Letters to the Editor

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Induced Thermoelectric Potential from Radiation Damage[*]

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The effect of radiation damage on the thermoelectric potential of iron and of constantan has been measured in a preliminary experiment. This work is a continuation of a previously reported effort[1] and represents an extension into a region of lower temperatures with a different technique.

The procedure was as follows: A five-mil wire was wound on a mica form measuring approximately one-by-five cm. The central part of the wire was then exposed to a beam of 10-Mev protons from the 60-inch Berkeley cyclotron in Crocker Laboratory. The two end sections of the wire were shielded from the beam and hence gave a length of wire with the central portion irradiated. During the irradiation the wire was maintained below zero degrees centigrade by passing helium, cooled by liquid nitrogen, over the sample.

Following the irradiation the wire was unwound from the mica form and annealed at various temperatures for a period of an hour in a furnace. After each anneal the thermoelectric potential of the irradiated section against the unirradiated section (see Fig. 1) was measured using a L & N Speed-O-Max, coupled with a L & N dc amplifier, Model 9835-B. A specially designed furnace was used as the variable temperature source and a standard ice water mixture for the reference temperature source.

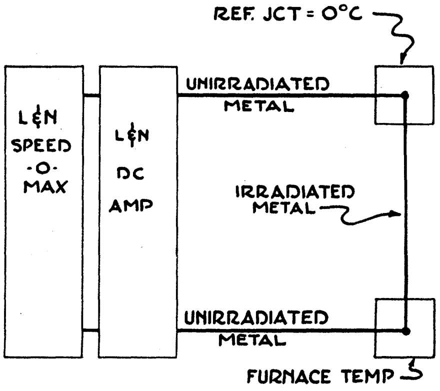

FIG. 1. Schematic diagram of equipment.

The 0.005-inch iron wire was irradiated with the 22 μa hr/cm^2 of 10-Mev protons. The 0.005-inch constantan wire was irradiated with 17 μa hr/cm^2 of 10-Mev protons. Iron was found to be positive with reference to the irradiated iron and constantan negative with reference to the irradiated constantan. The results are given in Figs. 2 and 3. From these curves it is seen that the maximum induced thermoelectric potentials are 0.3 microvolt per degree centigrade for iron and 0.1 microvolt per degree centigrade for constantan, after annealing to about 150 degrees centigrade.

There was a small drift and zero shift in the measurement of the emf of less than ± 1 μv. The variable temperature of the thermocouple loop was measured with another thermocouple, and the estimated variation of the temperature in the special furnace is less than ± 3 percent of the temperature as measured in centigrade units.

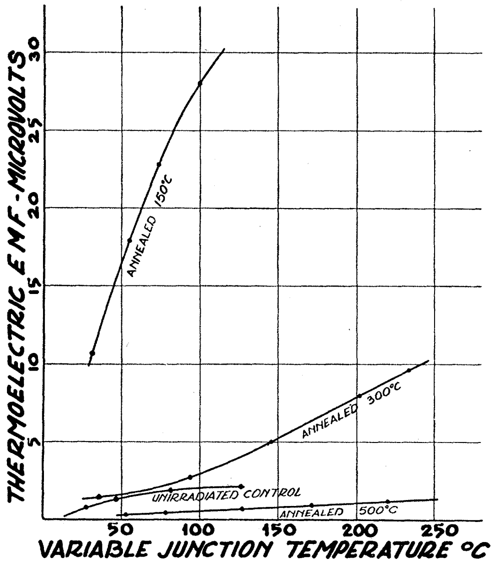

FIG. 2. Emf *vs* temperature for iron—irradiated iron thermocouple. Iron is positive with respect to irradiated iron. Reference junction = 0°C.

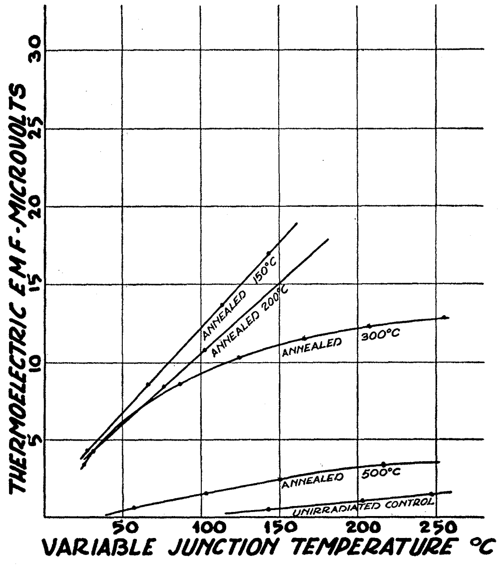

FIG. 3. Emf *vs* temperature for constantan—irradiated constantan thermocouple. Constantan is negative with respect to irradiated constantan. Reference junction = 0°C.

The control specimens were subjected to the same wrapping and twisting as the irradiated wires. They were not annealed before the control measurements were made. In both cases the control and irradiated wires were taken from the same spool, and consequently they should have very nearly the same composition and previous history.

It is a pleasure to acknowledge the interest and cooperation of Dr. J. G. Hamilton and G. B. Rossi of Crocker Laboratory and

the assistance of the members of the Irradiation Physics Group of North American Aviation, Inc., particularly L. E. Glasgow and B. T. Harwick.

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[1] Andrew, Jeppson, and Yockey, Phys. Rev. 86, 643 (1952).

