Proc. Indian natn. Sci. Acad., 55, A, No. 1, 1989, pp. 46–49

COMPUTED PARTIAL NEUTRON CROSS-SECTIONS OF ^{51}V AT 14 MeV FOR TRACE ELEMENTAL ANALYSIS OF BIOLOGICAL SAMPLES

R S KHANCHI *and* S K JAIN

Dyal Singh College, Karnal (Haryana) 132 001, India

and

R K MOHINDRA

Department of Physics, Kurukshetra University, Kurukshetra (Haryana) 132119, India

(*Received 23 March 1987; accepted 6 January 1988*)

The present paper describes the primary and secondary computed partial neutron reaction cross-sections at 14 MeV for ^{51}V. The computations are based on the compound nucleus theory using an optical model potential and Newton's shell-dependent level density formula. The computed partial cross-sections have been compared with the available experimental values and are fairly in good agreement. These cross-sections have been used for the trace elemental analysis of biological samples like brain, muscle, liver, testes, lung, lymph nodes and blood of human subjects.

The induced β-activity per gram of above biological samples per unit neutron flux have been computed for the reactions $^{51}V\,(n,p)\,^{51}Ti^*$ with $T_{1/2} = 5.8$ min and $^{51}V\,(n,\alpha)\,^{48}SC^*$ with $T_{1/2} = 1.81$ days and are tabulated here.

Key Words : Partial Reaction Cross-Sections; Trace Elemental Analysis; Neutron Flux; Induced Activity; Biological Samples; Optical Model Potential

INTRODUCTION

THE primary reactions like (n, n'); (n, p) and (n, α) induced by 14 MeV neutron energy are quite prominent. Out of all possible secondary reactions like $(n, 2n)$; (n, np); $(n, n\alpha)$, (n, pn); $(n, 2p)$; $(n, p\alpha)$; $(n, \alpha n)$; $(n, \alpha p)$ & $(n, 2\alpha)$ only $(n, 2n)$, (n, np) (n, pn) contribute significantly and have large cross-sections.

A knowledge of these computed interaction cross-sections may be useful for design of fission and fusion nuclear devices, thermal and fast breader reactors, controlled thermo-nuclear devices and shielding problems at low energies.

The compound nucleus theory based on Fermi gas and evaporation model with optical model potential and Newton's shell-dependent level density formula have been used here for the computation of the partial primary and secondary neutron cross-sections for ^{51}V at 14 MeV neutron energy. Using these computed partial cross-sections one can estimate the value of induced activity per unit neutron flux per gram of biological samples like brain, muscle, liver, testes, lung, lymph nodes and blood. These computed activities may be useful in designing the experiment and estimating the irradiation time of the above samples by the activation analysis for trace elemental analysis.

Hamilton *et al.*[1] reported the values of vanadium contents for adult human tissues in μg/g as brain – 0.03 ± 0.008, muscle — 0.01 ± 0.003, liver — 0.04 ± 0.01, testes — 0.2 ± 0.08, lung – 0.10 ± 0.02 and lymph nodes – 0.4 ± 0.2 wet weight. According to Underwood,[2] vanadium in human dental enamel is 0.1 μg/g and in whole blood varies from 1 to 2 μg/100 ml. Estimates of the normal average daily intakes of vanadium by man is about 1.2 mg. According to Prasad,[3] Vanadium is an important factor in controlling one or more enzymatic or catalytic reactions. Schroeder[4] reported 0.3 ppm vanadium in modern man. The toxicity of Vanadium has been found to be greater when the eatable compounds are fed in a purified diet than when these compounds are given in natural diet. Vanadium has been found to lower human serum cholestrol some what in some individuals but not others. It is concentrated highly in fats specially vegetable oils. Vanadium can suppress cholesterol and fat-metabolism. It has been analysed that there is a correlation of cadmium plus vanadium with heart disease.

Schroeder[4] reported that the burning of coal and petroleum products provides air polluted with vanadium and other elements.

Vanadium poisoning is confined to the workers cleaning petroleum storage tanks and accumulates in the human lungs. Vanadium workers who absorb a log of V get green tongues syndrome. Vanadium can be used to treat the diseases like syphilis, tuberculosis, anaemia, neurasthenia and rheumatism.

CALCULATIONS, RESULTS AND DISCUSSIONS

The computation of primary and secondary reaction cross-sections based on compound nucleus model, the optical potential parameters given by Mani *et al.*[5] have been used as described earlier by Wadhwa & Mohindra.[6] For the alpha induced inverse reaction cross-sections, the inverse reaction cross-sections listed by Huizenga and Igo[7] have been used.

Newton's level density formula as discussed by Wadhwa *et al.*[8] has been used for the computation of partial cross-sections. The recent Q-values and separation energies have been used as listed by Wapstra and Bos.[9] The gamma ray emission has been ignored in comparison to the particle emission. The computed partial cross-sections at 14 MeV neutron energy are listed in Table I, alongwith the available experimental cross-sections listed by Borman *et al.*[10] for comparison and these are in reasonable good agreement.

As reported earlier by Khanchi *et al.*[11,12] the beta-induced activity in micro Curies per unit neutron flux per gram of the biological samples containing ^{51}V for the experimental investigation is given by the relation :—

$$\frac{0.693 \times \text{No. of atoms of (Vanadium)} \times [\sigma_{(n,p)} \text{ or } \sigma_{(n,\alpha)} \text{ cm}^2)] \times \text{(Isotopic abundance)}}{3.7 \times 10^4 \times T_{1/2}\,\text{(Sec.)}}$$

where $T_{1/2}$ is the physical half life of the residual nuclei $^{51}Ti^*$ (= 5.8 min) and $^{48}Sc^*$ (= 1.81 days).

