trons stopping in metals. These data were interpreted as indicating the absence of appreciable triplet positronium in the liquids due to (1) no positronium being formed, or (2) its rapid conversion from the triplet to the singlet state.

By means of a different technique (that used previously by Deutsch[2]) we have obtained similar results concerning the presence of triplet positronium in liquid helium. Approximately 1 mC of $Na^{22}$ was sealed in a 0.001-in. aluminum envelope and lowered into a glass Dewar containing a mass of liquid helium (at about 4°K) sufficient to stop all positrons. The NaI(Tl) scintillation pulse-height spectrum of the annihilation quanta was observed and compared with that obtained

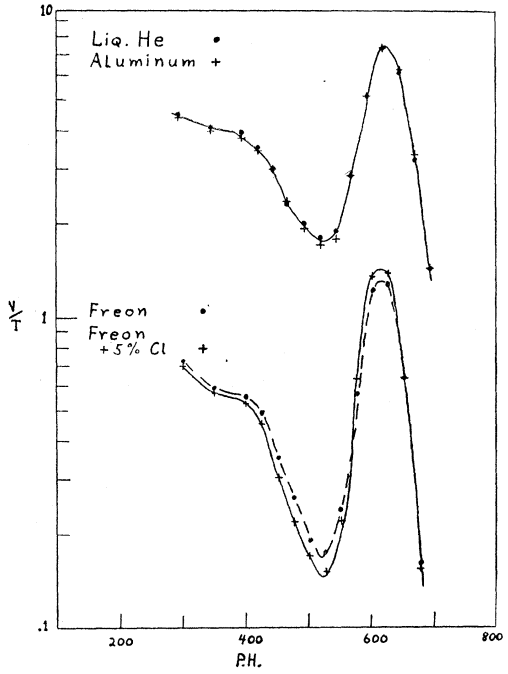


FIG. 1. Differential pulse-height spectra of annihilation radiation for positrons stopping in the indicated substances. The upper and lower pairs of curves have been separated to facilitate comparison.

upon surrounding the source (in the same container at room temperature) with a thickness of aluminum equivalent in g/cm² to the liquid helium. The two spectra (Fig. 1) were identical to within the statistical accuracy of the measurements, indicating no appreciable increase of triplet annihilations in liquid helium as compared with aluminum.

The sensitivity of the spectrum to the presence of triplet positronium was determined by repeating the Deutsch experiment[2] with the same source in the same container. Spectra were observed with the glass Dewar filled alternately with an atmosphere of Freon and an atmosphere of Freon+5-percent chlorine. As compared to the spectrum with Freon, that with the admixture of chlorine showed an increase in the 0.51-Mev 2-photon peak and a decrease in counting rate for 3-photon events at lower pulse heights. This difference was due to enhancement of the triplet to singlet conversion probability upon introduction of the chlorine. The effect was not so marked as in Deutsch's data, since the quantity of gas surrounding the source was not sufficient to stop all positrons. As a consequence, an appreciable fraction was annihilated in the glass wall.

* Sponsored by Office of Ordnance Research, U. S. Army.

[1] S. DeBenedetti and R. T. Siegel, Phys. Rev. **94**, 955 (1954). Similar results were obtained for the annihilation of positrons in liquid argon by T. A. Pond, thesis, Princeton, 1952 (unpublished).

[2] M. Deutsch, Phys. Rev. **82**, 455 (1951); M. Deutsch and E. Dulit, Phys. Rev. **84**, 601 (1951).

## Low-Temperature Bleaching and Restoration of Color Centers

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IN a recent Letter, Hesketh and Schneider[1] have suggested that a large-scale restoration of $F$ centers occurs in KCl on warming in the dark after bleaching at 113°K by irradiation in the $F$ band. Their main evidence is an absorption peak at 175°K in the $F$-band absorption *vs* temperature curve, with a similar effect for the $V$ band. These peaks could be produced repeatedly by recooling to 113°K, optical bleaching in the $F$ band, and rewarming.

While investigating optical absorption bands caused by trapped electrons in CdS and other crystals and their thermal bleaching characteristics, we obtained similar effects to those of Hesketh and Schneider.

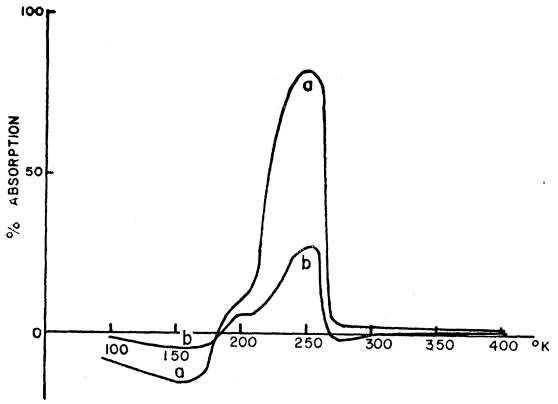


FIG. 1. Absorption peaks due to vapor condensation on crystal surfaces. (a) CdS, (b) KCl.

