Reactor Theory

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AGE TO THERMAL ENERGY (.025 e.v.) OF FISSION NEUTRONS IN H_2O-AL MIXTURES

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Nancy M. Dismuke and M. Ruth Arnette

The neutron age in a H_2O-Al mixture has been calculated as a function of energy for

$$\frac{\text{volume of Al}}{\text{volume of } H_2O} = 0,\ \tfrac{1}{2},\ 1,\ \text{and } 3/2.$$

The formula used in the calculation is that for the second moment of the slowing down range for neutrons in a given moderator (see A-1827 or MT-17):

$$\tau(x,u) = \frac{\overline{r^2}}{6}\Big|_{x \to u} = \frac{1}{3}\frac{\lambda^2(x)}{c(x)} + \frac{1}{3}\frac{\lambda^2(u)}{c(u)} + \frac{1}{3}\lambda(x)\lambda(u)\, e^{-\int_x^u [3/2-c(y)]\,dy} + \frac{1}{3}\lambda(u)\int_x^u \lambda(y)dy\, e^{-\int_y^u [3/2-c(s)]\,ds}$$

$$+ \frac{1}{3}\int_x^u \frac{\lambda^2(y)}{c(y)}dy + \frac{1}{3}\lambda(x)\int_x^u \lambda(y)dy\, e^{-\int_x^y [3/2-c(s)]\,ds}$$

$$+ \frac{1}{3}\int_x^u \lambda(y)dy \int_x^y \lambda(s)ds\, e^{-\int_s^y [3/2-c(w)]\,dw}$$

where:

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where:

$$\lambda = \frac{1}{\frac{\text{vol. of Al}}{\text{total vol.}} \sum_s^{Al} + \frac{\text{vol. of } H_2O}{\text{total vol.}} \sum_s^{H_2O}}$$

$$\lambda_H = \frac{1}{\frac{\text{vol. } H_2O}{\text{total vol.}} \sum_s^{H_2}}$$

$$c(x) = \lambda(x)/\lambda_H(x) .$$

$$\sum_s^{Al} = \frac{0.6}{27} \times 2.7 \times \sigma_s^{Al} ; \sum_s^{H_2O} = \frac{0.6}{18} \times 1 \; (2\sigma_s^{H} + \sigma_s^{O})$$

$$\sum_s^{H_2} = \frac{0.6}{18} \times 1 \times 2 \; \sigma_s^{H}$$

The energy is represented by $x = \ln \frac{6 \text{ mev}}{E(\text{in mev})}$.

U corresponds to x for E = .025 e.v.

Microscopic cross-sections used were taken from MUC-HHG-7, the neutron cross-section curves of H. H. Goldsmith and H. W. Ibser. In calculating the average age, $\bar{\tau}$, the thermal neutron fission spectrum of LA-84 was used.

Microscopic and macroscopic cross-sections, the calculated ages for $\frac{\text{volume of Al}}{\text{volume of } H_2O} = 0, \frac{1}{2}, 1, 3/2$, and the average age for each volume ratio are listed in Table I.

Figure I shows the age as a function of energy and Figure II shows the age averaged over the fission spectrum as a function of volume ratio.

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In the case of $\frac{\text{volume of Al}}{\text{volume of } H_2O} = 0$, the age was calculated for energies from .025 e.v. to 10 mev. The average age, $\bar{\tau}$, was found over the energy range .025 e.v. to 6 mev. and over the energy range .025 e.v. to 10 mev. The value of σ_s^o from 6 mev to 10 mev was assumed to be the same as σ_s^o(6 mev.). An error in σ_s^o in this energy interval would affect $\bar{\tau}$ very little. However, in the case of H_2O-Al mixtures the age calculation was not extended beyond 6 mev the highest energy for which σ_s^{Al} is known. The calculated $\bar{\tau}$(6 mev to .025 e.v.) for the H_2O-Al mixtures were normalized to the value obtained for $\bar{\tau}$(10 mev to .025 ev.) for H_2O by multiplying by the ratio of the two H_2O ages found experimentally and by calculation from MeV to thermal. Both the calculated and normalized values of $\bar{\tau}$ are shown in Table I and in Figure II.

