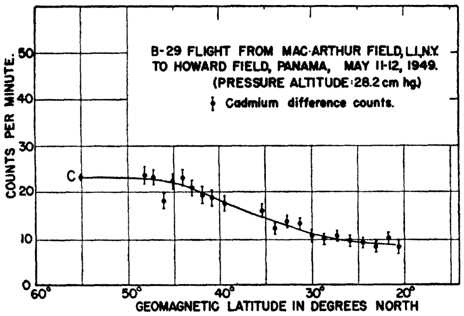

FIG. 2. Cadmium difference counts as a function of geomagnetic latitude.

Long Island, New York (geomagnetic latitude 52°N) to Tampa, Florida (38°30′N) and then to Howard Field, Panama (20°42′N). The altitude of the flight was maintained at 25,000 throughout the entire flight. Readings were taken every 10 minutes and the mean counting rates were plotted as a function of the geomagnetic latitude. The top curve shows the counting rates obtained in the tin-shielded counter and the lower curve those obtained in the cadmium-shielded one. The points A and B are the more accurate measurements obtained from constant latitude flights at Rome, New York (55°8′N). Figure 2 shows the cadmium difference counts plotted similarly to Fig. 1. Point C is a more accurate value of the cadmium difference value obtained at Rome, New York. There seems to be a knee at about 47°N for the slow neutron latitude curve. The ratio of the neutron intensities

$$n(55°\mathrm{N})/n(20°\mathrm{N}) = 2.9$$

at the altitude of 25,000 feet (28.2 cm Hg pressure altitude). These results agree well with those obtained by Simpson *et al.*[3]

As described in another paper,[4] the effective response cross section for the counter used in this experiment was determined to be 10.6 cm² and the air mass equivalent thus calculated is 52.0 g of air.

The absolute number, s, of slow neutrons absorbed in one g of air per minute at any latitude, can be obtained simply by dividing the air mass equivalent for this counter into the appropriate counting rates given in Fig. 2.

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On the Measurement of Slow Neutrons in the Cosmic Radiation on a B-29 Plane*

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OUR first extensive measurements of the cosmic-ray neutron intensities at medium high altitudes (around 30,000 ft.) were made in 1947, and a preliminary report of these results was given.[1] In this experiment, two identical proportional counters filled with enriched boron trifluoride, one bare and one shielded with cadmium, were installed in the navigator's cabin (the front pressurized compartment) of the plane. In spite of the good agreement between our results on the absorption depth, λ, $(N=N_0\exp(-x/\lambda))$ and that obtained by Agnew, Bright, and Froman,[2] Simpson,[3] and Yuan (balloon measurements),[4] the cadmium difference counts thus obtained were much higher than the free-space measurements carried out by means of free balloons. Tests were made during flight, but no appreciable effect on the slow neutron intensity was found that could be attributed to the gasoline tanks in the wings of the plane. Further tests on the possible influence of other materials present inside the cabin, such as Kapok insulation, etc., also proved to be negligible.

Since the measurements of Agnew *et al.* were made at the tail end of a B-29 plane and their cadmium ratio was considerably lower than ours, it seemed necessary to check our measurements at the tail section which unfortunately was unavailable to us at the time of the first experiment. Consequently, more recent results[5] were obtained by installing the counters in the pressurized cabin of the tail gunner's compartment of a B-29 plane. All hydrogeneous material and heavy equipment were removed from the cabin and its vicinity to reduce as much as possible the effect of the airplane surroundings on the counters. High voltage supplies as well as electronic equipment were installed at least 30 feet away from the counters and they were fed via long cables. The results thus obtained agree very well in their absolute values with the free-space measurements.[4] For example: At 20.1-cm Hg pressure, the cadmium difference counting rate obtained in Rome, New York (geomagnetic latitude 55°8′ N) on a B-29 plane was 44.3 ± 0.7 counts per minute; and that obtained in Princeton (geomagnetic latitude 51°46′ N) on free balloons was 42 ± 4 counts per minute after taking into account the respective air mass equivalent of the counters.[4]

From these results and from the fact that the nose wheel of the plane, when folded up during flight, was actually less than one foot away from the counters placed in the navigator's cabin, it seems to point to the massive rubber tire of the nose wheel as the probable source of excessive slow neutrons obtained in the earlier B-29 measurements. Presumably, a considerable fraction of fast neutrons in the atmosphere was slowed down by the rubber and was consequently detected by the slow neutron counters.

Since the measurements at the tail of a B-29 agree well with the free-space measurements, we may thus conclude that absolute measurement of the slow neutron intensities in the cosmic radiation can be justifiably made in the tail gunner's compartment of a B-29 plane with proper precautions.