Isomeric Branching and Threshold Behavior of the Reaction $Mo^{92}(n,2n)Mo^{91}$†

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In a recent paper,[1] we reported an experimental study of the reaction $Mo^{92}(n,2n)Mo^{91}$ employing neutrons in the range from threshold to 27 Mev. A number of investigators have produced Mo^{91} by the (γ,n) process using betatrons. They find, in addition to the 15.5-min Mo^{91}, another Mo^{91} activity of 65.5–75 sec. Katz[2] and collaborators have measured the (γ,n) thresholds of the two activities (15.5 min: 13.1±0.1 Mev, and 65.5 sec: 13.3±0.1 Mev) and the energy dependence of the two photo cross sections. In reference 1, we reported the absence of the shorter half-life, but in view of the recent betatron data, we made another search for it.

Neutrons of various energies were produced by bombarding tritium with deuterons accelerated in a Van de Graaff machine. The geometrical arrangement of foils (normal molybdenum) and tritium target was similar to that employed in the cyclotron experiments.[1] A knowledge of the deuteron energy plus the angular position of the molybdenum foil with respect to the deuteron beam axis makes possible a calculation of the energy of the neutrons passing through the foils. Irradiations of various lengths of time were performed on the foils. They were counted within one minute of bombardment termination on a Geiger counter apparatus adapted for measuring half-lives of the order of one minute. Two- and 15.5-minute bombardments with 14.4-Mev neutrons produced no measureable trace of the short half-life although the 15.5-min activity was abundant. It was interesting to note[2] that 14.5-Mev gamma-rays gave a value of about 0.2 for the ratio of the 65.5-sec to the 15.5-min photo cross sections. Eighteen-Mev neutrons gave a weak 65.5-sec activity. In view of these results, branching will not affect the comparison of the statistical theory to experiment made in reference 1.

We also measured a number of relative cross-section values for the 15.5-min isomer. These values are presented in Fig. 1. The vertical limits are 95 percent confidence intervals. The horizontal limits represent the maximum neutron energy spread intercepted by the foils. The curve drawn through the experimental points was calculated from the statistical theory using the values $a=3.16$ Mev^{-1} and $E_b=12.48$ Mev.

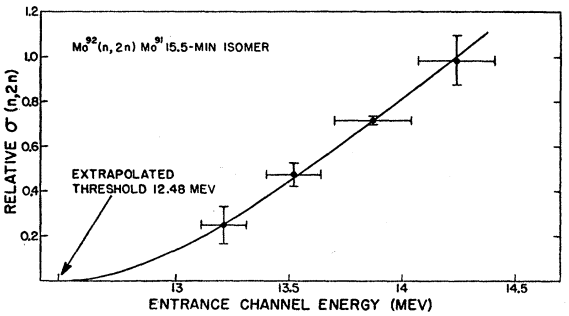

FIG. 1. Relative $\sigma(n,2n)$ as a function of channel energy: curve theoretical, points experimental.

Keith Zeigler performed an iterated least squares calculation to fit the theoretical formula[3] to the data. The above values give the best fit. It is interesting to note that the new value of a is rather close to that obtained in reference 1. However, the threshold energy obtained from these data is in disagreement with betatron measurements. If E_b is varied by 0.1 Mev, the theoretical curve departs markedly from the data. Table I summarizes the results of the least squares calculation.

TABLE I. Comparison of calculated and observed relative cross sections.

Entrance channel energy (Mev)	Observed relative $\sigma(n,2n)$	Calculated relative $\sigma(n,2n)$	Difference
13.21	0.249	0.251	−0.002
13.52	0.474	0.454	0.020
13.87	0.715	0.713	0.002
14.24	0.986	1.005	−0.019

H. C. Martin operated the facilities employed in this experiment which were generously extended by Group P-3. L. K. Schlacks assisted with the computations.

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† Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Brolley, Fowler, and Schlacks, Phys. Rev. 88, 618 (1952).

[2] L. Katz (private communication).

[3] U. S. Atomic Energy Commission Document NYO 636, p. 153 (unpublished).

Angular Correlation in the Decay of Li^8†

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Of the many processes which lead to the formation of the unstable Be^8 nucleus in its first excited state (~3 Mev), the $Li^8(\beta)Be^{8*}(\alpha)He^4$ reaction affords an interesting opportunity for performing a correlation experiment to provide information on this state. The beta-alpha correlation function may also depend on the nature of the Li^8 state and the degree of forbiddenness of the beta-process. Gardner[1] has given a discussion of the correlation functions expected for certain assignments of spin and parity to the participating states.

Li^8 nuclei were produced with the $Li^7(d,p)Li^8$ reaction by bombarding thin lithium targets with a deuteron beam of energy 0.65 Mev. In order to avoid detection of the many products of this bombardment, the beam was pulsed by means of a continuously rotating sector, and the decay products of the Li^8 nuclei were observed only during the period when the beam was interrupted by the sector.

Alpha-particles were detected with a thin, approximately 10-mil, sodium iodide crystal mounted in the vacuum of the target chamber and coupled to a photomultiplier tube through a quartz window. For convenience the alpha-detector was fixed at 90° to the deuteron beam. The target angle was 45°. Hence, the Li^8 nuclei, emitted into a forward 30° cone, were embedded in the target.

Beta-particles were detected with a sodium iodide crystal, 1 in.×1 in.×2 in., and a photomultiplier tube, free to rotate about the source. The cylindrical wall of the aluminum target chamber was about 20 mil thick, allowing beta-particles in the Mev range to pass through with an average loss of 250 kev. A lead collimator was provided between the chamber and the detector.

The pulses from each counter were amplified and passed through a discriminator, giving either a differential or an integral counting rate, and then to the coincidence detector. A switch between each amplifier and discriminator opened and closed the line in synchronization with the pulsing of the beam. The coincidence detector recorded the total number of coincidences, real and accidental, and also the accidental ones separately. The accidental rate was generally less than 10 percent of the real rate.

Differential pulse-height spectra of the alphas and betas are shown at the top of Fig. 1. In the detection of coincidences the