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Production of Hydrogen, Deuterium, and Helium by 15-MeV Neutrons

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The lifetime of the first wall of a fusion reactor is expected to be limited by radiation damage from 14-MeV neutrons. This radiation damage will be caused partly by hydrogen and helium produced in nuclear transmutations. We have measured the hydrogen and helium production cross sections for both natural elements and separated isotopes which are constituents of metals under consideration for the first wall of fusion reactors.

In most previous measurements cross sections have been deduced from induced radioactivities. Since many of the reactions of interest do not produce radioactive nuclides, emitted protons, deuterons, and alpha particles were observed directly in the present measurements. A magnetic lens system[1] focussed the charged particles that were produced by 15-MeV neutrons in a thin radiator, onto a detector about 2.5 m from the radiator. Fig. 1 shows the arrangement of the neutron source, the charged-particle

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transport system, and the detector. Charged particles emitted in different directions with respect to the incident neutrons were observed by moving the charged-particle transport system along its axis.

Monatomic 400-keV deuterons bombarded a rotating titanium tritide target[2] producing about 3×10^{12} neutrons/sec. A thin Si solid-state detector in coincidence with a thick Si detector served to identify the charged particles and measure their energy.

At each reaction angle the energy distributions were determined at nine different magnet settings to cover the entire charged-particle energy spectrum. From these measurements the charged-particle energy spectrum at one angle was deduced. Fig. 2 shows as an example the proton energy distribution from Ni. Measurements at several angles were combined to yield energy distributions from which the reaction cross section could be deduced. Absolute cross sections were obtained by normalization to the neutron-proton or neutron-deuteron scattering cross section.

Table 1 summarizes the results of all measurements of reaction cross sections obtained to date, including some previously published data[3-5]. The uncertainties include both statistical and systematic errors. Some of the present results may be compared with mass-spectroscopic helium production determinations[6]. The results of both types of measurements agree within the quoted uncertainties.

FIGURE CAPTIONS

Fig. 1. Experimental arrangement for observing charged particles produced by DT neutrons. A typical trajectory of a charged particle focussed by the magnetic quadrupole triplet is shown. The system is moved parallel to its axis for observations at different reaction angles.

Fig. 2. Energy distribution of protons from Ni at 90° reaction angle.

