W. Gordy and M. Kessler, Phys. Rev. **71**, 640 (1947).

Radiations from K^{38}

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WE have made a preliminary investigation of the beta- and gamma-radiations emitted from K^{38}. Radioactive K^{38} has been investigated by Hurst and Walke[1]; Pool, Cork, and Thornton[2]; and Ridenour and Henderson.[3] Hurst and Walke, Ridenour and Henderson produced this activity by the action of alpha-particles on chlorine, while Pool, Cork, and Thornton produced it by fast neutrons. The period was found to be 7.5–7.6 minutes. Walke and Hurst found a beta-ray end point of 2.0 Mev, while Ridenour and Henderson found 2.3 Mev.

We have studied the radiations from K^{38} with a view to correlating the energy levels of A^{38} formed by positron emission with those of the same element formed by the negatron emission from Cl^{38}, as reported by Hole and Siegbahn.[4]

K^{38} was formed by bombarding LiCl with 23-Mev helium ions from the cyclotron. This was separated chemically by adding KNO_3 carrier and bringing down the potassium as potassium cobaltinitrite. The absorption of the positrons in aluminum was measured, and the range was found to be 1.20 g/cm², corresponding to an end point of 2.53 Mev. The period was found to be 7.5 min.

The substance was shown to emit gamma-rays. The absorption of the gamma-rays in lead showed a highly absorbable component corresponding to an energy of about 0.5 Mev, no doubt caused by annihilation radiation, and a more penetrating component, corresponding to an energy of 1.5–2.0 Mev. Since the lead absorption coefficient varies only slowly with energy in this region, we determined the energy of the most energetic gamma-ray by measuring the range of the Compton electrons from an aluminum radiator with the help of a coincidence counting set.[5] The range of the Compton secondaries corresponds to a gamma-ray whose energy lies between 2.0 and 2.15 Mev.

Hole and Siegbahn[4] have measured the gamma-rays associated with Cl^{38} which come from excited levels of A^{38}. These have been found to be 1.60 Mev and 2.15 Mev, and are in cascade, the 2.15-Mev ray coming from the first excited state to the ground state of A^{38}. Our measurement of the gamma-ray at 2.15 Mev associated with K^{38} shows that the 2.15-Mev state of A^{38} is excited by positron emission from K^{38} as well as by negatron emission from Cl^{38}. Work is continuing with a view to obtaining the complete disintegration scheme of K^{38}.

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[1] D. G. Hurst and H. Walke, Phys. Rev. **51**, 1033 (1937).
[2] M. L. Pool, J. M. Cork, and R. L. Thornton, Phys. Rev. **52**, 239 (1937).
[3] L. N. Ridenour and W. J. Henderson, Phys. Rev. **52**, 889 (1937).
[4] N. Hole and K. Siegbahn, Arkiv f. Mat, Astr. och Fysik, **33**, 1 (1946).
[5] A. C. G. Mitchell, L. M. Langer, and P. W. McDaniel, Phys. Rev. **57**, 1107 (1940).

On the Positively Charged Particles Accompanying the Beta-Rays of P^{32}

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IN the cloud chamber pictures of beta-ray tracks from radioactive sources such as Ra($B+C$), Th($C+C'+C''$), RaE, P^{32}, etc., a few tracks are often present because of positively charged particles.[1,2] The ratio of the number of positive particles to that of the ordinary decay electrons which has been found in this way by others ranges from 0.2×10^{-2} to 1×10^{-2}. But with the beta-ray spectrometer[3,4] this ratio was found only to be of the order of 10^{-4}.

We have recently taken about a thousand cloud chamber pictures of the beta-ray tracks of P^{32}. P^{32} was chosen in order to avoid the effect of gamma-rays. Since positive particles might be emitted by the source itself or created by the beta-rays, we took three series of pictures with the beta-rays filtered through materials of different thicknesses. In the first series the source was put in a thin-walled glass tube of thickness 0.01 g/cm², in the second we surrounded the thin-walled tube with an Al filter of thickness 0.11 g/cm², and in the third we used a source in a glass tube of thickness 0.09 g/cm². We chose filters of light elements in order to avoid the gamma-ray effect. The cloud chamber had a diameter of 8 inches. Air and ethyl alcohol vapor were used. The thin glass tube had a diameter of 1.1 mm and the thicker one and the Al filter had the same outer diameter of 2.1 mm, the length being about 4 cm. The radio-phosphorus in Na_2HPO_4 was deposited on the middle portion of the inner wall of the tubes, and the tube in each case was attached to the covering glass of the chamber. The magnetic field was about 360 gausses, and stereoscopic pictures were obtained by using two mirrors.

The result of our experiment is given in Table I.

Since tracks caused by negative particles moving towards the source might be mistaken for those of positive particles, the pictures are analyzed in the following way. (a) Both