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NEUTRON SPECTRUM FOR FAST FISSION OF 25

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ABSTRACT

A disk of enriched 25 was irradiated by 300- to 650-Kev neutrons from the $Li^7(p,n)Be^7$ reaction. Photographic emulsions placed at ~170° to the target were used to detect the fission neutrons. The resulting spectrum has a higher average energy (2.6 Mev compared to 2.3 Mev) than the data reported in LA-84 for which thermal neutrons were used to produce fission in 25. However, it is not certain that the difference in spectra is the result of the added energy of excitation because the thermalizing material used in the LA-84 measurement would also produce some degradation of the fission neutrons.

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NEUTRON SPECTRUM FOR FAST FISSION OF 25

Introduction

With the availability of larger amounts of enriched 25 it became feasible to study the neutron spectrum which results from the fast fission of 25. This measurement is important (a) because exposure conditions can be chosen such that scattering and degradation of the fission neutrons can be kept to a minimum and (b) because the neutron spectrum may be different for higher excitation energy of the compound nucleus.

Exposure Arrangement

The exposure arrangement is sketched in Fig. 1. 2.34-Mev protons accelerated by the short electrostatic generator bombarded a ~100-Kev-thick rotating lithium target which had been evaporated on the 10-mil-thick tantalum target cup. The 2" x 0.33" cadmium-covered disks of 64% metallic 25 were placed about a centimeter from the target so that a blast of air could be used to cool the rotating target. The Ilford Special Halftone emulsions (200 μ thick) were mounted at ~170° to the target and 6.2" from the 25 disks.

For 2.34-Mev protons the maximum energy of the primary neutrons is ~650 Kev in the forward direction where the 25 disks are located but is only ~150 Kev maximum in the backward direction where the photo plates are mounted. Fortunately the $Li^7(p,n)Be^7$ reaction has an asymmetric yield with considerably more of the neutrons in the forward than in the backward direction. This asymmetry in yield makes possible the irradiation of the 25 disks with a strong flux of ~300- to 650-Kev neutrons while the emulsions were in a relatively weak flux of <150-Kev neutrons. Under these circumstances a 75-μampere-hour bombardment of the target produced in the plates an ade-

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quate number of recoils from fission neutrons, while the background grains made developable by the low-energy primary neutrons were so few as to cause no trouble in measuring. In fact the background grains on these plates were much fewer than those on the plates used in the LA-84 measurements.

Measuring Criteria

These were the same as used for all our earlier neutron spectrum measurements[1,2].

Results

Approximately 1500 recoil proton tracks have been measured on the exposed plates (1300 by L.S., 200 by H.T.R.). These have been plotted in energy intervals by means of the calibration data of LA-60, corrected for the variation of the n-p scattering cross section with energy, and corrected for the discrimination against slightly inclined long tracks which results from the finite thickness of the emulsion (see references 1 and 2). The inferred neutron spectrum is given in Fig. 2, and for comparison the data of LA-84 has been normalized to equal areas and also plotted on the same graph.

Discussion

The general shape of the present curve and of the thermal data (LA-84) is similar except in the very-low-energy region. The fast-fission data has, however, a considerably higher average energy. With reasonable extrapolations to zero energy the LA-84 data give an average energy of ~2.27 Mev while the present fast fission data

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1) Richards, H. T., Phys. Rev., 59, 796 (1941).

2) Richards, H. T., LA-60, LA-66, LA-84, LA-85, LA-111.

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has an average energy of about 2.63 Mev. (The probable error for each of these values is certainly at least 0.1 Mev.) While it is possible that part of this difference in average energy is the result of the higher excitation energy available for fast fission, the difference may perhaps be caused by the degradation of the fission neutrons by the thermalizing material used in the experiment (LA-84). Serber (private communication) estimates that for the experimental arrangement of LA-84 at least 16% of the recorded fission neutrons may have been scattered by the carbon in the thermalizing paraffin sphere. Multiple collisions with the hydrogen may also be important, so until more careful calculations are performed it remains uncertain whether the fast fission spectrum actually differs from the thermal data (see also below).

Whatever the explanation of the difference between the two fission spectra, there is some evidence that the present spectrum is in better agreement with other experimental data. Thus in Table I we list the experimentally observed $\overline{r^2}$ for the slowing of fission neutrons in graphite and in H_2O. The computed $\overline{r^2}$ for the LA-84 and the present data is also included and the agreement is much better for the present spectrum. Another check on the fission spectrum is now available from the measurements (performed by the R-1 group)[3] of the average fission cross section for 25 fission neutrons of 28 and 25. These results and the computed values from our spectra are listed in Table II and the comparison again favors the present data over that of LA-84.

All of the data in Table I and Table II indicates that the present spectrum (this report) has slightly more high-energy neutrons than one would expect from the slowing down measurements or from the $\overline{\sigma_f}$ measurements. It should be remembered though, that these experimental checks were all done using neutrons resulting from

3) LAMS-193, Progress Report Number 5 - Research Division.