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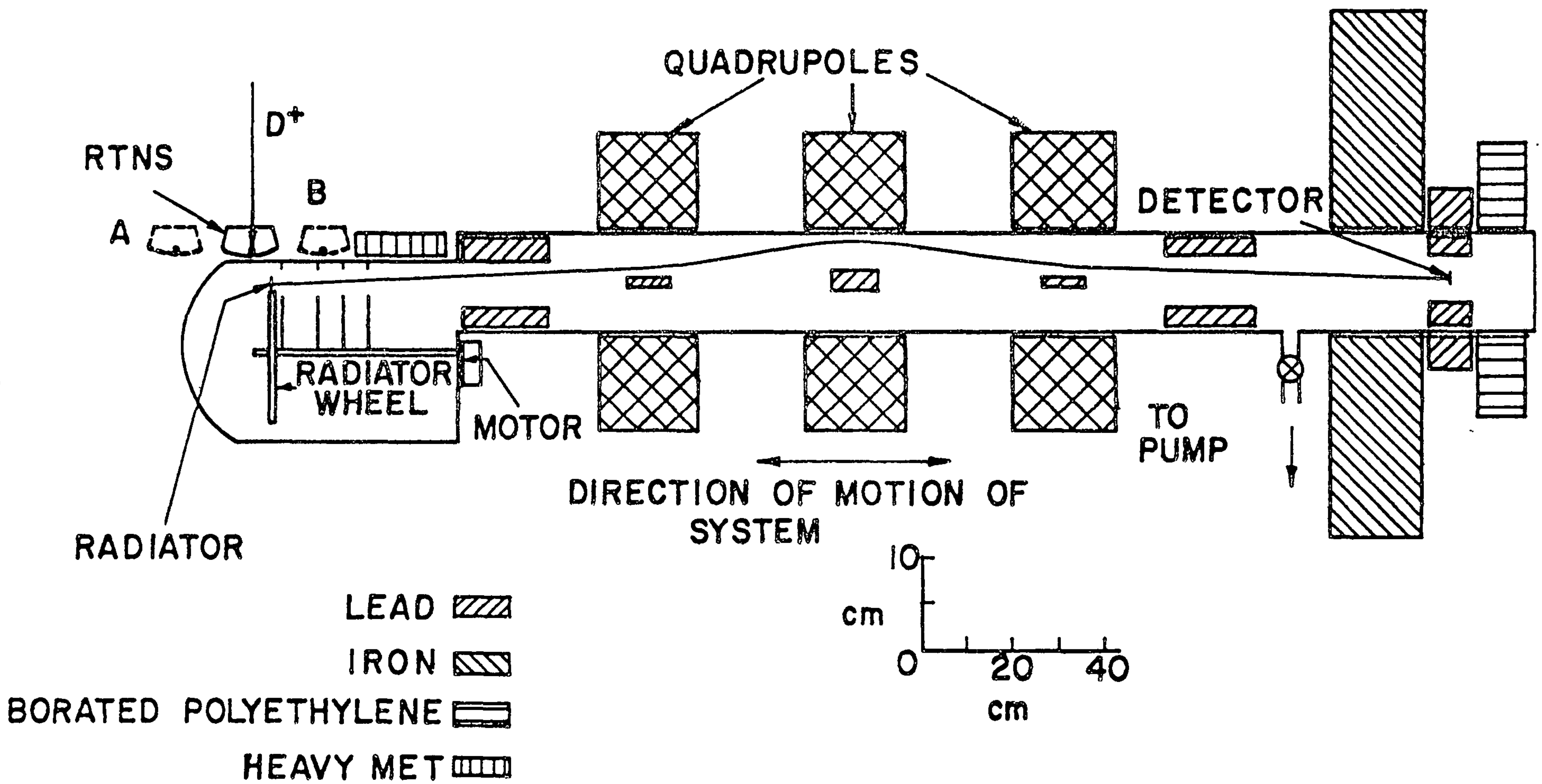
TABLE 1

Cross Sections for 15-MeV Neutrons (mb)