The author wishes to thank Professor R. Ladenburg for suggesting this paper for the purpose of calling the attention of other workers who are interested in making absolute measurements of cosmic-ray neutrons on a B-29 plane.

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A Theory of Pressure Absorption

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SYMMETRICAL diatomic molecules, such as H_2, O_2, N_2, have no dipole moment both in static and vibrating states, so they are not expected to have infra-red absorption due to vibration and rotation. But recently Herzberg[1] succeeded in obtaining a very weak absorption line in the near infra-red with H_2 gas, which is, according to his view, the quadrupole absorption. After that, Crawford, Welsh, and Locke[2] obtained the infra-red absorption with O_2 and N_2 at 1556 and 2331 cm^{-1}, respectively. When they changed the pressure of the gases, they found that the absorption intensity is proportional to the square of the pressure, so they suggested that these absorptions are induced by intermolecular forces. In this note a theoretical formula for the absorption of the latter kind is given.

When a molecule is under an electrostatic field $\mathbf{E}$ and a radiation field $\mathbf{E}_r \cos\omega t$, the perturbation Hamiltonian which makes the molecule absorb light quanta is $\boldsymbol{\mu}(\mathbf{E}+\mathbf{E}_r\cos\omega t)$, where $\boldsymbol{\mu}$ is the dipole moment of this molecule. In our problem, the external field $\mathbf{E}$ is due to the molecules surrounding the one under consideration. Thus, if the ith molecule has dipole moment $\boldsymbol{\mu}_i$ and quadrupole moment $\mathbf{Q}_i$ (which is represented by $Q_{zz}=2P$ and $Q_{xx}=Q_{yy}=-P$ for the above type molecules), and is at a distance $\mathbf{R}_i$ from the central molecule, then

$$\mathbf{E}=\sum_i \mathbf{E}_i=\sum_i\left\{\frac{2\mu_i\cos\theta_i}{R_i^4}+\frac{3P_i(3\cos^2\theta_i-1)}{2R_i^5}+\cdots\right\}\mathbf{R}_i, \quad (1)$$

where θ_i is the angle between $\mathbf{R}_i$ and the axis of ith molecule.

If ψ_i is the wave function of ith molecule, the absorption coefficient of the transition $\psi_0\rightarrow\psi_0^*$ at the resonance frequency ν is

$$\frac{8\pi^3\nu}{3hc}\left\{\sum_{**}\frac{\left(\int\psi_0\cdots\psi_N\boldsymbol{\mu}_0\mathbf{E}\psi_0^{**}\cdots\psi_N d\tau\right)\times\left(\int\psi_0^{**}\cdots\psi_N\boldsymbol{\mu}_0\psi_0^{*}\cdots\psi_N d\tau\right)}{W_0-W_0^{**}}\right\}^2 n$$

$$=\frac{8\pi^3\nu}{3hc}\left\{\sum_{**}\frac{\int\psi_0\boldsymbol{\mu}_0\psi_0^{**}d\tau'\int\psi_0^{**}\boldsymbol{\mu}_0\psi_0^{*}d\tau'}{W_0-W_0^{**}}\right\}^2 \times\left(\int\psi_1\cdots\psi_N\mathbf{E}\psi_1\cdots\psi_N d\tau''\right)^2 n$$

$$=\frac{8\pi^3\nu}{3hc}\left(\int\psi_0\boldsymbol{\alpha}\psi_0^{*}d\tau'\right)^2\left\{\sum_i\left[\frac{2\bar{\mu}_i\cos\theta_i}{R_i^4}+\frac{3\bar{P}_i(3\cos^2\theta_i-1)}{2R_i^5}+\cdots\right]\mathbf{R}_i\right\}^2 n, \quad (2)$$

where $\boldsymbol{\alpha}$ is the polarizability tensor, and n is the number of molecules in unit volume. It must be remembered that only the diagonal elements (permanent moments) $\bar{\mu}_i$ and $\bar{P}_i$ appear in (2). The matrix elements of $\boldsymbol{\alpha}$ have already been obtained.[3]

