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| Title | Activation Cross Sections for Reaction Leading to Long-lived Reaction Products on Titanium, Manganese, Copper, Zinc, Strontium, Yttrium, Cadmium, Indium and Tellurium for 14. 6 MeV Neutrons (Commemoration Issue Dedicated to Professor Takuji Yanabu on the Occasion of his Retirement) |
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NOTE

# Activation Cross Sections for Reaction Leading to Long-lived Reaction Products on Titanium, Manganese, Copper, Zinc, Strontium, Yttrium, Cadmium, Indium and Tellurium for 14.6 MeV Neutrons

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Although many workers[1] have measured the activation cross sections for 14 MeV neutrons, relatively a few data have been reported for the reaction leading to the long-lived reaction-products. The activities produced are measured either by absolute beta or gamma counting. The method is severely limited in accuracy when the cross sections are small and the reaction products are long-lived. The use of the high-resolution Ge (Li) detector permits the identification of very low activities and accurate measurement of their cross sections. Therefore we have undertaken to measure the reaction cross sections leading to the long-lived reaction products on Ti, Mn, Cu, Zn, Sr, Y, Cd, In and Te for 14.6 MeV neutrons with a shielded Ge(Li) detector.

Experimental procedures were similar to those of a previous investigation,[2] so that they are described only briefly here.

Sample powders of SrO and $Y_2O_3$ were pressed into plastic cups. Other samples were natural metal plates. Weights of the samples used were 0.3～1.5 gr. Thin Al-foils of about 50 mg were placed in the front and back of each sample. The samples and the monitor foils were covered with Cd-plates of 0.5 mm thick and were then irradiated for period of 200 m by 14.6 MeV neutrons.

After cooling periods of 14～30 d in which short-lived activities had decayed, the $\gamma$ spectra of long-lived activities were measured for periods of 8～24 h with a 60 $cm^3$ coaxial Ge(Li) detector shielded with iron-plates of 30 mm thick and lead-plates of 70 mm thick. By the use of this shield, background counting rate was reduced by a factor of 40.

The $^{27}Al(n, \alpha)^{24}Na$ reaction with a cross section of $114.5 \pm 4$ mb[3] was used to monitor the neutron flux. The activities of Al were measured after several hours from the end of neutron irradiation.

Typical gamma energy spectrum is shown in Fig. 1. Tables I and II summarize the $(n, p)$ and $(n, \alpha)$ cross sections and $(n, 2n)$ cross sections, respectively, measured in the present work. These tables also show the half-lives[4] of the products, the $\gamma$-ray energies[4] and the number of $\gamma$ quanta[4] emitted per disintegration used in the calcula-

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tion of the cross sections.

The $(n, p)$ and $(n, \alpha)$ cross sections predicted from the empirical formulas proposed by Kumabe and Fukuda[5,6] are also shown in Table I. The predicted values are in good agreement with the present experimental cross sections.

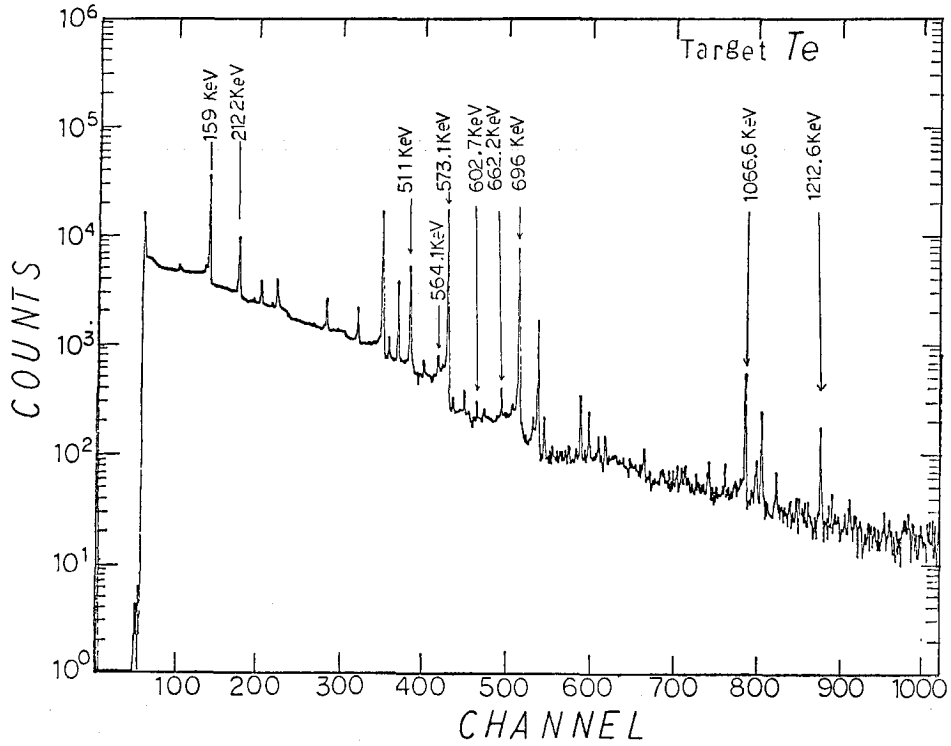


Fig. 1. Gamma energy spectrum for Te target after cooling period of 13 days.