In these calculations we have assumed that the Al is infinitely heavy, and that it scatters spherically symmetrically in the c. of g. system. The first assumption introduces very little error; but the second assumption is probably incorrect. The total scattering cross-section of Al at a few MeV is already larger than the theoretical maximum for s scattering. This means that there must be some p or higher scattering, which, depending on its sign, would make these calculated ages either too high or too low.

This calculation was made under the direction of A. M. Weinberg and H. Soodak.

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E (mev)	$\ln \frac{6\ mev}{E}$	Microscopic cross-sections (in barns) H	O	Al	Macroscopic cross-sections $(\frac{cm^2}{cm^3})$ H_2O	Al	H_2	Neutron Age, τ, from E to thermal energy (.025 e.v.) in (cm^2)			
$2.5x10^{-8}$	19.30	57	4.1	1.51	3.93	.091	3.81				
$3.163x10^{-8}$	19.06	53	4	1.67	3.66	.100	3.54				
$1x10^{-7}$	17.91	36	4	1.60	2.53	.096	2.41	.24	.52	.89	1.37
$3.163x10^{-7}$	16.76	25	4	1.55	1.80	.093	1.67				
$1x10^{-6}$	15.61	22	4	1.51	1.60	.091	1.47	.99	2.03	3.44	4.95
$3.163x10^{-6}$	14.46	21	4	1.49	1.53	.089	1.40				
$1x10^{-5}$	13.30	21	4	1.46	1.53	.088	1.40	1.90	3.95	6.40	8.82
$3.163x10^{-5}$	12.15	21	4	1.41	1.53	.085	1.40				
$1x10^{-4}$	11.00	21	4	1.42	1.53	.085	1.40	2.59	5.91	9.63	13.97
$3.163x10^{-4}$	9.851	21	4	1.42	1.53	.085	1.40				
$1x10^{-3}$	8.700	21	4	1.42	1.53	.085	1.40	3.53	7.88	12.95	19.19
$1.778x10^{-3}$	8.124	20.5	4	1.50	1.50	.090	1.37				
$3.163x10^{-3}$	7.548	20.5	3.9	1.50	1.50	.090	1.37				
$5.623x10^{-3}$	6.973	20	3.9	1.50	1.46	.090	1.34				
$1x10^{-2}$	6.397	19.5	3.8	1.50	1.43	.090	1.30	4.61	10.01	16.43	25.00
$1.778x10^{-2}$	5.821	18.5	3.8	1.60	1.36	.096	1.24				
$3.163x10^{-2}$	5.245	17	3.8	1.90	1.26	.114	1.14				
$5.623x10^{-2}$	4.670	15.5	3.9	2.30	1.16	.138	1.04				
$1x10^{-1}$	4.094	13	3.8	3.20	.99	.192	.87	6.54	13.41	21.78	32 *
$1.778x10^{-1}$	3.519	11.5	3.3	3.80	.88	.228	.77	7.28	14.73	23.71	35 *
$3.163x10^{-1}$	2.943	8	4	4.00	.67	.240	.53	8.76	17.27	27.30	39.50
$5.623x10^{-1}$	2.370	6	3.4	3.90	.51	.234	.40	11.20	21.21	32.70	46.25
1	1.7918	4.5	4.6	3.50	.45	.210	.30	14.42	26.47	40.03	57.90
1.778	1.2163	3.	1.3	2.90	.24	.174	.20	25.58	42.06	60.63	77.70
3.163	.6402	2	1.5	2.40	.18	.144	.13	45.60	69.17	96.03	116.2
5.623	.0649	1.5	1.1	2.00	.14	.120	.10	78.20	112.85	151.30	197
6.00	0.0	1.3	1.0	2.00	.1202	.120	.0868	91.46	128.96	170.13	208.05
6.80	-.125	1.2	1.0		.1136		.0802	104.90			
7.68	-.250	1.0	1.0		.1002		.0668	130.27			
8.73	-.375	.9	1.0		.0935		.0601	153.24			
9.89	-.500	.8	1.0		.0868		.0534	181.76			
10	-.5108	.8	1.0		.0868		.0534	183.05			

$\bar{\tau}$, average age, using the fission spectrum from LA-84:

