1.2 PHOTONEUTRON SOURCES

Reactions of the (γ,n) type can be used for neutron production. The gamma radiation is produced naturally by radioactive or artificially radioactive sources. Targets are restricted to a few light elements, those elements in which a neutron is rather loosely bound. Beryllium (Be^9) and heavy hydrogen (H^2) are alone among the isotopes having low enough (γ,n) thresholds (1.63 Mev and 2.185 Mev respectively)* to be useful with natural gamma emitters.

The Ra-γ-Be source † yields neutrons in two energy groups (0.12 Mev and 0.51 Mev) since two radium gammas are above the threshold. A practical rule for calculating the total number of neutrons per second in a Ra-γ-Be source is: *1 gm of Ra at 1 cm from 1 gm of Be gives 3 X 10^4 neutrons/second.*

A fairly complete survey of photoneutron sources has been made at Argonne National Laboratory. Various artificial radioactive gamma emitters have been used with beryllium and heavy water. For some of these the emitted neutron energies have been measured. Table 1 lists these data.

TABLE 1. PHOTONEUTRON SOURCES.

Source	Half-Life	Neutrons/second/curie *Standard source	Neutrons/second/curie *Other source	Neutron Energy In Kev Mean	Neutron Energy In Kev Maximum	Reference †
$Na^{24}+D_2O$	14.8H	29.0×10^4	2.7×10^6	220	320	A,B
$Na^{24}+Be$	14.8H	14.0	2.4	800	1020	A,B
$Mn^{56}+D_2O$	2.6H	0.31	0.029	220		A,C
$Mn^{56}+Be$	2.6H	2.9	0.50	300 <150	375 <150	A,B
$Ga^{72}+D_2O$	14H	6.9	0.64	130		A,C
$Ga^{72}+Be$	14H	5.9	1.04			A
$In^{116}+Be$	54M	0.82	0.14	300 <150	400 <150	A,B
$Sb^{124}+Be$	60D	19.0	3.2	35	68	A,B
$La^{140}+D_2O$	40H	0.68	0.062	130		A,C
$La^{140}+Be$	40H	0.23	0.041	620		A,C
$Y+Be$	100D			220 ±20		D

*"Standard" source is one curie at a distance of one centimeter from one gram of target material. "Other" source is described in Figure 1 of reference A.

†References:
A. B. Russell, D. Sachs, A. Wattenberg, R. Fields, *Phys. Rev.*, 73: 545(1948), on neutron yields.
B. D. J. Hughes, C. Eggler, *Phys. Rev.*, 72: 902(1947), on neutron energies.
C. A. Wattenberg, *Phys. Rev.*, 71: 497(1947), on neutron energies.
D. R. D. O'Neal, *Phys. Rev.*, 70: 1(1946), on neutron energies.

*M. L. Wiedenbeck and C. J. Marhoefer, *Physical Review* 67: 54(1945).

†G. R. Gamertsfelder and M. Goldhaber in *Physical Review* 69: 36B(1946) report a Ra-γ-Be source with a yield of 62±7 neutrons/second/Mc Ra.

a-93-10