netic field and neglecting perturbations due to neighboring levels,

$$\mathcal{H}=a\frac{K}{2}+b'\frac{(3/8)K(K+1)-(1/2)I(I+1)J(J+1)}{I(2I-1)J(2J-1)},$$

where $K=F(F+1)-J(J+1)-I(I+1)$. The first term gives the dipole-dipole interaction between the nucleus and the electrons, and the second term gives the interaction between the electric quadrupole moment of the nucleus and the gradient of the electric field at the nucleus due to the electrons. In terms of the interaction constants a and b', the hyperfine separations are

$$\Delta\nu(F=4-F=3)=4a+(4/5)b',$$
$$\Delta\nu(F=3-F=2)=3a-(9/20)b',$$
$$\Delta\nu(F=2-F=1)=2a-(4/5)b'.$$

From these relations and the observed separations, the constants a and b' are found to be

$$a=94.27\pm0.04 \text{ megacycles per second},$$
$$b'=18.66\pm0.25 \text{ megacycles per second}.$$

Following the method of Davis, Feld, Zabel, and Zacharias,[2] we find the quadrupole moment of the nucleus to be

$$Q=+(0.156\pm0.003)10^{-24}\text{ cm}^2.$$

The perturbation of the $F=3$ and $F=2$ levels by the corresponding levels of the ground $^2P_{\frac{1}{2}}$ term can be shown to be too small by a factor of a hundred to account for the observed deviation from the interval rule of the hyperfine separations of the metastable state.

In the identification of aluminum as the substance on which the above measurements have been made, primary dependence has been placed on the mass spectrograph. Using the positions of Na^{23} and K^{39} as the reference points, the peak of the substance studied occurs at mass number 27 and does not occur at mass number 54. At mass numbers 26 and 28, the only particles observed are those due to scattering. Further confirmation is afforded by the fact that a rough determination of the hyperfine separation of the ground state yields $\Delta\nu=1500\pm50$ mc/sec., which overlaps the spectroscopic value of 1440 ± 30 mc/sec. found by Jackson and Kuhn.[4]

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the Office of Naval Research.

[1] Jerrold R. Zacharias, Phys. Rev. **61**, 270 (1942).
[2] L. Davis, Jr., B. T. Feld, C. W. Zabel, and J. R. Zacharias, Phys. Rev. **73**, 525(L) (1948).
[3] James S. Allen, Rev. Sci. Inst. **18**, 739 (1947).
[4] S. Millman and P. Kusch, Phys. Rev. **56**, 303 (1939); M. Heyden and R. Ritschl, Zeits. f. Physik **108**, 739 (1938); Jackson and Kuhn, Proc. Roy. Soc. **A164**, 48 (1938).

Light Scattering in Supersonic Streams*

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September 30, 1948

In a previous note[1] experiments were briefly described in which light was scattered from a supersonic free stream of dried dust-free air. The observed light scattering by various regions of the stream was interpreted by the well-known theory of light scattering[2] as indicating density variations in the respective regions. In extending these light scattering experiments it has been found that in addition to density variations in the supersonic stream itself a number of other phenomena connected with supersonic streams or jets may contribute to the observed light scattering. Under certain special conditions the intensity of the light scattered due to the density variations alone is small in comparison to the other scattering so the various phenomena therefore may be studied.

If dried dust-free air at a pressure, say, of 70 lb./in.[2] (gauge) is allowed to expand through a de Laval nozzle into the ordinary atmosphere containing moisture, and a beam of parallel light is directed perpendicularly through the resulting supersonic stream, very intense light scattering is observed where the supersonic stream or free jet mixes with the atmosphere, i.e., along the boundary of the stream the amount of light scattering is many times greater than that which can be accounted for by density variations alone.

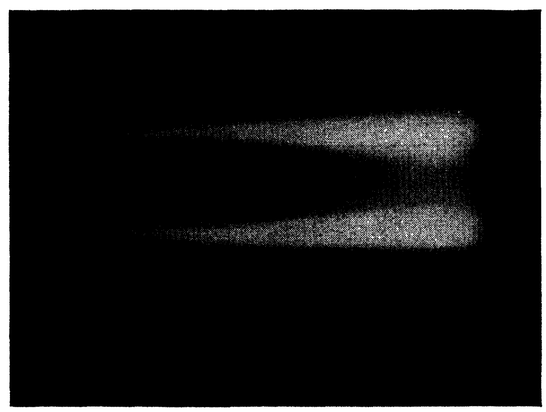

FIG. 1. Photograph of light scattered from a one-inch supersonic cylindrical jet emerging into the undried atmosphere.

