Previous analyses by the charcoal adsorption method are also given in Table I and indicate no diffusive separation even in the case of bottles 32 and 45 which sampled in the vicinity of 65 km. These two and other V-2 samples, because of the location of the bottles in the rocket, were subject to possible contamination by rocket-borne ground air. On the other hand Aerobee instrumentations, particularly that of SC-17, were designed to prevent such contamination. A radioactive tracer technique used on one Aerobee showed contamination by trapped air to be less than 0.002 ±0.002 percent, and it is thought that the other Aerobee samples also were not contaminated.

The diffusive separation found in samples from SC-17 occurred in the 64- to 72-km range. According to recent measurements[8] this is a region of rapidly decreasing temperature. On this basis it would seem that this region would be characterized by considerable turbulence and mixing rather than by the quiescence necessary for the amount of diffusion separation measured in the SC-17 samples. This may indicate that for sufficient lengths of time there is a considerable departure from the temperature pattern reported over White Sands, New Mexico, or that air is moved in without mixing from a different latitude or a higher altitude where the temperature increases with increasing height.

Further measurements at 70 km and an extension of the methods to permit sampling and analysis of 100-km air are planned. A complete description of the apparatus and methods used to obtain the samples will soon be published. We are indebted to Professor Paneth for analyzing the samples and to the Signal Corps Engineering Laboratories for cooperation and financial support.

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[1] Van Allen, Fraser, and Floyd, Science 108, 746 (1948).
[2] Chackett, Paneth, Reasbeck, and Wiborg, "Variations in the chemical composition of stratosphere air" (to be published).
[3] Chackett, Paneth, and Wilson, J. Atmos. Terr. Phys. 1, 49 (1950).
[4] Progress Report No. 1, Engineering Research Institute, University of Michigan, Signal Corps Contract (January, 1951).
[5] Hagelbarger, Loh, Neill, Nichols, and Wenzel, Phys. Rev. 82, 107 (1951).
[6] Final Progress Report, Engineering Research Institute, University of Michigan, Signal Corps Contract (October, 1950).
[7] Hagelbarger, Neill, Nichols, and Wenzel, "Remote opening and sealing of metal tubes by soldering and by cold welding" (to be published).
[8] Best, Havens, and LaGow, Phys. Rev. 71, 915 (1947). Also Havens, Koll, and LaGow, *Pressures and Temperatures in the Earth's Upper Atmosphere* (Naval Research Laboratory Report, Washington, D. C., March, 1950).
[9] J. H. McQueen, Phys. Rev. 80, 100 (1951).

The Gamma-Ray Spectra of K^{38} and Cl^{34}*

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By means of a scintillation γ-ray spectrometer[1] some preliminary results on the energies of the γ-rays of Cl^{34} (33 min)[2] and K^{38} (7.5 min)[3] have been obtained. The activities were produced by (p, pn) reactions on bombardment of NaCl and KI by 18-Mev protons from the U.C.L.A. fm cyclotron.

Three NaI(Th) crystals were mounted in a straight line and 5.6 cm apart, directly on the faces of three 5819 photomultipliers. The output pulses of the center 5819 were clipped, amplified, and applied to the deflecting plates of a specially constructed high stability oscilloscope. The sweep and intensity could be triggered by this same pulse (1-crystal operation)[1] by a twofold coincidence of the center 5819 and either of the outer ones (2-crystal operation)[4] or by a coincidence of pulses from all three counters (3-crystal operation). The pattern on the scope screen was photographed. Calibration by means of artificial pulses demonstrated that the electronic system was linear to ±1 percent.

For γ-ray energy determinations, the apparatus was always calibrated with the 1.28-Mev γ-ray of Na^{22}. The photopeak to pair-peak distance also served as an independent $2m_0c^2$ standard.

Figure 1 shows the 1-crystal spectrum of K^{38} between two Na^{22} spectra. Small pulses were rejected by an integral discriminator.

FIG. 1. γ-ray spectrum of K^{38} between two γ-ray spectra of Na^{22} used for calibration. The gain for K^{38} was reduced by 1.96 relative to the gain for Na^{22}.

