PHOTONEUTRONS FROM NATURAL MAGNESIUM*

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Recent experiments on photoneutron production from natural magnesium have produced contradictory results. Katz *et al.* (1954) have used bremsstrahlung from a 22 MeV betatron to irradiate a natural magnesium target. The emitted neutrons were detected with boron trifluoride (BF_3) counters placed in a paraffin block. The counting system was based on a design by Halpern, Mann, and Nathans (1952). The measured yield curve was analysed by the photon difference method (Katz and Cameron 1951*a*) to give a cross section versus energy curve. This indicated two peaks in the magnesium (γ, n) cross section ; one of 1·8 mbarn at 13 MeV, and one of 14 mbarn at 20 MeV.

Natural magnesium has three stable isotopes with percentage abundances and (γ, n) thresholds as shown in Table 1. The (γ, n) thresholds were calculated from tables of mass defects given by Wapstra (1955).

Table 1

Isotopic abundances and (γ, n) thresholds of magnesium isotopes

Isotope	Abundance (%)	(γ, n) Threshold (MeV)
^{24}Mg	78·60	16·57
^{25}Mg	10·11	7·33
^{26}Mg	11·29	11·12

Katz *et al.* (1954) attributed the 20 MeV peak to the giant resonance of the $^{24}Mg(\gamma, n)$ reaction and the 13 MeV peak to the $^{25}Mg(\gamma, n)$ giant resonance. The $^{24}Mg(\gamma, n)$ ^{23}Mg reaction had been investigated previously by detecting the 12 sec ^{23}Mg β^+-activity (Katz and Cameron 1951*b*). The results obtained in this experiment did not agree with the result obtained from the direct detection of the neutrons (a peak cross section of 9·8 mbarn compared with 14 mbarn). If, however, the residual activity curve is normalized so that the activity measured at 22 MeV is equal to the measured neutron yield from the natural element at 22 MeV, the agreement is much improved.

Nathans and Yergin (1955) have studied the photoneutron yields from enriched isotopes of magnesium (in the chemical form of oxides). Their ^{24}Mg sample was enriched to 99·59 per cent. ^{24}Mg, and their ^{25}Mg sample to 92·33 per cent. ^{25}Mg. Using BF_3 counters contained in a paraffin block they obtained

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yield curves for the individual magnesium isotopes. The yield curves were corrected for background due to the $^{16}O(\gamma, n)$ reaction using the results of Ferguson *et al.* (1954), and were analysed for the cross section by the total spectrum method. The $^{24}Mg(\gamma, n)$ peak cross section (9 mbarn) agreed with the original residual activity result of Katz and Cameron (1951*b*) (9·8 mbarn), but was lower than the renormalized value (14 mbarn). The $^{25}Mg(\gamma, n)$ cross section had a peak at 20 MeV, which is 7 MeV higher than the result of Katz *et al.* (1954). There was a plateau in the energy range 11–13 MeV.

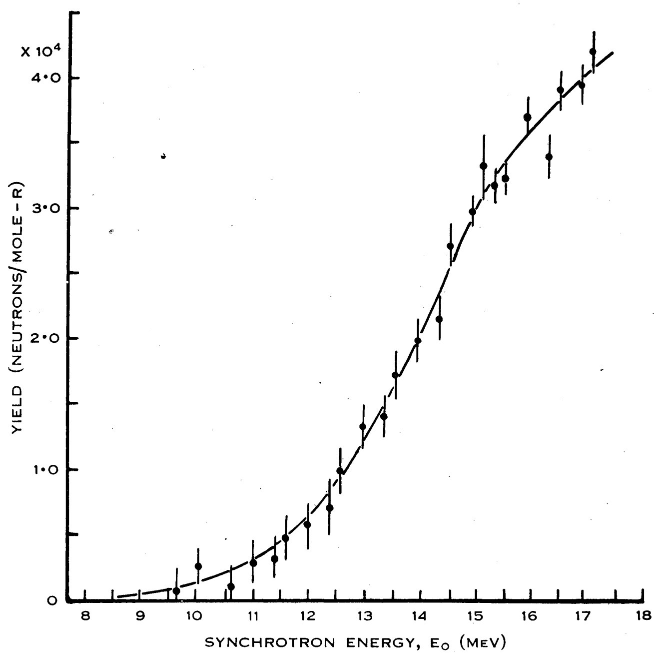

Fig. 1.—Yield of photoneutrons from natural magnesium. Background has been subtracted.

More recently, Yergin (1956) has obtained a neutron yield curve for natural magnesium (using magnesium oxide) which had a different shape from the earlier result of Katz *et al.* (1954). The yield curve obtained here was not analysed to give a cross section. As a result of this measurement, Yergin has said that the results of Nathans and Yergin (1955) cannot be reconciled with the 13 MeV peak obtained by Katz *et al.* He has suggested that Katz's result might be in error if small heavy element impurities were present in the sample.