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thermal fission whereas the spectrum measurement refers to neutrons from fast fission. Hence the disagreement between calculated and observed $\overline{\sigma_f}$ and $\overline{r^2}$ could represent a real difference between the energy of the neutrons emitted in fast fission and in thermal fission. There is some evidence which supports this view. When the spectra of the mock fission sources[4)] (as measured by the emulsion method) are used to compute $\overline{\sigma_f}$, the computed values agree surprisingly well with the values measured by Hanson. (See LAMS-193 and LA-201.) However, these argeements (and disagreements) ought not to be taken too seriously especially when one considers the general similarity within statistics of data on Fig. 2 and then realizes the really different $\overline{r^2}$ and $\overline{\sigma_f}$'s which are computed from the two sets of data.

It is hoped that the spectrum from thermal fission of 25 can be remeasured in the near future under conditions of negligible scattering material. In this manner we may be able to establish whether or not a real difference in neutron spectra exists between thermal and fast fission.

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4) Richards, H. T., LA-201

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TABLE I

Computed and Observed $\overline{r^2}$ for Fission Neutrons

	Computed* from LA-84	Computed* from Present data	Experimental (for Thermal Fission)	Reference
$\overline{r^2}$ in graphite	1958 cm^2	2099 cm^2	2070 cm^2	LAMS-175
$\overline{r^2}$ in H_2O	177 cm^2	215 cm^2	194 cm^2‡	CP-1531

* Private communication - C. Richman.

‡ This value may be considerably in error for reasons discussed in CP-1531.

TABLE II

Computed and Observed $\overline{\sigma_f}$ for Fission Neutrons

Cross sections for fission neutrons	Computed from LA-84 data*	Computed from Present data*	Experimental Values
$\overline{\sigma_f}(25)$	1.292	1.341	
$\overline{\sigma_f}(28)$	.258	.370	
$\left(\frac{\overline{\sigma_f}(28)}{\overline{\sigma_f}(25)}\right)$	.200	.276	.255†

* Private communication - C. Richman.

† R. R. Wilson, LAMS-193.

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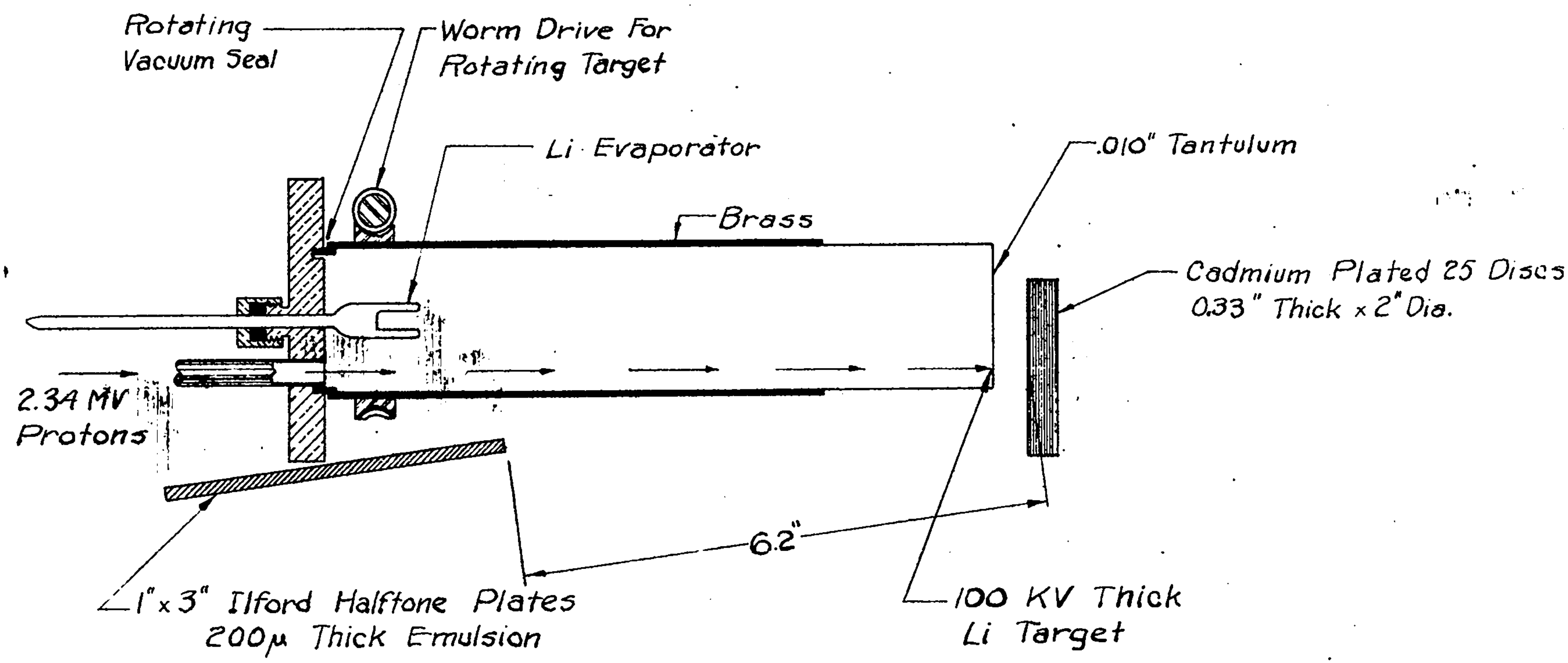