On the Na^{22} spectrum the annihilation photoline, and the photoline and Compton distribution of the 1.28-Mev γ-ray are easily identified. For the K^{38} spectrum, the gain of the linear amplifier was reduced by a factor of 1.96. The features of this pattern are interpreted as photoline, pair-line, and Compton distribution of a single γ-ray of 2.16±0.03 Mev.

The 1-crystal spectrum of Cl^{34} was not well suited for energy determinations. The photoline of a high energy γ-ray is easily located and the corresponding energy is 3.22±0.03 Mev, in good agreement with previous results.[2] However, the photoline and the

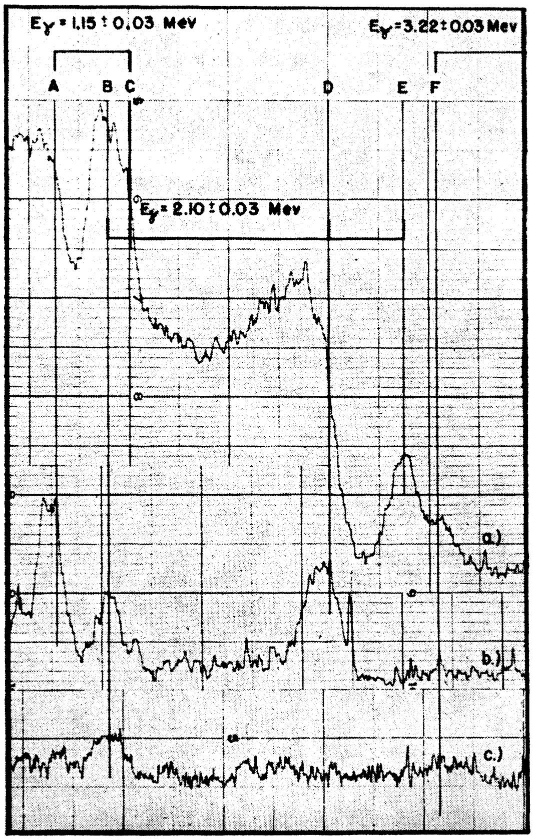

FIG. 2. Microdensitometer trace of Cl^{34} spectrum in the energy region 1–2.5 Mev. (a) 1-crystal operation, (b) 2-crystal operation with second crystal at 135° with respect to incident γ-ray beam. (c) 3-crystal operation.

pair-lines of the second γ-ray overlap the pair-line of the 3.22-Mev γ-ray and the photoline of a third γ-ray, respectively. The microdensitometer trace of the energy region in question is shown in Fig. 2, top. The unresolved doublets are in the region *BC* and *EF*. The next lower trace resulted from 2-crystal operation when the second crystal was oriented such that the line joining the crystals was at 135° with respect to the incident γ-ray beam. Using this trace, the pair-line of the second γ-ray was found at *B*; the γ-ray has an energy of 2.10±0.03 Mev, and its photoline and "135° edge" should be located at *E* and *D*, respectively. It will be noticed that the calculated line *D* does not pass through the center of the 2-crystal Compton line: this is because the recoil electron energy changes very slowly with scattering angle beyond 135°. Using this information, line *A* was drawn for the "135° edge" of the third γ-ray whose energy is then computed to be 1.16±0.03 Mev. The photoline of this γ-ray should lie at *C*. The bottom trace of Fig. 2 results on 3-crystal operation; only the pair-lines of the 3.22- and 2.10-Mev γ-rays remain.

It is a pleasure to thank Professor J. R. Richardson for much helpful advice in the course of this experiment.

* This work was assisted by the joint program of the ONR and AEC.

[1] R. Hofstadter and J. A. McIntyre, Phys. Rev. **80**, 631 (1950). The author is also indebted to Dr. Hofstadter for many helpful suggestions.

[2] L. Ruby and J. R. Richardson, Phys. Rev. **80**, 760 (1950).

[3] Ramsey, Meem, and Mitchell, Phys. Rev. **72**, 639 (1947).

