The thresholds for the production of neutrons from various elements were obtained by irradiating samples, of the order of 200 grams, placed just outside the x-ray donut. The neutron yields from these materials were determined by the use of rhodium foils placed near the samples. In order to reduce the background of neutrons from the x-ray target a special tube was used with Ag or Al probe targets placed at a position 90° away from the injector structure. The materials were in the form of laminated metal samples with the exception of the Zr which was in the form of the oxide.

The excitation functions near threshold in nearly all cases could be represented by parabolas which makes it possible to estimate the threshold from a linear extrapolation of the square root of the yield plotted as a function of the x-ray energy.

The results are shown in Table I. It is assumed that the

TABLE I. Thresholds for photo-neutron reactions.

Parent isotope	Activity detected	Observed threshold (Mev)	Previous work (Mev)	Empirical binding energy (Mev) Eq. 3[1]	Feenberg
$_{25}Mn^{55}$	Neutrons	10.15±0.20		10.9	10.3
$_{30}Zn^{64}$	38 min. β^+	11.80±0.20	11.6±0.4†	11.7	11.9
$_{30}Zn^{70*}$	52 min. β^-	9.20±0.20		9.0	9.1
$_{40}Zr^{90}$	4.5 min.	12.48±0.15	12.0±0.2††	10.1	10.4
$_{40}Zr^{91}$	Neutrons	7.20±0.40		7.5	7.1
$_{42}Mo^{92}$	15.5 min. and 75 sec. β^+	13.28±0.15	13.5±0.4†	10.8	11.6
$_{42}Mo^{97}$	Neutrons	7.10±0.30		7.1	6.2
$_{48}Cd^{113}$	Neutrons	6.44±0.15		6.8	6.6
$_{50}Sn^{119}$	Neutrons	6.51±0.15		6.6	7.1
$_{50}Sn^{124}$	40 min. β^-	8.50±0.15		7.3	8.1
$_{59}Pr^{141}$	3.5 min. β^+	9.40±0.10	9.8±0.3††	8.4	8.2
$_{60}Nd^{150}$	1.7 hr. β^-	7.40±0.20		7.2	7.5
$_{79}Au^{197}$	Neutrons	8.00±0.15		7.4	8.0
$_{80}Hg^{201}$	Neutrons	6.25±0.20		5.9	6.5
$_{81}Tl^{205}$	Neutrons	7.48±0.15		7.0	7.6
$_{82}Pb^{207}$	Neutrons	6.85±0.20	6.9†††	5.9	6.5

* Supplied by the Y-12 Plant, Carbide and Carbon Chemicals Corporation, through the Isotope Division, US-AEC, Oak Ridge, Tennessee.
† G. C. Baldwin and H. W. Koch, Phys. Rev. **67**, 1 (1945).
†† W. E. Ogle, Nuclear Sci. Abstracts **2**, 363 (1949).
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thresholds defined by the neutron yields are those for the isotope of the highest odd mass number of the element irradiated. The binding energies as obtained from semi-empirical relations[1] are shown in the table for comparison. It can be seen that there is fair agreement between the observed and calculated thresholds with the exception of the Zr^{90}, Mo^{92}, and Pr^{141} which have been pointed out as being exceptionally stable nuclei having closed shells of 50 and 82 neutrons.[2] The recent assignment of the 17 (15.5)-minute activity in Mo to Mo^{92} [3] serves to explain one of the large discrepancies between the observed and semi-empirical thresholds reported in the earlier work.

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Analysis of the Temperature Coefficient of Shear Modulus of Aluminum

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THE shear modulus G of a specimen of cubic symmetry may be regarded as an implicit function of temperature (through its volume V) and as an explicit function. Thus, $G=G\{V(T), T\}$. The temperature coefficient of this modulus will, therefore, contain two terms, namely,

$$d\ \ln G/dT=(\partial\ \ln G/\partial\ \ln V)_T\cdot d\ \ln V/dT+(\partial\ \ln G/\partial T)_V. \quad (1)$$

The purpose of this note is to estimate the contribution of each term to the total temperature coefficient for an aluminum crystal which is fairly isotropic and for which sufficient experimental data are available. Such a study has recently been made by Lazarus for a number of cubic crystals.[1]

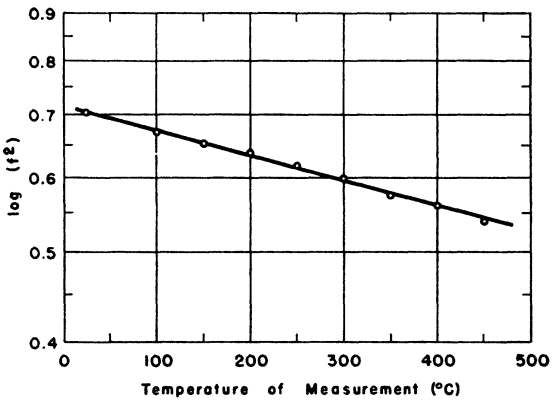

FIG. 1. Variation of the logarithm of the square of the frequency of vibration as a function of temperature.

In order to determine the left-hand term of Eq. (1), the shear modulus of an aluminum single crystal of commercial purity was determined by measuring the frequency of torsional vibration of the wire carrying a small torsional bar. The apparatus and the experimental procedure used in the measurement have been previously described.[2] Figure 1 plots the logarithm of the measured value of the square of the frequency of vibration as a function of temperature. From this curve, which is a straight line, the value of $d\ \ln G/dT$ was computed, due allowance being taken of the change of volume with thermal expansion, an allowance which increases the value by 13 percent. This gives

$$d\ \ln G/dT=-6.8\times10^{-4}\ \text{deg.}^{-1}.$$

It is to be pointed out that this value has been found to be the same for polycrystalline aluminum at temperatures when the grain boundary relaxation does not occur.[2] This indicates that the temperature variation of the shear moduli of aluminum along various crystallographic directions is similar.

The value of $(\partial\ \ln G/\partial\ \ln V)_T$ was computed from the measured values of $(\partial\ \ln G/\partial P)_T$ by Birch[3] and by Lazarus[1] and of $(\partial\ \ln V/\partial P)_T$ by Ebert[4] and by Bridgman[5] for commercial aluminum at 30°C and one atmospheric pressure. This gives

$$(\partial\ \ln G/\partial\ \ln V)_T=-5.64.$$

Upon combining this value of $(\partial\ \ln G/\partial\ \ln V)_T$ with the average volume expansion coefficient of commercially pure aluminum for the temperature range 20°C to 400°C, which is 8.0×10^{-5} [6] we obtain -4.5×10^{-4} as the first term in the right-hand side of Eq. (1), and hence, -2.3×10^{-4} for the second term $(\partial\ \ln G/\partial T)_V$. It is seen that the explicitly temperature-dependent term contributes more than one-third of the total temperature coefficient. This indicates that even for a first approximation, the shear modulus cannot be regarded as a sole function of volume, and this is in corroboration with Lazarus' observations for other cubic crystals and other types of elastic moduli.

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