Table I. Cross sections for $(n, p)$ and $(n, \alpha)$ reactions with 14.6 MeV neutrons

| REACTION | $T_{1/2}$ | $E_\gamma$ (keV) | $\eta$ (%) | cross section (mb) | |
|---|---|---|---|---|---|
| | | | | experimental | predicted |
| $^{46}Ti(n, p)^{46}Sc$ | 83.8 d | 1120.5 | 100 | 230 ±50 | 229. |
| $^{48}Ti(n, p)^{48}Sc$ | 43.7 h | 983.3 | 100 | 55.0 ± 5.0 | 61.5 |
| $^{86}Sr(n, p)^{86}Rb$ | 18.65 d | 1076.6 | 8.76 | 34.9 ± 8.4 | 36.5 |
| $^{110}Cd(n, p)^{110m}Ag$ | 253 d | 657.7 | 94.4 | 27.1 ± 4.7 | |
| $^{115}In(n, p)^{115g}Cd$ | 53.5 h | 527.9 | 27.5 | 5.1 ± 0.8 | |
| $^{122}Te(n, p)^{122}Sb$ | 2.72 d | 564.1 | 63 | 14.5 ± 3.1 | 14.6 |
| $^{124}Te(n, p)^{124g}Sb$ | 60.3 d | 602.7 | 98.1 | 8.4 ± 1.1 | |
| $^{50}Ti(n, \alpha)^{47}Ca$ | 4.54 d | 1296.8 | 75 | 11.5 ± 5.3 | 9.85 |
| $^{63}Cu(n, \alpha)^{60g}Co$ | 5.272 y | 1332.5 | 100 | 50.4 ± 5.7 | |
| $^{89}Y(n, \alpha)^{86g}Rb$ | 18.65 d | 1076.6 | 8.76 | 4.8 ± 2.1 | |
| $^{128}Te(n, \alpha)^{125g}Sn$ | 9.65 d | 1066.6 | 9 | 0.78± 0.45 | |

$\eta$: Intensity of $\gamma$-rays per disintegration

Table II. Cross sections for $(n, 2n)$ reaction with 14.6 MeV neutrons

| REACTION | $T_{1/2}$ | $E_\gamma$ (keV) | $\eta$ (%) | experimental cross section (mb) |
|---|---|---|---|---|
| $^{55}Mn(n, 2n)^{54}Mn$ | 312.5 d | 834.8 | 100 | 884± 58 |
| $^{66}Zn(n, 2n)^{65}Zn$ | 243.7 d | 1115.5 | 49.8 | 588± 65 |
| $^{86}Sr(n, 2n)^{85g}Sr$ | 65.2 d | 514 | 99.3 | 918± 74 |
| $^{89}Y(n, 2n)^{88}Y$ | 106.6 d | 898 | 93 | 962± 78 |
| $^{116}Cd(n, 2n)^{115m}Cd$ | 44.6 d | 934.1 | 1.9 | 799± 82 |
| $^{116}Cd(n, 2n)^{115g}Cd$ | 53.5 h | 527.9 | 27.5 | 842± 70 |
| $^{115}In(n, 2n)^{114m}In$ | 49.51 d | 189.9 | 17.7 | 1331±110 |
| $^{120}Te(n, 2n)^{119m}Te$ | 4.7 d | 1212.6 | 67 | 673± 74 |
| $^{120}Te(n, 2n)^{119g}Te$ | 16 h | 644.1 | 88 | 679±121 |
| $^{122}Te(n, 2n)^{121m}Te$ | 150 d | 212.2 | 81 | 906± 73 |
| $^{122}Te(n, 2n)^{121g}Te$ | 17 d | 573.1 | 79.1 | 721± 60 |
| $^{124}Te(n, 2n)^{123m}Te$ | 119.7 d | 159 | 83.5 | 863± 69 |
| $^{130}Te(n, 2n)^{129m}Te$ | 33.4 d | 696 | 2.9 | 1203± 97 |

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