

It would be expected that the plastic strain of a metal should increase the term ρ_0 without appreciably affecting the temperature-dependent resistance. Our results appear to indicate, however, that cold working has a considerable effect on ρ_T as well as on ρ_0 . Thus if $\Delta\rho$ is the change in resistivity due to cold working we can write

$$\Delta\rho = \Delta\rho_T + \Delta\rho_0.$$

Hence, if $\Delta\rho_T$ is zero, we should have merely, $\Delta\rho = \Delta\rho_0$. Now according to very general theoretical considerations ρ_0 is independent of temperature, so that $\Delta\rho$ (which is the absolute value of the increase in resistivity caused by cold working) should also be independent of temperature. Experimental results show that this is not the case. In Fig. 1, ρ is shown as a function of cold working for three different temperatures in the case of aluminum. It can be deduced immediately that $\Delta\rho$, for all degrees of cold working, does depend on the temperature; e.g., at 40 percent reduction of area $\Delta\rho$ is found to be 1.9×10^{-8} , 1.0×10^{-8} and 0.8×10^{-8} ohm-cm at temperatures of 297°K, 90°K and 20°K, respectively. Similar results are found for copper. Hence we conclude that, since $\Delta\rho$ is not independent of temperature, $\Delta\rho_T$ cannot be zero.

The same conclusion follows from another consideration. It will be clear that even with metals of the present degree of purity the observed values of ρ at 20°K will be comprised largely of the "residual" resistance term ρ_0 . Hence an approximate value of ρ_T can be obtained by taking the difference between ρ at 297°K and ρ at 20°K. (A better value for ρ_0 would, of course, have been obtained by measuring ρ at still lower temperatures, but we were not able to make observations below 20°K at the time.) In Fig. 2,

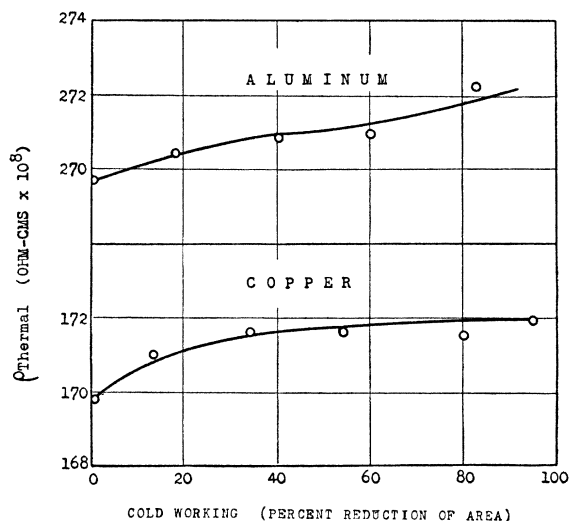


Fig. 2. Variation of thermal component of resistivity with cold working.

ρ_T obtained in this way is shown as a function of cold working for both aluminum and copper. It is immediately obvious that $\Delta\rho_T$ is not zero, and in fact, at high degrees of cold working, amounts to somewhat over 1 percent of the room temperature value of ρ , for both metals. From consideration of Figs. 1 and 2 it can further be deduced that for aluminum at, for example, 50 percent reduction of area, $\Delta\rho_T$ amounts to 0.5 percent and $\Delta\rho_0$ amounts to 0.2 percent of the room temperature value of ρ . For copper the corresponding figures are $\Delta\rho_T = 0.9$ percent and $\Delta\rho_0 = 0.4$ percent.

These results therefore suggest that the change in resistivity which occurs on cold working is due not only to an increase in the "dislocation" resistance ρ_0 , but also to an increase which takes place in the temperature dependent resistance ρ_T . In addition, the above figures indicate that $\Delta\rho_T$ is about twice as large as $\Delta\rho_0$ in the present experiments.

According to recent theoretical estimates of Mackenzie and Sondheimer² an increase in dislocation resistance of 0.4 percent would correspond, in polycrystalline cold-worked copper, to the formation of approximately 2×10^{11} dislocation pairs per cm². This estimate agrees much more closely with the figure obtained from measurements³ of the energy stored during work hardening, viz. 2.9×10^{11} , than do previous estimates based on results which did not recognize a change in the thermal component of resistance with cold working.

¹ We are greatly indebted to the Canadian Wire and Cable Company of Toronto who provided facilities for cold working the metals used.

² J. K. Mackenzie and E. H. Sondheimer, Phys. Rev. **77**, 264 (1950).