However, if the atmosphere into which the supersonic stream expands is carefully dried, the amount of light scattering is very greatly reduced. It is believed that the intense scattered light is due to small water droplets formed by the mixing of the cold supersonic stream with the undried air of the atmosphere. If this is the case, the light scattering caused by the small droplets gives an outline of the mixing region around the supersonic stream as well as an indication of the magnitude of the mixing. Also since the size of the droplets can be determined by the relative amount, color, polarization, etc., of the scattered light, the heat transfer from the stream may be studied by observing the growth of the droplets. Clearly if a small amount of another condensible vapor is substituted for the water vapor in the atmosphere, the rate of growth of droplets other than water can be studied. Figure 1 shows a photograph taken of scattered light from a one-inch supersonic cylindrical jet Mach No. about 1.8 emerging into the undried atmosphere. The stream was illuminated by a beam

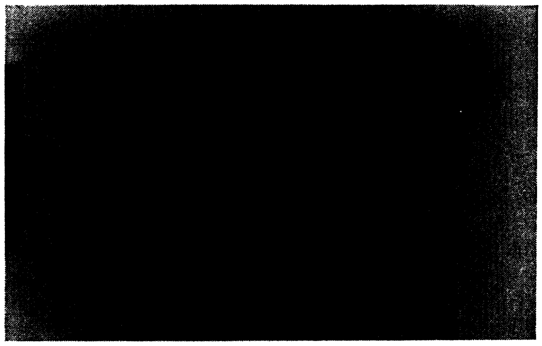

Fig. 2. Short spark shadowgraph of a supersonic jet taken under conditions similar to those of Fig. 1.

of sunlight with rectangular cross section $\frac{3}{8}$ inch wide and 3.5 inches long with the 3.5-inch dimension parallel to the stream. The plane of the beam passed through the axis of the stream. The photograph is a snapshot taken perpendicular to both the stream and incident light. For comparison, Fig. 2 shows a short spark shadowgraph[3] taken under approximately the same conditions. The thickening of the mixing boundary layer of the stream is shown as it extends into the atmosphere.

* This work was supported by Contract NOrd-7873 with the Bureau of Ordnance of the Navy.

[1] McQueen, Beams, and Snoddy, Phys. Rev. **73**, 260 (1948).

[2] See Bhagavantam, *Scattering of Light and Raman Effect.*

[3] Beams, Kuhlthau, Lapsley, McQueen, Snoddy, and Whitehead, J. Opt. Soc. Am. **37**, 868 (1947).

Gamma-Rays from the Reaction $H^1(n, \gamma)D^2$ and the Binding Energy of the Deuteron

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October 5, 1948

The γ-ray accompanying the capture of a neutron by a proton has been studied in a magnetic lens β-ray spectrometer by photoelectric conversion in a thin U radiator.

The γ-rays were produced in a slab of pure paraffin 5″×25″×25″ placed in the thermal column of the Chalk River pile. A Pb collimator limited the γ-rays to a solid angle having the shape of a thin conical shell of 15° half-angle, converging to a small region outside the thermal column at the end of the β-ray spectrometer. A boron shield prevented the escape of neutrons from the thermal column. By placing a radiator in the γ-ray flux at the end of the β-ray spectrometer, secondary electrons ejected by the γ-rays could be studied. Figure 1 shows the momentum distribution of the photoelectrons and Compton recoil electrons ejected from a U radiator of 142 mg/cm². The counting rate taken with a spectrometer line width of 2.4 percent in momentum is plotted as a function of the focusing current in the lens coil, which is an accurate relative measure of the electron momentum. The effect due to the γ-rays from the paraffin is superposed on a background due to the γ-rays from the graphite in the thermal column. This background is constant over the energy range of this experiment. The peak at 4.800 amp. is due to photoelectrons ejected from the *K*-shell of U by the γ-rays from the paraffin. The general shape of the Compton background taken with a brass radiator is shown in this region as a broken line. The γ-ray energy deduced from the position of the photoelectron line is 2.236±0.005 Mev, using the ThC″ 2.620-Mev γ-ray as a standard to calibrate the spectrometer. The position of the paraffin γ-ray photoelectron line was determined accurately relative to the standard γ-ray photoelectron line by placing a source containing ThC″ in the Pb collimator behind the radiator and