$\bar{\tau}$ average over 0-6 mev energy interval	30.00	47.53	67.57	86.7
0-10 Mev. Ener. Int.	33.27	52.28	74.33	95.4

$\bar{\tau}$ Normalized to $\bar{\tau}$ H_2O = 33

* These values of τ were read from the curve, Figure I

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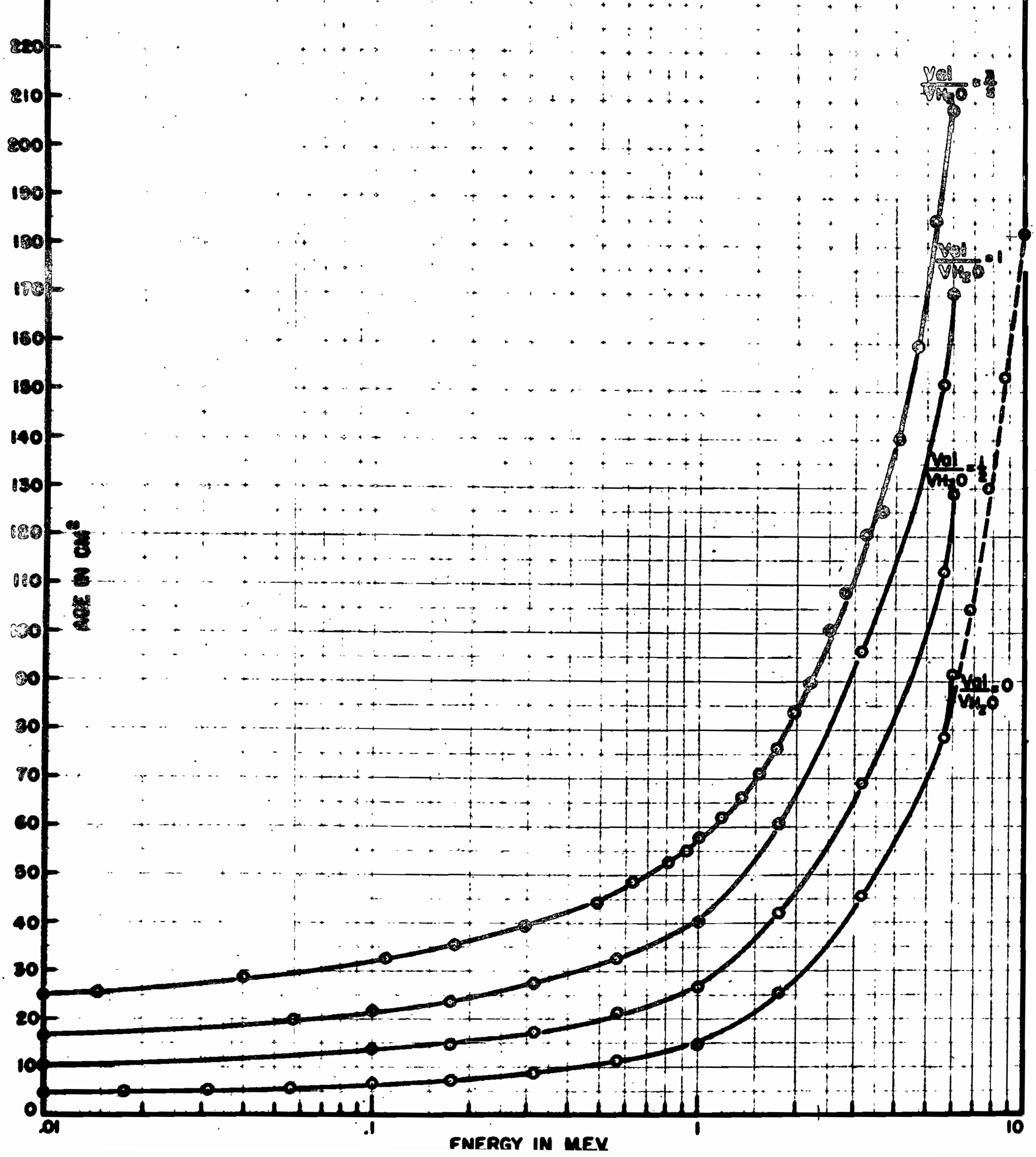