The reactions $^{51}V(n, p)$ $^{51}Ti^*$ with $\sigma_{(n,p)} = 36.27$ mbs and $^{51}V(n, \alpha)$ $^{48}Sc^*$ with $\sigma_{(n,\alpha)} = 20.0$ mbs are the most suitable for the ^{51}V trace elemental analysis out of the various possible reactions listed in the Table I. The computed induced β-activities of human biological samples like brain, muscle, liver, testes, lung, lymph nodes and blood in μc per unit neutron flux per gram of the samples are listed in Table II. These activities seem sufficient for the experimental investigation with 14 MeV neutron generators having flux of the order of 10^8 to 10^{10} neutrons per cm^2 per second.

TABLE I

Computed ^{51}V partial reaction cross-sections for 14 MeV neutrons

S. No.	Nuclear Reaction	Q-Value (Mev)	Computed Cross-sections (mbs)	Available Experimental Cross-sections (mbs)
1.	^{51}V (n, n') $^{51}V^*$	0	1237.8	—
2.	^{51}V $(n, 2n)$ $^{50}V^*$	—11.052	47.63	—
3.	^{51}V (n, np) $^{50}Ti^*$	—8.056	247.7	—
4.	^{51}V $(n, n\alpha)$ $^{47}Sc^*$	—10.293	~0	—
5.	^{51}V (n, p) $^{51}Ti^*$	—1.676	36.27	20 ± 7
6.	^{51}V (n, pn) $^{50}Ti^*$	—6.372	12.12	—
7.	^{51}V $(n, 2p)$ $^{50}Sc^*$	—12.483	~0	—
8.	^{51}V $(n, p\alpha)$ $^{47}Ca^*$	—9.815	~0	—
9.	^{51}V (n, α) $^{48}Sc^*$	—2.055	20.0	43 ± 4
10.	^{51}V $(n, \alpha n)$ $^{47}Sc^*$	—8.238	<1	—
11.	^{51}V $(n, \alpha p)$ $^{47}Ca^*$	—9.444	~0	—
12.	^{51}V $(n, 2\alpha)$ $^{44}K^*$	—11.145	~0	—

TABLE II

Computed induced β–activity for ^{51}V (n, p) $^{51}Ti^*$ and ^{51}V (n, α) $^{48}Sc^*$ in human organs (wet-weight)

S. No.	Organs or Tissue	Vanadium content (μg/g)	Induced β-activity μC/Unit flux/g with	
			(n, p) reaction	(n, α) reaction
1.	Brain	0.03 ± 0.008	(0.69 ± 0.184) × 10^{-18}	(1.41 ± 0.376) × 10^{-22}
2.	Muscle	0.01 ± 0.003	(0.23 ± 0.069) × 10^{-18}	(0.47 ± 0.141) × 10^{-22}
3.	Liver	0.04 ± 0.01	(0.92 ± 0.23) × 10^{-18}	(1.88 ± 0.47) × 10^{-22}
4.	Testes	0.20 ± 0.08	(4.6 ± 1.84) × 10^{-18}	(9.4 ± 3.76) × 10^{-22}
5.	Lung	0.10 ± 0.02	(2.3 ± 0.46) × 10^{-18}	(4.7 ± 0.94) × 10^{-22}
6.	Lymph nodes	0.40 ± 0.20	(9.2 ± 4.6) × 10^{-18}	(18.8 ± 9.4) × 10^{-22}
7.	Dental Enamel	0.10	2.3 × 10^{-18}	4.7 × 10^{-22}
8.	Blood	(1 — 2) (a)	(23 — 46) × 10^{-18} (b)	(47 — 94) × 10^{-22} (b)

(a) μg/100 ml.

(b) μC/Unit flux/100 ml.

ACKNOWLEDGEMENTS

Authors (R S K & S K J) are grateful to NDRI, Karnal for liberal use of their library facilities and RSK is also acknowledges the University Grants Commission for a research grant.

REFERENCES

1 E I Hamilton *et al.* *Total Env* (1972/1973) 375
2 E J Underwood *Trace Elements in Human* Academic Press New York (USA) (1977)
3 A S Prasad *Trace Elements in Human Metabolism* Plenum Medical Book Company New York & London (1978)
4 H A Schroeder *The Trace Elements and Nutrition* F Faber and Faber 3 Queen Square London (1973)
5 G S Mani *et al.* *Proton and Neutron Penetrabilities Rep CEA* No 2379 & 2380 Saclay France (1963)
6 B S Wadhwa and R K Mohindra *Nucl Sci Engng* (*USA*) **56** (1975) 96–98
7 J R Huizenga and G Igo *Nucl Phys* **29** (1962) 462
8 B S Wadhwa *et al.* *Indian J pure & appl Phys* **12** (1974) 645-647
9 A H Wapstra and K Bos *Atom Data nucl Data Tables* (1977) 190
10 M Borman. H Neuert and W Scobal *Handbook of Neutron Cross-sections* IAEA Austria (1974)
11 R S Khanchi and R K Mohindra *Proc Indian natn Sci Acad* **50**A (1984) No. 4, 382–385
12 R S Khanchi *et al.* *Proc Indian natn Sci Acad* **51**A (1985) No. 6, 998–1002