³ J. S. Koehler, Phys. Rev. **60**, 398 (1941).

Fine Structure of HDO near 3.7μ in the Solar Spectrum*

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IN the region between the 3.2μ water vapor band and the nitrous oxide band at 3.9μ , the solar spectrum shows many strong absorption lines, most of which are dependent on the amount of water vapor in the atmosphere. Many of these lines have now been identified with lines in the HDO spectrum obtained in the laboratory.

Atmospheric HDO was first observed by Adel¹ in the 7.2μ region of the solar spectrum. Recently, the 3.68μ band of HDO in the atmosphere has been observed by Gebbie, Harding, Hilsom, and Roberts² using a LiF prism spectrometer and a path length of about $1\frac{1}{2}$ miles at sea level.

In the present work, both the laboratory and solar spectra were obtained on a prism-grating spectrometer, utilizing a 7200-line/in. echelette, replica grating and a Perkin-Elmer thermocouple with their 13-cycle/sec. amplifier.

For the laboratory spectra, a 10-cm absorption cell with silver chloride windows was used, which could be heated to about 40°C. At this temperature, the vapor pressure is about 50 mm of Hg, which gives absorption lines strong enough for favorable comparison with solar spectra taken on days of low atmospheric water vapor content.

Spectra were recorded with the absorption cell, (a) evacuated, (b) saturated with the vapor from pure D₂O, and (c) saturated with the vapor from a 50-50 mixture of H₂O and D₂O. At equilibrium the latter mixture contains about 50 percent HDO and equal parts of H₂O and D₂O.

In the region 3.4 to 3.8μ in the laboratory spectra no lines due to H₂O were present, but the two strong bands of D₂O gave rise to many unwanted lines, in addition to those due to HDO. Comparison with the pure D₂O spectrum, however, permitted elimination of many of the interfering D₂O lines and positive identification of about 50 lines of HDO in the laboratory spectrum. These lines have been compared with lines in the solar spectrum of the same region and were found to match in position and relative intensity.

A tracing of the solar spectrum in this region is reproduced in Fig. 1 on which absorption lines identified with HDO are marked with dots. All frequencies are corrected to vacuum and the maximum absorption is about 35 percent.

Undoubtedly other lines not marked are also due to HDO, but their identification was made uncertain by the interference of intense D₂O absorption lines on the laboratory comparison spectra. These intense lines were also checked against the solar spectrum but no trace of them could be found, indicating, as would be expected, that the amount of D₂O in the atmosphere is negligible as compared with the amount of HDO.

Day to day fluctuation in the intensities of some of the unidentified lines relative to those of HDO indicate that other gases contribute to the absorption in this region.

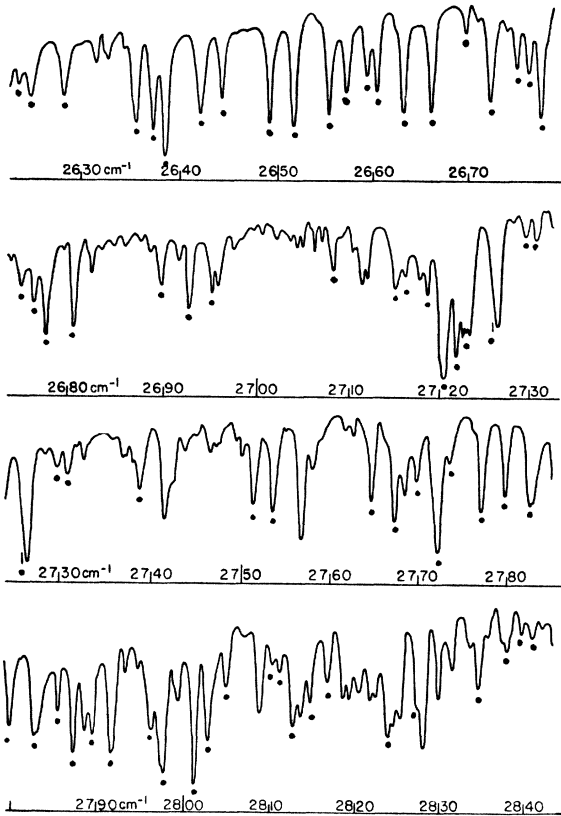


FIG. 1. Some lines of HDO in the solar spectrum near 3.7μ .

For a more thorough investigation of the HDO laboratory spectrum, it is planned to use an absorption cell of the multiple-reflection type with a path length of at least four meters. By using such a long path length, the ratio of D_2O to HDO can be reduced considerably without lessening the intensity of the HDO absorption.