[4] R. Hofstadter and J. A. McIntyre, Phys. Rev. **78**, 619 (1950).

Paramagnetic Resonance in Liquids*

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PARAMAGNETIC resonance absorption in solutions containing Mn^{++} ions has been observed in solutions sufficiently dilute for the hyperfine structure (hfs) to be easily observed. These solutions are as much as 100 times as dilute as those reported by Halliday and Wheatley,[1] in which no hfs was observable, and are about the same concentrations as those observed by England and Schneider.[2] The microwave apparatus used included a Pound stabilized oscillator, 6 kc/sec crystal modulator, magic Tee, and rectangular cavity (TE_{012} mode). The magnetic field was swept through the resonance region with a period of about 7 seconds. Figure 1 is an example of the observed absorption spectrum.

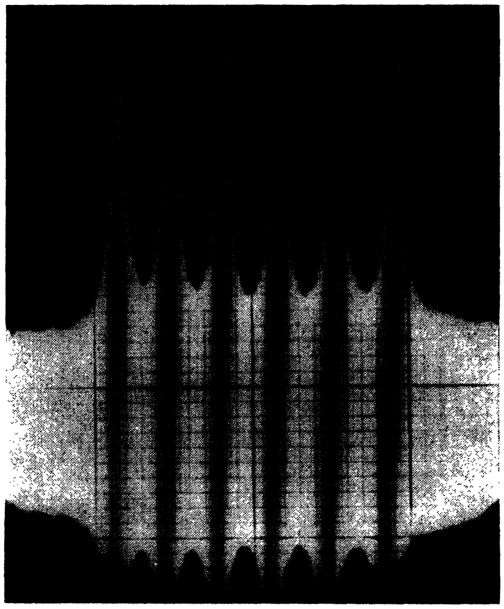


FIG. 1. Absorption spectrum of 0.15*M* $MnCl_2$ solution at 80°C.

All observable structure is explained by the simple Hamiltonian

$$\mathcal{H}=g\beta\mathbf{H}\cdot\mathbf{S}+A\mathbf{I}\cdot\mathbf{S},$$

where g is the g value of a free electron. The Hamiltonian given by Bleaney and Ingram[3] for the Mn^{++} ion in crystals reduces to this form if spherical symmetry is assumed. It predicts absorption lines ($M\leftrightarrow M-1$) when

$$H=\frac{h\nu}{g\beta}-Am-\frac{A^2}{2}\frac{g\beta}{h\nu}\left[\frac{35}{4}-m^2+m(2M-1)\right]\quad \begin{array}{l} m=-5/2,\cdots,5/2 \\ M=-3/2,\cdots,5/2. \end{array}$$

The term in $(2M-1)$ gives only a broadening, with no shift of the center of each of the hfs lines. The observed lines fit this form with

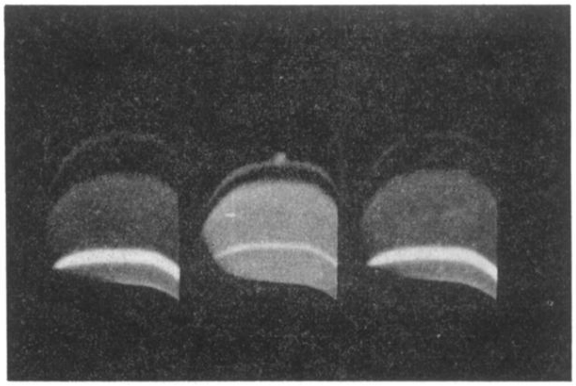
$$g=2.001\pm0.001 \quad \text{and} \quad A=95 \text{ gauss}.$$

The g value was established by comparison with an organic radical mounted directly on the sample capillary, and the distances of the 6hfs lines from this reference were determined by use of a sychronous flip coil.[4] This observed g value is within experimental error of the free electron value, the values obtained by Bleaney and Ingram in two dilute manganese salts, the value obtained by England and Schneider for Mn^{++} activators in a ZnS phosphor,[5] and their value for Mn^{++} ions in solution. The A value differs markedly from the 68 gauss obtained by England and Schneider for the phosphor, but not so strongly from the approximately 100 gauss obtained by Bleaney and Ingram and the 98 gauss given by England and Schneider for solutions. These differences indicate that the strength of the configurational interaction which produces the hfs depends on the ionic environment more strongly than might have been anticipated.

