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TWO-GROUP CONSTANTS FOR AQUEOUS HOMOGENEOUS REACTOR CALCULATIONS

T. B. Fowler and M. Tobias

Introduction

A set of constants which have been used in two-group calculations for aqueous homogeneous reactors has been compiled. These data, assembled from a variety of sources, are believed to be reasonably reliable and consistent. The authors would appreciate notification of errors or improvements in the figures cited.

Cross Sections

Tables 1 and 2 list thermal microscopic absorption and fission cross sections for various elements and for various temperatures. Table 3 lists thermal macroscopic absorption cross sections for H_2O , D_2O , and Zr, and the density of H_2O and D_2O at the various temperatures. All cross sections listed under the columns headed by $^{\circ}C$ have been corrected for a Maxwell-Boltzmann flux distribution.

Values of η and ν for U^{233} , U^{235} , Pu^{239} , and Pu^{241} are given in Table 4.

Diffusion Constants, Ages, and Resonance Escape Probability

Figures 1 through 4 show τ , D_1 , D_2 , and $p^{(7)}$ as functions of concentration of Thorium-232 in mixtures of ThO_2 and heavy water (99.75% D_2O) at various temperatures. Figures 5 through 13 give values of τ , D_1 , D_2 , and $p^{(3)}$ at $280^{\circ}C$ and $330^{\circ}C$ as functions of concentration of U^{238} in solutions of UO_2SO_4 and H_2O and D_2O , and solutions of $UO_2SO_4-Li_2SO_4$ and H_2O and D_2O , where Li_2SO_4 is in molar concentration equal to uranium.

The diffusion coefficients and ages were calculated using an Oracle code devised by M. Tobias.⁽⁸⁾

TABLE 1

THERMAL MICROSCOPIC ABSORPTION CROSS

SECTIONS AT VARIOUS TEMPERATURES

(Corrected for Maxwell-Boltzmann Distr. and also non $\frac{1}{v}$ cor. as in BNL 325)

Element	$\sigma_a^{(1)}$ -barns										
	Neutron Velocity 2200 meters/sec	20°C	50°C	100°C	150°C	200°C	250°C	280°C	300°C	320°C	330°C
U ²³³	588	526	504	460	430	410	385	376	371	364	361
U ²³⁴	92	82	78	72	68	64	61	59	58	57.3	56.8
U ²³⁵	689	595	561	515	479	449	430	411	402	397	392
U ²³⁶	6	5.3	5.1	4.7	4.4	4.2	4.0	3.9	3.8	3.7	3.7
U ²³⁸	2.73	2.42	2.31	2.15	2.01	1.90	1.81	1.76	1.73	1.70	1.69
Pa ²³³ (2)	150	133	127	118	111	105	100	97	95	94	93
Th ²³²	7.45	6.60	6.29	5.85	5.50	5.20	4.94	4.81	4.72	4.64	4.60
Pu ²³⁹	1025	975	931	905	895	896	915	950	954	957	969
Pu ²⁴¹	1399	1240	1189	1118	1061	1016	972	952	940	927	914
S	0.49	0.43	0.41	0.39	0.36	0.34	0.33	0.32	0.31	0.30	0.30
Li ⁷ (99.98%)(3)	0.23	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.14	0.14

TABLE 2

THERMAL MICROSCOPIC FISSION CROSS
SECTIONS AT VARIOUS TEMPERATURES

(Corrected for Maxwell-Boltzmann Distr. and also non $\frac{1}{v}$ cor. as in BNL 325)

Element	$\sigma_a^{(1)}$ -barns										
	Neutron Velocity 2200 meters/sec	20°C	50°C	100°C	150°C	200°C	250°C	280°C	300°C	320°C	330°C
U ²³³	532	472	452	412	386	368	346	337	332	326	324
U ²³⁵	582	506	478	438	408	382	366	350	342	338	334
Pu ²³⁹	748	711	680	660	653	654	668	693	696	699	707
Pu ²⁴¹	970	860	824	776	736	705	674	660	652	643	634

