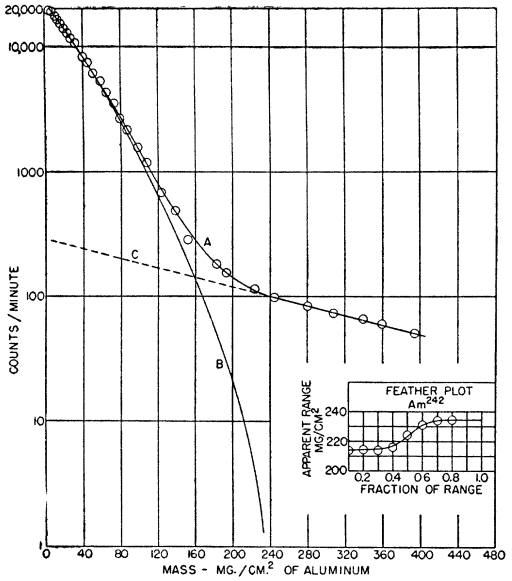

FIG. 1.

the original one by ratios to give a continuous absorption curve, which has a very well-defined end point. The sample itself was used as a reference to check the stability of the counter, no corrections for the decay during the experiment then being necessary.

The absorption curve, shown in Fig. 1, has two components. The soft component, β-radiation, was shown to come from 16-hour Am^{242} produced by this neutron irradiation, and to decay with the correct half-life. The hard component C, which is unrelated to Am^{242}, is probably due to x-radiation from Am^{241}. This was subtracted from A to give B, the absorption curve of the 16-hour component alone.

A Feather[2] type of analysis was made using UX_2 as a standard. Depending on which range-energy relationship is used, a slightly different energy value will be obtained, as is shown in Table I. The maximum energy, E, is in Mev, and the range, R, is in g/cm^{-2} Al.

The first three values agree well, with the Feather result differing considerably from them. This is caused by the low value (compared with the others) used by Feather for the range of the β-rays from RaE, which displaces his curve.

We propose a value of 0.63 ± 0.01 Mev (obtained by equally weighting the first three results and averaging) as the maximum energy of the β-rays emitted by Am^{242}. This differs from a previous value obtained by Seaborg *et al.*[6] of a range of 280 mg/cm^{-2} Al with a resulting energy of 0.8 Mev.

TABLE I. Maximum energy of β-rays.

	Relation	Range from UX_2 used by worker	Range from Am^{242}	Maximum energy
Flammersfeld[a]	$E=1.92(R^2+0.22R)^{\frac{1}{2}}$	1.105	0.234 ± 2	0.62 ± 0.01
Glendenin[b]	experimental curve	1.105	0.234 ± 2	0.65 ± 0.01
Sargent[c]	$E=\frac{R+0.094}{0.526}$	1.126	0.238 ± 2	0.63 ± 0.01
Feather*	$E=\frac{R+0.160}{0.543}$	1.105	0.234 ± 2	0.72 ± 0.01

* See reference 2.
[a] A. Flammersfeld, Zeits. f. Naturforsch. **2a**, 370 (1947).
[b] L. E. Glendenin, Nucleonics 2, 12 (1948).
[c] B. W. Sargent, Can. J. Research **A17**, 82 (1939).

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[1] L. Yaffe and Katharine M. Justus, Can. J. Research **B26**, 734 (1948).
[2] N. Feather, Proc. Camb. Phil. Soc. **35**, 599 (1938).
[3] G. T. Seaborg, R. A. James, and L. O. Morgan, Nuclear Science Abstracts **1**, 322 (1948), A1066.

The Effect of Cold Working on the Electrical Resistivity of Copper and Aluminum

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AS is well known, the electrical resistivity of a nearly pure metal can be regarded as made up of two parts, the first being temperature independent and the second depending only on the impurity content and degree of internal strain in the metal. We can express this as

$$\rho=\rho_T+\rho_0,$$

ρ_T being the "thermal" resistance and ρ_0 the "residual" or "dislocation" resistance.

Using polycrystalline copper and aluminum of the highest purity available (Johnson, Matthey Ltd., "H-S" brand, purity better than 99.999 percent) we have carried out experiments over a range of temperatures to measure the effect of cold working on the resistivity. The metals were in the form of rods, cold working from the annealed state being carried out by drawing at uniform speed through diamond dies.[1]

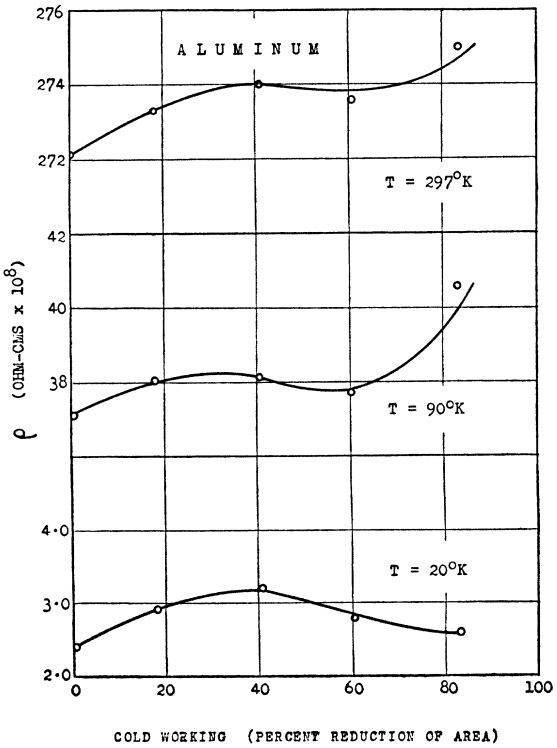

FIG. 1. Electrical resistivity of polycrystalline aluminum as a function of cold working.

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,

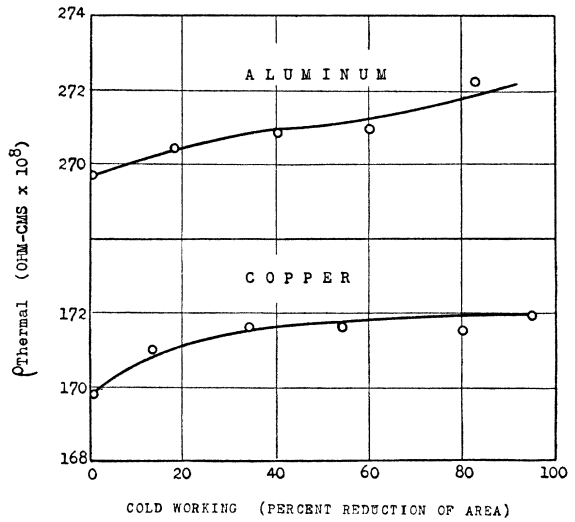

FIG. 2. Variation of thermal component of resistivity with cold working.

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 Sondheimer[2] 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 measurements[3] 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 Adel[1] 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, Hilsum, and Roberts[2] using a LiF prism spectrometer and a path length of about $1\frac{1}{4}$ 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 D_2O, and (c) saturated with the vapor from a 50-50 mixture of H_2O and D_2O. At equilibrium the latter mixture contains about 50 percent HDO and equal parts of H_2O and D_2O.

In the region 3.4 to 3.8μ in the laboratory spectra no lines due to H_2O were present, but the two strong bands of D_2O gave rise to many unwanted lines, in addition to those due to HDO. Comparison with the pure D_2O spectrum, however, permitted elimination of many of the interfering D_2O 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 D_2O 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 D_2O 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.