Almost identical curves of absorption *vs* temperature are obtained for CdS and for KCl as shown in Fig. 1. The absorption is not spectrally sensitive and occurs also for other transparent solids such as glass plates. The intensity and form of the curves shown in Fig. 1 are dependent on the rate of heating, the vacuum in the crystal cryostat, and on previous treatment. Detailed investigation shows that the peaks in Fig. 1 are due to interference effects from condensed surface films on the crystals, the latter acting as efficient vapor traps as they lag behind their surroundings during warming. Using dry air in the cryostat at atmospheric pressure reduces the effect, presumably by reduction of the mean free path of vapor molecules. Deliberate introduction of known vapors produces peaks at temperatures specific to each vapor and related to its boiling point.

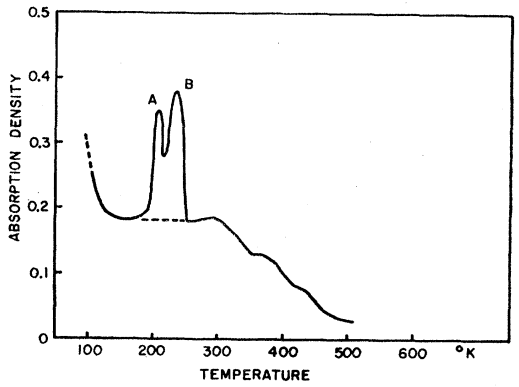


FIG. 2. Thermal bleaching curve for the $F$ band of KCl colored by x-rays at 100°K.

Figure 2 shows the thermal bleaching curve for KCl colored by x-ray irradiation at low temperatures. Apart from the "interference" peaks, $A$ and $B$, the form of the curve is as expected from previous knowledge of the thermal stability of $F$ centers in KCl, true bleaching occurring above room temperature in the region of 400°K.

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[1] R. V. Hesketh and E. E. Schneider, Phys. Rev. **94**, 494 (1954)

## Polarization in $n$-$p$ Scattering at 100–200 Mev*

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THIS note reports some recent results obtained from the study of azimuthal asymmetries in the charge-exchange scattering of partially polarized neutrons by hydrogen and carbon. The experimental method and some preliminary data have already been briefly reported.[1,2] Additional runs have been made, including measurements at first-scattering angles $\theta_1=15°$ and 30°, and at a variety of neutron threshold energies.

Considerable work was done to obtain an accurate knowledge of the center line of the neutron beam, since the asymmetries that we observed were generally small while their sensitivity to angular error of the center line was of the order of 25 percent per degree for $CH_2$ second scatterers. In our procedure, an optical line-of-sight passed through the centers of targets located at three points in the cyclotron, defining first-scattering angles of $+\theta_1$, 0, and $-\theta_1$, respectively. The axis of two collimators in the second-scattering proton telescope was set to this optical line. The telescope could then be rotated to the left and right of the center line, and angles set within one minute of arc. The angular acceptance of the proton telescope was 2° at half-maximum. Inequality of left-right angular settings with respect to the actual neutron beam could be deduced from the second-scattering left-right asymmetry for neutrons produced at zero first angle; it could also be deduced from the *mean* left-right asymmetry produced by equal and opposite first angles.

In this way we have found apparent angular errors as large as nine minutes, without being able to locate their source. In such cases, however, the two methods of deducing the angular error were in good agreement and provided a consistent correction to the data.

The energy spectra of the neutron beams were found to be similar to those previously measured.[3] Lower limits to the acceptable neutron energy were set by means of copper absorbers in the proton telescope, and these limits were kept constant as the angles were changed, assuming free $n$-$p$ collision kinematics.

Figures 1 and 2 present asymmetries observed in this way for a primary proton energy of 230 Mev, first angles of 15° and 30°, first targets of Be and C, a neutron threshold of 100 Mev, second scatterers of C and H, and second angles up to 55°. Asymmetries are given as $2e$, defined in the usual way,[1] and all angles are in the laboratory system. The asymmetries found at $\theta_1=30°$ are consistently larger than those found at $\theta_1=15°$. Results were also obtained at neutron thresholds of 125, 150, and 175 Mev, but no significant energy dependence was found.

From the results shown, an estimate can be made of the polarization, $P$, for the exchange scattering of neutrons by C and H, and of protons by Be and C. Assuming charge symmetry and ignoring the energy change between the two events, we obtain $P(p\text{-C-}n,\ 30°)=P(n\text{-C-}p,\ 30°)=+0.19\pm0.02$. Then $P(p\text{-Be-}n,\ 30°)=+0.13\pm0.03$; $P(n\text{-H-}p,\ 30°)=+0.15\pm0.05$; and