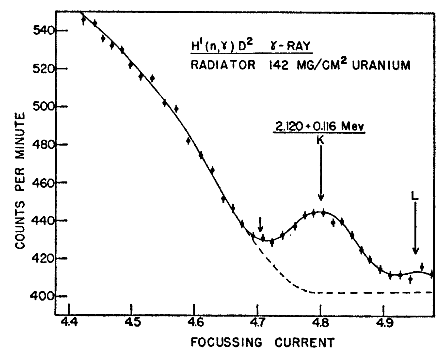

Fig. 1. The momentum distribution of the secondary electrons ejected from a U radiator. The standard deviations of the experimental points are indicated by vertical bars.

carefully determining the position of each line without any change in the arrangement of the apparatus. Any error due to the effect of finite radiator thickness is small because the paraffin γ-ray is close to the standard γ-ray in energy, and is further reduced by calculating the relative position of the two photoelectron lines from their high energy edges.

By adding the nuclear recoil energy to the above γ-ray energy, we obtain 2.237±0.005 Mev for the binding energy of the deuteron, using the ThC″ 2.620-Mev γ-ray as standard. This is surprisingly different from the previously accepted value of the deuteron binding energy.[1] The magnitude of the discrepancy is illustrated in Fig. 1 by the small arrow at 4.704 amp., marking the position the photoelectron peak would occupy were the deuteron binding energy as low as the previously accepted value. As a further check the ThC″ source was replaced by a Ra source and the RaC 2.198-Mev γ-ray was shown to have an energy about 1.5 percent lower than that of the paraffin γ-ray. This precludes the disintegration of the deuteron by that particular γ-ray of RaC and invalidates Kimura's[2] argument leading to a low value of the deuteron binding energy. The low value quoted by Myers and Van Atta[3] could be due either to voltage instability in the electrostatic generator or to non-linearity of the generating voltmeter calibration.

Taking the $H^1H^1-D^2$ separation[4] as 1.433±0.002 Mev together with the value of the deuteron binding energy

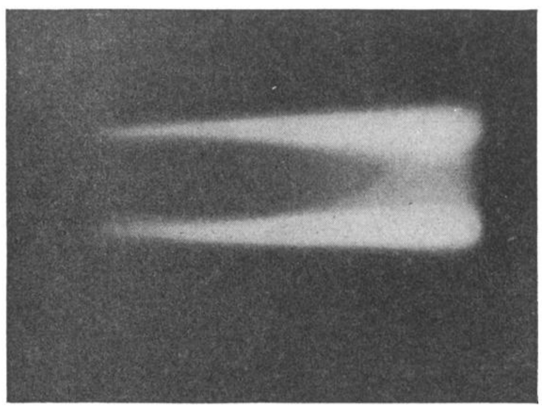

FIG. 1. Photograph of light scattered from a one-inch supersonic cylindrical jet emerging into the undried atmosphere.

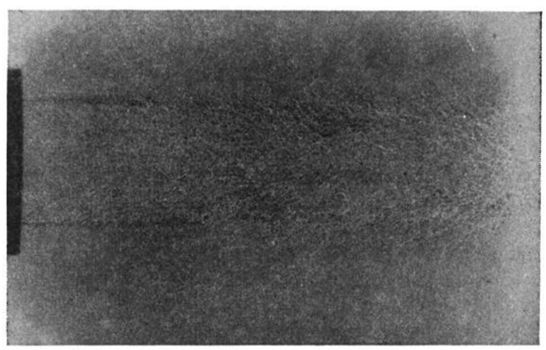

FIG. 2. Short spark shadowgraph of a supersonic jet taken under conditions similar to those of Fig. 1.