LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Minimum Neutron Energy to Produce Neutron Loss Process and Its Application to the Measurement of Q Values

The cyclotron in Berkeley produces a beam of very high energy deuterons, which in bombardment of the light elements give rather high energy neutrons, especially in the forward direction.

Assumption of the conservation of energy and momentum gives the following formula

$$Q=\tfrac{1}{2}MV^2-\tfrac{1}{2}M_dV^2_d+(1/2Mn)\times(M^2V^2-2MM_dVV_d\cos\phi+M_d^2V_d^2), \quad (1)$$

where Q is the total energy evolved in the reaction which is usually expressed by the following type of formula

$$Z^A+{}_1H^2=(Z-1)^{A+1}+n+Q.$$

M, V, M_d and V_d are the mass and velocity of a neutron and of a deuteron respectively. Mn is the mass of residual nucleus, and ϕ the angle between the direction of the deuteron and that of the emitted neutron.

In the case of the Be target, for example, the energy of a neutron is expressed as follows

$$E_n=\frac{10}{11}Q+\frac{9}{11}E_d+\frac{MVM_dV_d}{11}\cos\phi,$$

where E_n and E_d are the energy of the neutron and of the deuteron. The maximum energy from the Be target varies by a fairly large amount, as a function of ϕ and E_d, especially when a value of E_d is as high as 8 Mev.

If the scattering from the materials around the target is negligible, it is possible to bombard a sample with a neutron beam of known maximum energy by placing it at various angles with the Be target or by changing the energy of the bombarding deuterons.

Since the end of 1936 it has been reported by several persons[1, 2] that neutron loss reactions can be observed on bombardment of certain elements by neutrons of sufficiently high energy. In other words, a high energy neutron can knock out one or more neutrons from a stable nucleus of certain elements, and the corresponding characteristic periods for neutron loss have been observed.

The detection of the presence of neutron-loss periods after bombardment with neutrons of known maximum energy makes it possible to determine the minimum energy of neutrons necessary to produce the neutron-loss process in measurable amount.

The results of some preliminary tests are as follows, some of which have been reported at the Stanford meeting.

Element	Limits of E_n (Mev)	T (min.)
N	$5.5>E_n>7$	10
P	$5>E_n>7$	2.8
Cu	$12>E_n>13$	10
Zn	$9.0>E_n>10$	35
Ga	$6>E_n>7$	66
Ge	$5.5>E_n>7$	30
Br	$9>E_n>13$	6
Mo	$12>E_n>13$	17
Ag	$5>E_n>7$	25
In	$12>E_n>13$	1
Sb	$5.5>E_n>7$	16

Although the minimum energies for the following elements are close to each other, it is still possible to detect which elements need higher energy than others, and this can be written in the following order:

$$\text{Ga}>\text{Ge}>\text{Sb}>\text{Ag}>\text{P}.$$

When these values are calibrated more accurately we shall be able to estimate roughly the maximum energy of neutrons from various targets subjected to deuteron bombardment by observing in what elements the neutrons are capable of producing neutron loss. Then using the formula (1) we can determine the Q value.

A test of this possibility was made on Al, Fe, Cu, and a rough estimate of the maximum energy of neutrons emitted gives the following figures:

	Al	Fe	Cu
Limits for E_n (Mev)	$6<E_n<9$	$5.5<E_n<7$	$5.5<E_n<7$
Q (Mev)	<3.5	<1.5	<1.5

It should be mentioned that the samples are not free from the bombardment of scattered neutrons and also those from the cyclotron walls or dees; but fortunately scattering turned out to be negligible and the maximum energy of the neutrons from copper is not very high so that the tests for neutron energies higher than that from Cu can be made fairly accurately.

The author wishes to express his gratitude to Professor Ernest O. Lawrence and the staff of the Radiation Laboratory for the privilege of the use of the cyclotron and for their valuable help and discussions. The financial support of the Research Corporation, the Chemical Foundation, and the Josiah Macy, Jr. Foundation, is greatly appreciated.

R. SAGANE

Radiation Laboratory, Department of Physics,
University of California,
Berkeley, California,
January 18, 1938.

[1] Heyn, Physica **4**, 161 (1937).
[2] Pool, Cork, Thornton, Phys. Rev. **52**, 239 (1937); Chang, Goldhaber, Sagane, Nature **139**, 962 (1937).
[3] Phys. Rev. **53**, 212 (1938).