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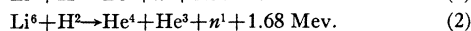
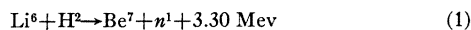
¹ A. Adel, *Astrophys. J.* **90**, 627 (1939).

² Gebbie, Harding, Hilsum, and Roberts, *Phys. Rev.* **76**, 1534 (1949).

Neutrons from the Bombardment of Li^6 by Deuterons*

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WHEN lithium enriched in the mass six isotope became available through the AEC, it was felt worth while to examine the neutrons from the following reactions:



The yield curve for neutrons from these reactions has already been reported.¹

In the present experiments the neutron energy spectrum has been analyzed from cloud-chamber photographs of recoil protons in the direction of the deuteron beam. A target of $Li_2^6SO_4$, 375 μg per cm^2 (about 150 keV at the bombarding energy used) was irradiated with 595-keV deuterons from the Rice Institute Van de

Graff generator. The low bombarding energy was chosen to minimize the neutrons from deuteron bombardment of carbon contamination on the target and on the tube wall in the analyzing magnet.

The neutron energy was determined from the range of the recoil protons in a Wilson cloud chamber filled with CH_4 and C_2H_5OH at 2 atmos. pressure. The cloud chamber was 17 cm from the target in the direction of the deuteron beam, the sensitive volume subtending a maximum angle of 16° at the target. Only tracks within 10° of the direction of the incident neutrons were accepted. Tracks shorter than 8 mm (corresponding to a 1-Mev recoil) were not counted because of the difficulty of determining their direction.

From some 6000 photographs, 1100 acceptable tracks were found. The number of tracks lying within 250-keV intervals are plotted in the histogram of Fig. 1. The curve in Fig. 1 gives the relative neutron spectrum and was obtained from the histogram by dividing by the neutron-proton scattering cross section.²

To extend the energy measurements to lower values, the chamber was filled with H_2 and C_2H_5OH at 2 atmos. These tracks were not so sharp as before, and only tracks longer than 1.3 cm (500 keV) were counted. With the same geometry as before, 160 tracks were measured for neutron energies below 1500 keV. The energy distribution, corrected for cross section and fitted to the higher energy spectrum, is shown by the open circles in Fig. 1.

In order to determine whether or not the 435-keV state of Be^7 reported by Brown, Chao, Fowler, and Lauritsen³ appears in this reaction, the tracks corresponding to neutrons in the 3- to 4-Mev energy range have been analyzed in smaller energy intervals. The number of tracks in 100-keV intervals is shown in Fig. 2. The asymmetric shape of the spectrum and the one high point at 3.35 Mev (400 keV below the energy of neutrons from the formation of Be^7 in the ground state) may be interpreted as an indication that this 435-keV state in Be^7 is formed in this reaction. Although it is not definite from Fig. 2 that this excited state does appear in this reaction, one might conclude that if it is formed, only about 30 percent or less of the disintegrations result in the excited state.

Using the peak of the curve at 3.75 Mev in Fig. 2, as the energy of the neutrons from the formation of Be^7 in the ground state, the Q -value calculated for the reaction is 3.27 Mev.

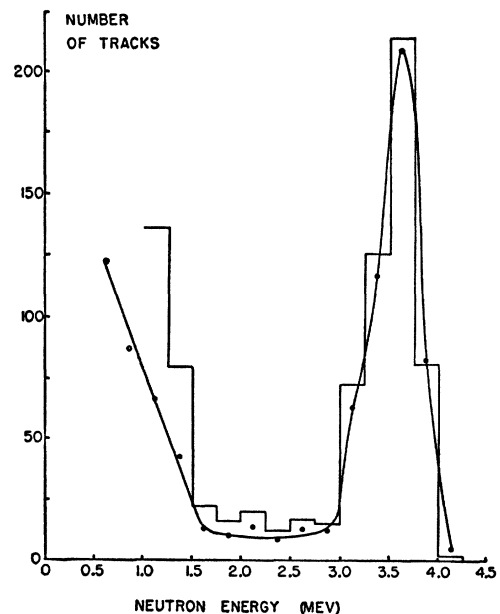


FIG. 1. Number of recoil tracks in 250-keV intervals. Smooth curve has been corrected for $n-p$ scattering cross section. Solid circles refer to data in CH_4 and open circles to data in H_2 . Point at 1.12 Mev is common to both sets of data.