Line widths have been inferred from the ratio of the depth of the valley between lines to the height of one line, using the assumption of a Lorentz line shape. These widths have been interpreted in terms of electric and magnetic perturbations produced on the absorbing ion by its ionic neighbors and by the sheath of water molecules surrounding it. These perturbations broaden the energy levels in two general ways: by causing small randomly distributed shifts in the positions of the levels and by shortening the lifetimes by inducing transitions. To get a quantitative dependence on temperature, the random Brownian motion is decomposed into a noise spectrum,[6] the intensity of which depends on frequency by the factor $\tau_c/1+\omega^2\tau_c^2$, where τ_c is the "correlation time" of the random motion. The first general mechanism is produced by electric and magnetic fields with frequency components ω small compared to the frequency width of the line; that is, by fields which do not "average out" over the lifetime of a state. Thus the noise factor approximately reduces to τ_c, and this contribution to line width increases with τ_c. The second mechanism acts through components near the Larmor frequency. With X-band frequencies, this makes $\omega\tau_c>1$, causing this contribution to depend approximately on $1/\omega^2\tau_c$. Since τ_c is proportional to η/T, where η is the viscosity, it turns out that the line width W between half-maximum points for a given sample should be approximately expressible in the form

$$W=C_1/(\eta/T)+C_2[W(\eta/T)]^{\frac{1}{2}}.$$

The coefficients C_1 and C_2 depend on the nature and concentration of the ions in solution, and may be approximately fairly well by linear combinations of these concentrations. Figure 2 shows the experimental results for samples containing various concentrations of $MnCl_2$ and $CaCl_2$ solutions. These results fit curves of the above form as well as expected in view of the number of approximations involved. For example, the approximation of $\tan^{-1} 2\tau_c/\tau$ by $2\tau_c/\tau$ eliminates the observed leveling off at large τ_c. By holding total ionic strength constant in three of these runs, the effect of the magnetic ions is largely isolated. It should be noted that with dilute solutions and high temperatures the width can be reduced



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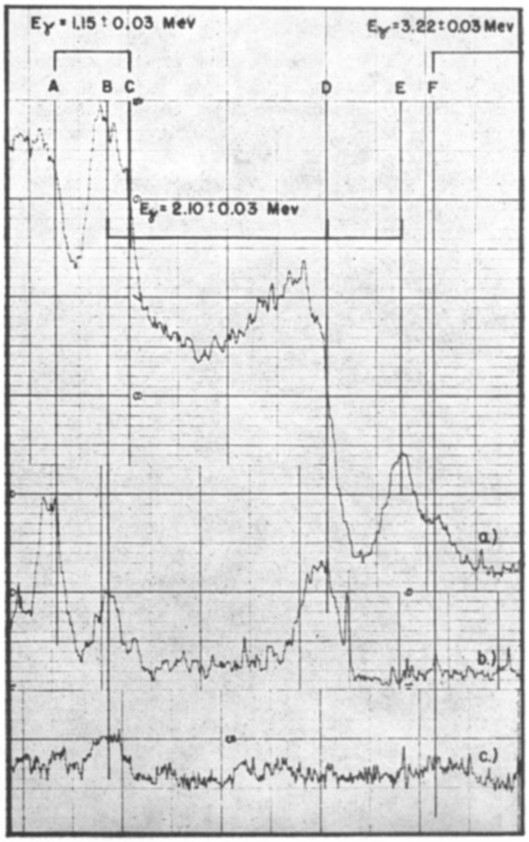

FIG. 2. Microdensitometer trace of Cl^{34} spectrum in the energy region 1–2.5 Mev. (a) 1-crystal operation, (b) 2-crystal operation with second crystal at 135° with respect to incident γ-ray beam. (c) 3-crystal operation.