TABLE 3

THERMAL MACROSCOPIC ABSORPTION CROSS SECTIONS
AND DENSITIES AT VARIOUS TEMPERATURES

Element	(All Cross Sections Corrected for Maxwell-Boltzmann Distribution on Basis of $\frac{1}{v}$ Cross Section)									
	20°C	50°C	100°C	150°C	200°C	250°C	280°C	300°C	320°C	330°C
$\Sigma_a(\text{H}_2\text{O})^{(1)}$	0.0196	0.0184	0.0167	0.0149	0.0133	0.0117	0.0107	0.0100	0.0092	0.0087
$\Sigma_a(\text{D}_2\text{O})^{(4)}$	8.02×10^{-5}	7.55×10^{-5}	6.85×10^{-5}	6.15×10^{-5}	5.49×10^{-5}	4.86×10^{-5}	4.44×10^{-5}	4.14×10^{-5}	3.82×10^{-5}	3.59×10^{-5}
$\Sigma_a(\text{Zr})^{(1)}$	0.00674	0.00642	0.00598	0.00561	0.00531	0.00504	0.00491	0.00482	0.00474	0.00470
$\rho(\text{D}_2\text{O})^{(5)}$	1.105	1.100	1.062	1.015	0.958	0.880	0.828	0.785	0.733	0.703
$\rho(\text{H}_2\text{O})^{(5)}$	1.000	0.990	0.962	0.916	0.864	0.798	0.749	0.712	0.667	0.640

TABLE 4

VALUES OF η AND ν FOR U AND PU⁽⁶⁾

<u>Element</u>	<u>η</u>	<u>ν</u>
U ²³³	2.25	2.50
U ²³⁵	2.08	2.46
Pu ²³⁹	1.93	3.08
Pu ²⁴¹	2.23	3.21

Diffusion coefficients for Zircaloy:⁽⁴⁾

$$D_1 = D_2 = 0.98 \text{ for all temperatures.}$$

Resonance Integrals⁽⁹⁾

Some formulas used in calculating resonance integrals are given below.

For U^{238} :

$$RI = 3.9 \left(\frac{\Sigma_s}{N^{28}} \right)^{0.415} \quad 0 \leq \frac{\Sigma_s}{N^{28}} \leq 10^3$$

$$\ell_n RI = 5.48 - \frac{39.2}{\sqrt{\Sigma_s/N^{28}}} \quad \frac{\Sigma_s}{N^{28}} > 10^3$$

$$RI(\infty) = 240 \text{ b}$$

For Th^{232} :

$$RI = 8.33 \left(\frac{\Sigma_s}{N^{02}} \right)^{0.253} \quad 0 \leq \frac{\Sigma_s}{N^{02}} \leq 160$$

$$\ell_n RI = 4.233 - \frac{10.54}{\sqrt{\Sigma_s/N^{02}}} \quad \frac{\Sigma_s}{N^{02}} > 160$$

$$RI(\infty) = 69 \text{ b}$$

For U^{233} and U^{235} :

$$RI = 2 RI(\infty) \left[\sqrt{(1 + \beta) \beta} - \beta \right]$$

$$\beta = \frac{0.1 \pi}{RI(\infty)} \left(\frac{\Sigma_s}{N} \right)$$

$$RI(\infty) = \int_{E^*}^{\infty} \sigma_a \frac{dE}{E} \quad (E^* = \text{thermal cut-off energy})$$

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Fig. 5

Fermi Age and Fast and Thermal Diffusion
Coefficients vs Concentration of U^{238} in
Solutions of UO_2SO_4 and Pure D_2O at $280^\circ C$

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Fig. 6

Permeability and Fast and Thermal Diffusion
Coefficients vs Concentration of U^{238} in
Solutions of UO_2SO_4 and Pure H_2O at $280^\circ C$

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Fig. 7

Fermi Age and Fast and Thermal Diffusion Coefficients vs. Concentration of U^{238} in Solutions of $UO_2SO_4 \cdot Li_2SO_4$ (Li_2SO_4 Molar Concentration Equal to Uranium) and Pure D_2O at $280^\circ C$

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Fig. 8

Fermi Age and Fast and Thermal Diffusion Coefficients vs. Concentration of U^{238} in Solutions of $UO_2SO_4 \cdot Li_2SO_4 (Li_2SO_4 \text{ Molar Concentration Equal to Uranium})$ and Pure H_2O at $280^\circ C$

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Fig. 9

Fermi Age and Fast and Thermal Diffusion Coefficients vs. Concentration of U^{238} in Solutions of $UO_2SO_4 \cdot Li_2SO_4$ (Li_2SO_4 Molar Concentration Equal to Uranium) and Pure D_2O at $330^\circ C$

Fig. 10

Fermi Age and Fast and Thermal Diffusion Coefficients vs. Concentration of U^{238} in Solutions of UO_2SO_4 - Li_2SO_4 (Li_2SO_4 Molar Concentration Equal to Uranium) and Pure H_2O at $330^\circ C$

Fig. 11
Resonance Escape Probability vs. Concentration
of U^{238} in Solutions of UO_2SO_4 and Pure D_2O and
 H_2O at $280^\circ C$

Fig. 12
Resonance Escape Probability vs. Concentration
of U^{238} in Solutions of $UO_2SO_4-Li_2SO_4$ (Li_2SO_4
Molar Concentration Equal to Uranium) and Pure
 D_2O and H_2O at $280^\circ C$