To provide further experimental evidence, the 18 MeV electron synchrotron at Melbourne has been used to irradiate a natural magnesium target and thus determine the neutron yield as a function of synchrotron energy between 8 and 17 MeV. A sample of the target was analysed spectrographically and found to contain less than 0·1 per cent. aluminium and less than 0·05 per cent. manganese. The photoneutrons were detected by BF_3 counters with essentially the same counting system as in the experiments mentioned above. The one difference is that no gating circuit was used. This was unnecessary since the γ-ray yield was spread over a 250 μsec interval, thus removing any danger of a pile-up of electron pulses. The dose was measured by a $0 \cdot 25$ r Victoreen thimble used as a transmission ionization chamber. Its response was compared with that of a 25 r thimble in an 8 cm Lucite cube to find the absolute dose. The neutron yield was corrected for background by subtracting from it the result of a run without the target in position.

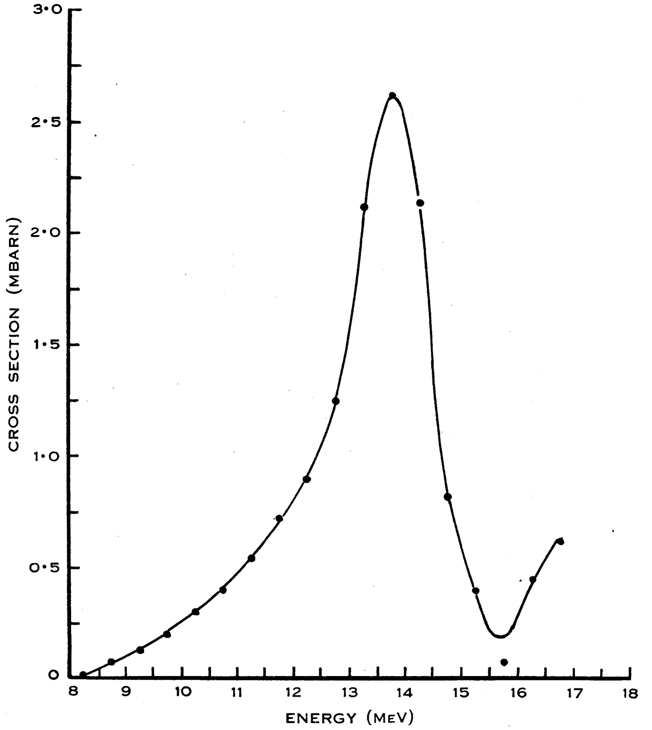

Fig. 2.—Cross section for photoneutron production from natural magnesium.

The resulting yield curve is shown in Figure 1. This curve was analysed for the cross section by the photon difference method after smoothing the first differences of the yield curve as suggested by Katz and Cameron (1951*a*). The cross section curve is shown in Figure 2. It has a peak at $13 \cdot 5$ MeV of height $2 \cdot 6$ mbarn. The absolute yield of neutrons at 17 MeV was calculated to be 4×10^4 neutrons mole^{-1} r^{-1}, in excellent agreement with the results of the earlier experiments. Katz *et al.* (1954) give 4×10^4 neutrons mole^{-1} r^{-1}, and Yergin (1956) gives 3×10^4.

This experiment supports Katz's contention that there is a maximum in the cross section near 13 MeV.

When comparing the yield curve obtained by Katz *et al.* (1954) with his own measurement, Yergin normalized the two curves together at 21 MeV. He then found that they disagreed below 17 MeV. If, however, these yield curves are normalized together at 15 MeV (below the $^{16}O(\gamma, n)$ threshold, remembering that Yergin's measurement was done with MgO), the two curves diverge above 15·7 MeV. This is where the neutron yield from oxygen becomes appreciable, suggesting that the oxygen subtraction made by Yergin could be faulty.

In the light of the experiment on the neutron yield from ^{25}Mg by Nathans and Yergin (1955), the original interpretation given to the 13 MeV peak should be revised. This attitude is supported by noting the arbitrary normalization process required to relate the earlier experiments on $^{24}Mg(\gamma, n)$ using residual activity techniques (Katz and Cameron 1951*b*) with the $^{24}Mg(\gamma, n)$ cross section deduced from the natural magnesium experiment.

A recent experiment by Cook (1957) has shown the existence of a " pigmy " resonance, that is, a small resonance on the low energy side of the giant resonance, for ^{13}C. With this in mind, we suggest that the peak in the sum of the (γ, n) cross sections for ^{25}Mg and ^{26}Mg may be of this type. The $^{24}Mg(\gamma, n)$ reaction does not contribute in this energy region because its threshold is at 16·6 MeV. As there has not been an accurate determination of the $^{26}Mg(\gamma, n)$ cross section, it is not possible to assign the peak to one isotope or the other.

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