Target	Proton Production	Deuteron Production	Alpha Particle Production
^{27}Al	400 ± 60	19 ± 8	121 ± 25
^{46}Ti	670 ± 90	9 ± 4	98 ± 18
^{48}Ti	85 ± 16	7 ± 3	28 ± 6
^{51}V	91 ± 14	7 ± 3	17 ± 3
^{50}Cr	830 ±100	13 ± 4	94 ± 15
^{52}Cr	182 ± 25	8 ± 3	38 ± 6
^{nat}Cr	182 ± 25	9 ± 3	37 ± 6
^{54}Fe	900 ±110	10 ± 4	80 ± 13
^{56}Fe	190 ± 20	8 ± 3	41 ± 7
^{nat}Fe	220 ± 30	8 ± 3	43 ± 7
^{58}Ni	1000 ±120	14 ± 6	106 ± 17
^{60}Ni	330 ± 40	11 ± 4	76 ± 12
^{nat}Ni	800 ±100	13 ± 5	97 ± 16
^{63}Cu	320 ± 50	9 ± 4	56 ± 10
^{65}Cu	44 ± 5	10 ± 4	14 ± 3
^{93}Nb	51 ± 8	8 ± 3	14 ± 3
304SS	260 ± 38	8 ± 2	48 ± 7
316SS	260 ± 38	8 ± 2	48 ± 7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D+
RTNS
B
A
DETECTOR
RADIATOR WHEEL
MOTOR
TO PUMP
DIRECTION OF MOTION OF SYSTEM
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LEAD
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BORATED POLYETHYLENE
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10
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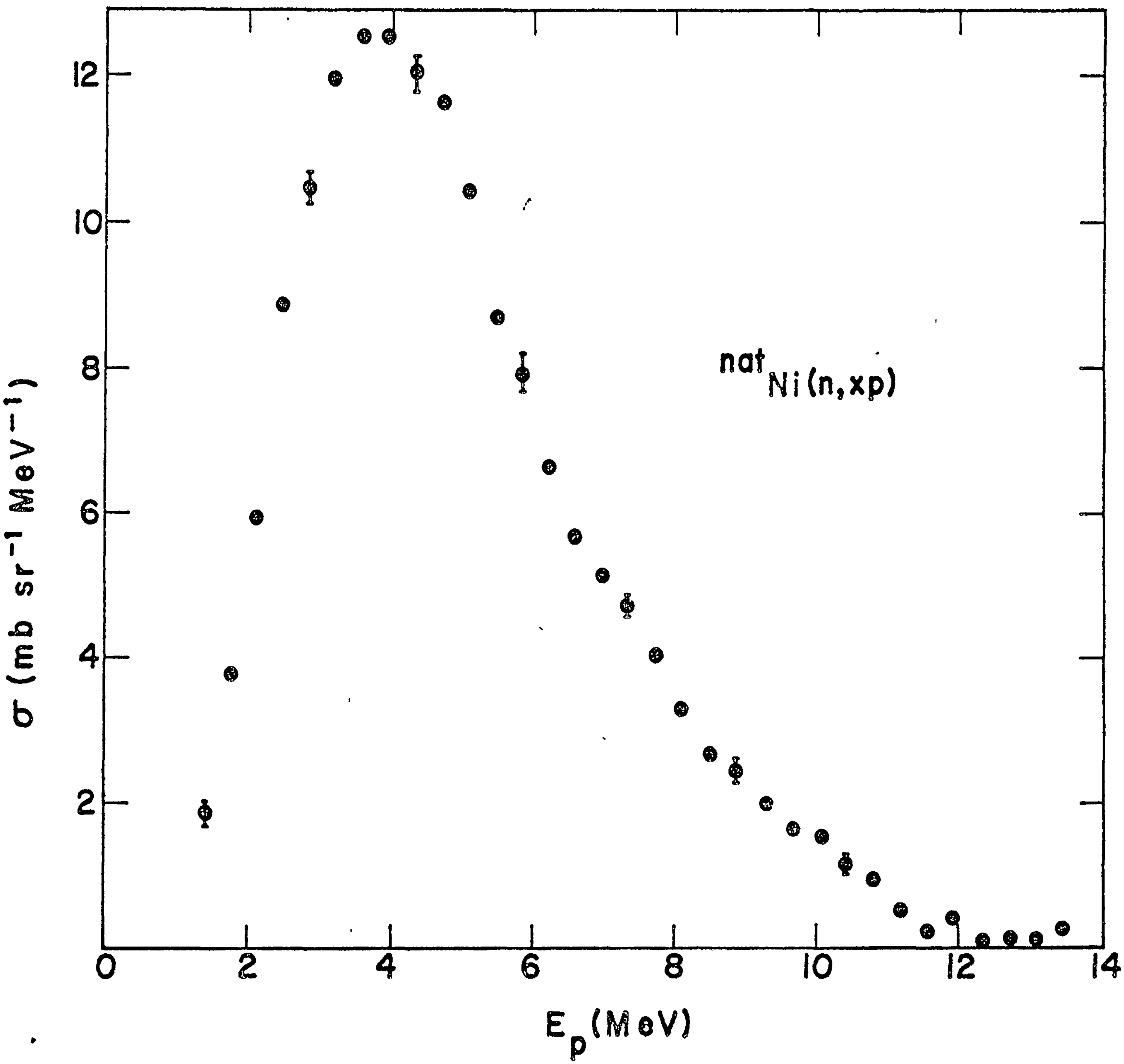

σ (mb sr⁻¹ MeV⁻¹)
12
10
8
6
4
2
0
2
4
6
8
10
12
14
E_p (MeV)
natNi(n,xp)