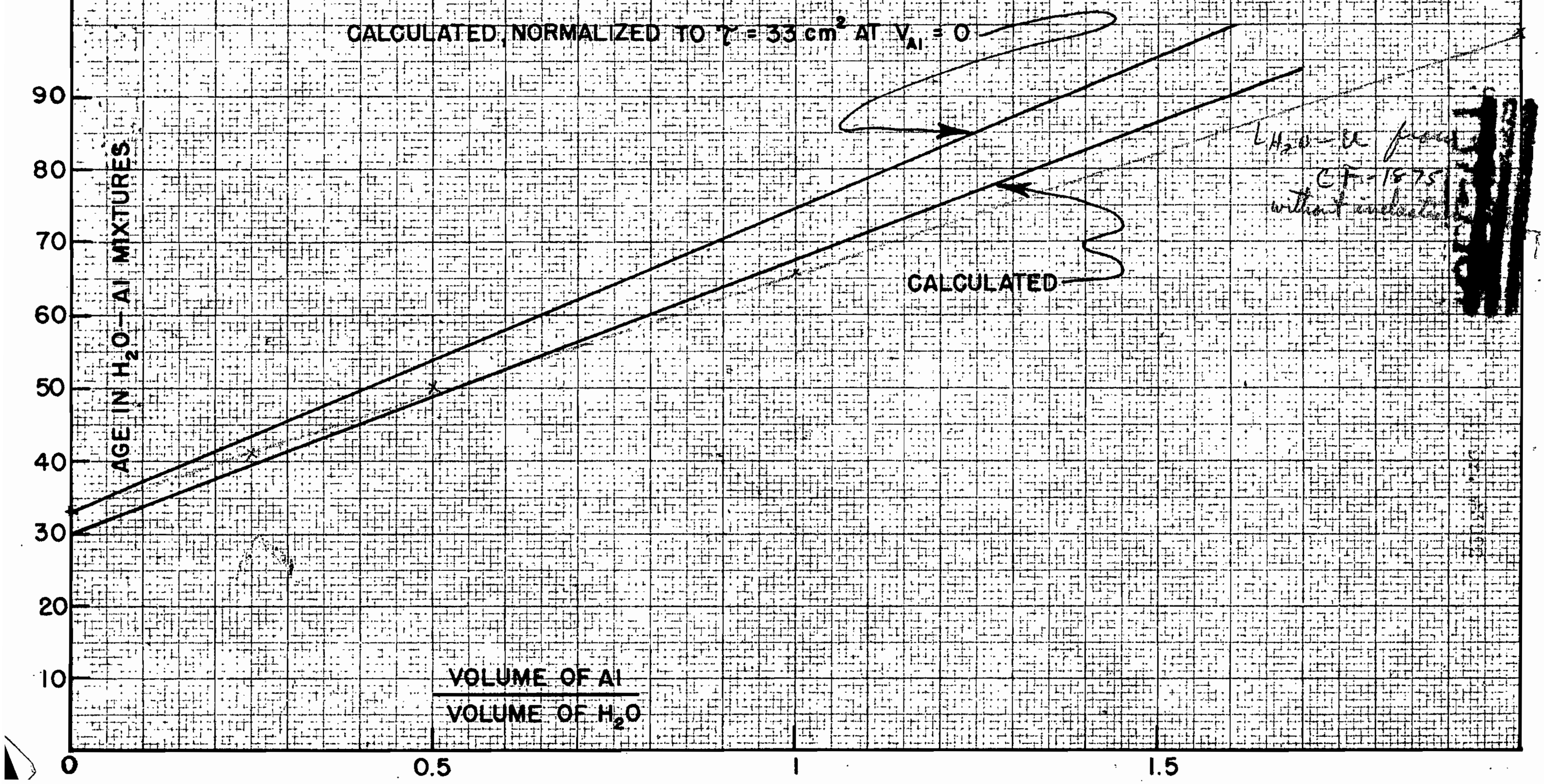
FIG. I

NEUTRON AGE AS A FUNCTION OF ENERGY IN MIXTURES OF H_2O AND AL



— FIG. 2 —

AGE TO THERMAL ENERGY (.025) OF FISSION NEUTRONS IN H_2O — Al MIXTURES



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