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Figure 1

Schematic Exposure Arrangement

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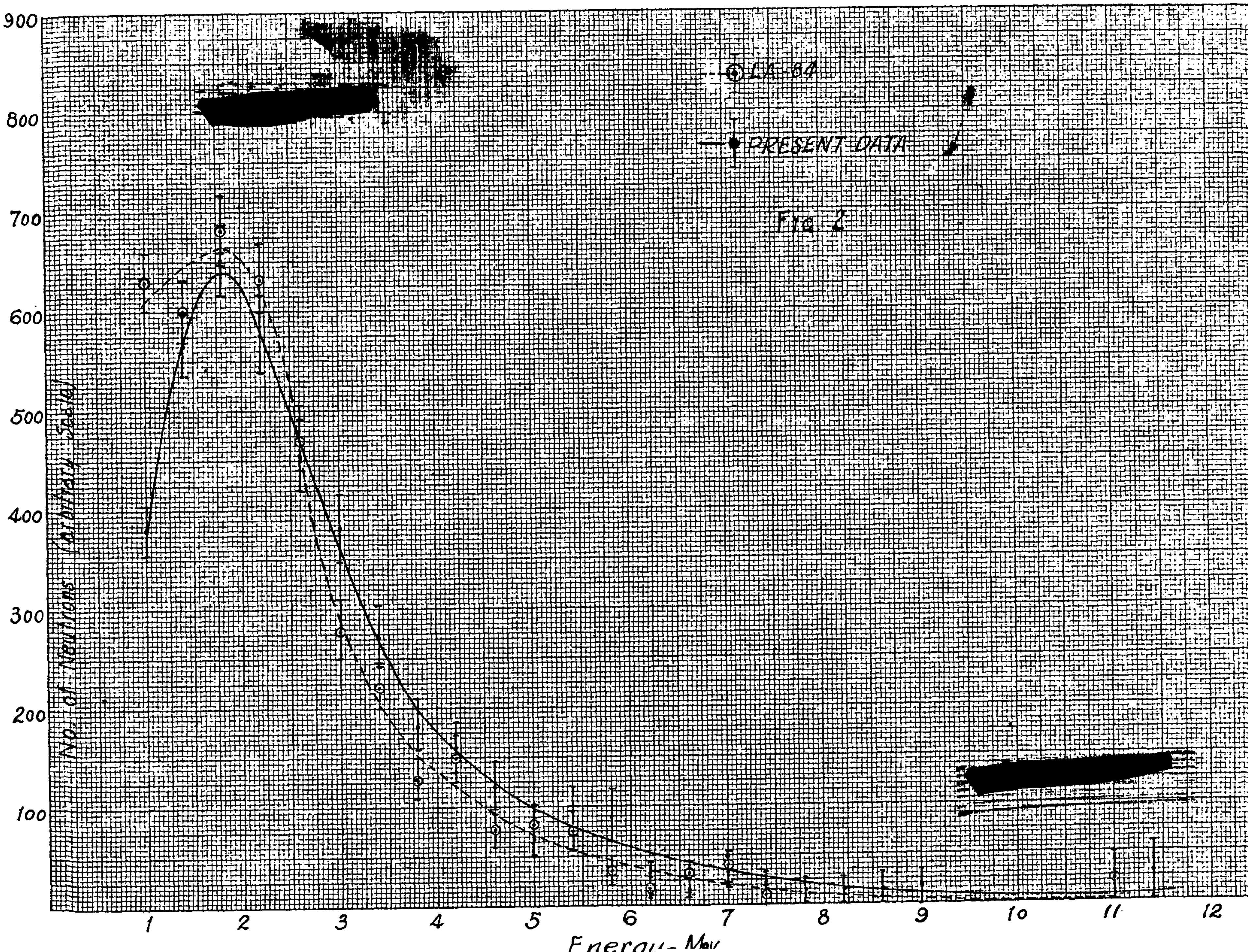
[redacted]
LA-84
PRESENT DATA
[redacted]
No. of Neutrons (Arbitrary Scale)
900
800
700
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12
Energy - Mev

FIG. 2

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