We will calculate the sum of $\mathbf{E}_i$, assuming the so-called statistical theory.[4] When the molecules are randomly distributed, the $\mathbf{E}_i$'s are also spherically distributed. To sum these electric field vectors is equivalent to searching for the position of a Brownian particle whose unit displacement is spherically distributed. The solution of the latter problem is obtained by Markoff's method;[5] thus, the probability that the summed field has an absolute value between E and $E+dE$ is given by the formula

$$W(E)dE=\frac{4\pi\exp(-3E^2/2\langle\Sigma_i E_i^2\rangle)}{(2\pi\langle\Sigma_i E_i^2\rangle/3)^{\frac{3}{2}}}E^2dE, \quad (3)$$

where $\langle\Sigma_i E_i^2\rangle$ is the average of $\Sigma_i E_i^2$, which is

$$\langle\Sigma_i E_i^2\rangle=\int_{R_0}^{\infty}\int_0^{\pi}\left\{\frac{2\bar{\mu}\cos\theta}{R^3}+\frac{3\bar{P}(3\cos^2\theta-1)}{2R^4}+\cdots\right\}^2\times 2\pi\sin\theta d\theta R^2dRn$$

$$=4\pi n\left\{\frac{4\bar{\mu}^2}{9R_0^3}+\frac{9\bar{P}^2}{25R_0^5}+\cdots\right\}. \quad (4)$$

The absorption coefficient of gas is

$$\frac{8\pi^3\nu}{3hc}\left(\int\psi_0\boldsymbol{\alpha}\psi_0^{*}d\tau'\right)^2\int_0^{\infty}E^2W(E)dEn =\frac{16\pi^3\nu}{3hc}\left(\int\psi_0\boldsymbol{\alpha}\psi_0^{*}d\tau'\right)^2\langle\Sigma_i E_i^2\rangle n. \quad (5)$$

For the Q-branch of symmetric diatomic molecules at room temperature this formula is reduced to

$$\frac{192\pi^4\nu n^2}{25hcR_0^5}\bar{P}^2\left(\beta^2+\frac{11}{30}\gamma^2\right), \quad (6)$$

where

$$\beta=\int\psi\tfrac{1}{3}(\alpha_{xx}+\alpha_{yy}+\alpha_{zz})\psi^{*}d\tau,$$

$$\gamma=\int\psi(\alpha_{zz}-\alpha_{xx})\psi^{*}d\tau.$$

In the paper of Crawford, Welsh, and Locke,[2] the intensity curve for the vibration line of O_2 near 1556 cm^{-1} is given, from which the absorption coefficient of the Q-branch is calculated to be 4.0×10^8 cm^{-1} sec.$^{-1}$ at 1 atmos.

In this case, n is 2.72×10^{19} cm^{-3}, R_0 may be considered to be equal to twice the interatomic distance of O_2, thus $R_0=2.4$A. For $\bar{P}$, there are no experimental data, but, from the curve of Lassettre and Dean,[6] we can estimate it to be 3.4×10^{-26} cm^2. In order to explain the experimental result with these values, $\beta^2+(11/30)\gamma^2$ must be 2.1×10^{-50} cm^4. Although no direct measurements of the latter exist, at least the order of this value is certainly valid. (An estimation with classical model yields 6.6×10^{-50} cm^4 for it.) Thus we may consider that the experimental result was explained by our formula (6).

By (6) we can estimate the contribution of the pressure absorption in the Herzberg's experiment.[1]

If we assume that the change of P during the vibration is nearly equal to $\bar{P}$ in the static state, the proportion of quadrupole absorption to pressure absorption is about

$$1:\frac{n}{R_0^5}\left(\beta^2+\frac{11}{30}\gamma^2\right)\doteqdot 1:10^{10}$$

at 10 atmos. (his experimental condition); thus the pressure absorption is predominant.

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Experimental Study of the Compton Effect at 1.2 Mev

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SINCE the Compton effect represents one of the most fundamental interactions between radiation and matter, it is desirable that the theory be compared carefully with experiment. The angular distribution of the scattered gamma-rays has been predicted by Klein and Nishina,[1] and while it is true that the total cross sections have been well checked by many investigators,[2] search of the literature reveals that angular distribution studies have been relatively neglected. Angular investigations in the x-ray region show reasonably good agreement with theory,[3] and Chao,

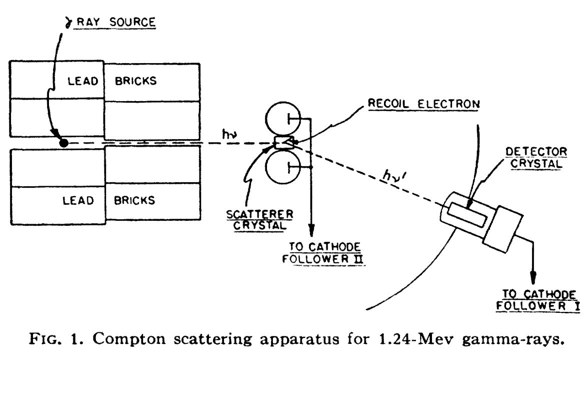

FIG. 1. Compton scattering apparatus for 1.24-Mev gamma-rays.