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Letters to the Editors

Use of Soluble Poisons in Fuel Processing

An infinite volume of solution of fissile material may be rendered subcritical by the inclusion of a soluble poison. The important questions of stability of such solutions and compatibility with the overall processing will not be considered here. The study is limited to establishing a universal relation between the numbers of atoms of fissile material, hydrogen and poison.

The development employs two-group diffusion theory. The sufficient condition for subcriticality is the absence of a positive root for the material buckling equation. This is equivalent to:

$$ah > bg, \text{ where}$$

a is the sum of the rates of absorbing and moderating fast neutrons less the rate of production by fast fission

b is the rate of production by thermal fission

g is the rate of formation of thermal neutrons from moderation of fast neutrons

h is the rate of absorption of thermal neutrons.

The system is limited to three components: fuel (F), moderator (M), poison (P). Whence

$$a = x\sigma_1^M - (\eta_1 - 1)\sigma_1^F$$

$$b = \sigma_2^F \eta_2$$

$$g = x\sigma_1^M$$

$$h = \sigma_2^F + \sigma_2^M (x + z),$$

where

$$x = N^M/N^F$$

$$z = (N^P/N^F)(\sigma_2^P/\sigma_2^M).$$

The sigmas are microscopic cross sections and the subscripts 1, 2 refer to the fast and the thermal group respectively. The N's are nuclide densities. Since only ratios of dimensioned quantities are used in the development, units are of no consequence.

Fast absorption by the moderator and by the poison is neglected. Hence we have from $ah = bg$

$$z = \frac{x^2 - (\zeta_1 r_1 + \zeta_2 r_2) - \zeta_1 r_1 r_2}{\zeta_1 r_1 - x},$$

where

$$r_1 = \sigma_1^F/\sigma_1^M$$

$$r_2 = \sigma_2^F/\sigma_2^M$$

$$\zeta_1 = \eta_1 - 1$$

$$\zeta_2 = \eta_2 - 1\ .$$

The etas are the average numbers of fission neutron for each neutron absorbed. The equation for z may be written

$$z = (x + C)(B - x)/(x - A),$$

where

$$A = \zeta_1 r_1$$

$$C = \zeta_1 r_1 r_2/(r_1 \zeta_1 + r_2 \zeta_2)$$

$$B = C + (r_1 \zeta_1 + r_2 \zeta_2).$$

Figure 1 shows z vs x on a log-log plot for solutions of U^{235} and Pu^{239}. Note vertical asymptotes at $x = A, B$.

As an example, consider how much natural boron is required to make a uranyl nitrate solution, containing 400 g/liter of U^{235}, subcritical.

For this system

$$N^M/N^F = x = 65.2\ .$$

From Fig. 1

$$z = 4800$$

but

$$\frac{\sigma_2^P}{\sigma_2^M} = \frac{755}{.294} = 2.57 \times 10^3,$$

TABLE I

Nuclide	σ_1 (barns)	σ_2 (barns)	ζ_1	ζ_2	A	C	B
H^1	0.73	0.294	—	—	—	—	—
U^{235}	11.0	695.0	1.30	1.06	19.6	2590	18.0
Pu^{239}	14.0	1030.0	1.34	1.10	25.7	3914	23.6

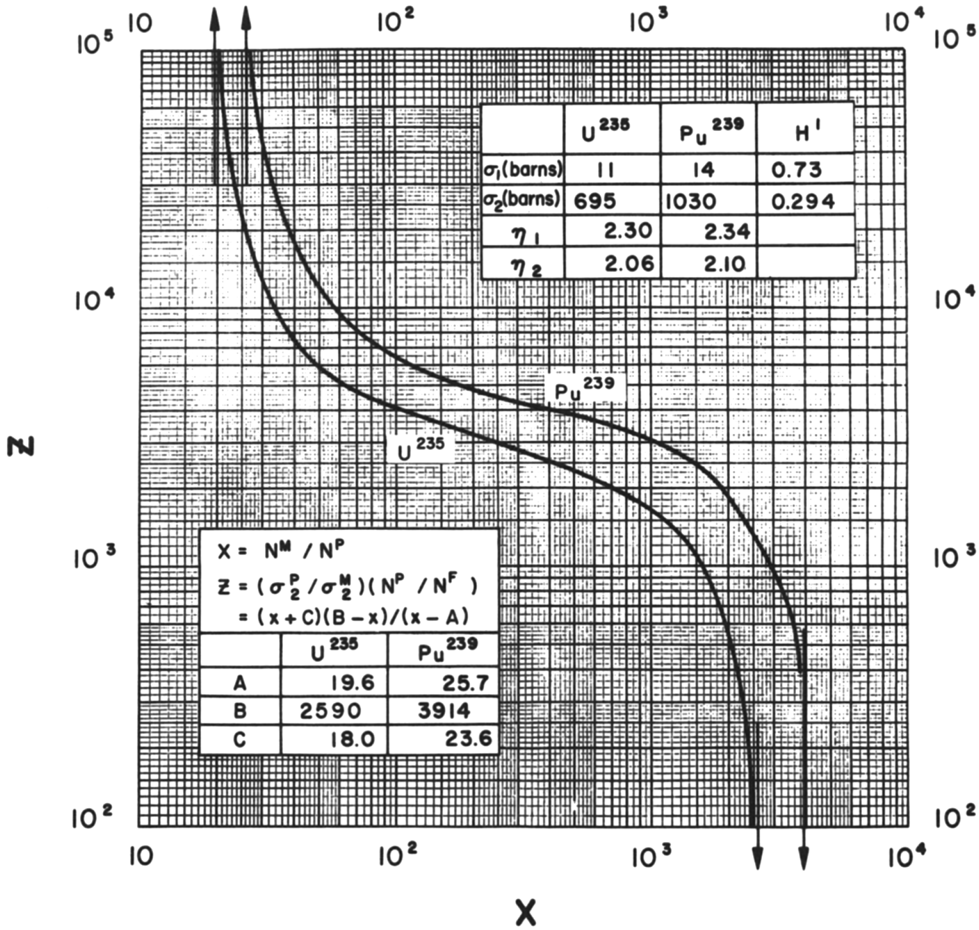

Fig. 1.

hence

$$\frac{N^P}{N^F} = \frac{4.80}{2.57} = 1.87.$$

Similar curves can be constructed for other fissionable materials.

The parameters used in obtaining the curves of Fig. 1 are given in Table I.

The thermal cross sections are taken from ANL 5800 Table 2.1. The fast cross sections were obtained from the Reactor Physics Branch of Phillips. These are considered reasonable but conservative values for the intended purpose.

W. B. Lewis

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Thermal Power of Promethium-147*

INTRODUCTION

More extensive use of large radioactive sources to produce heat (in thermoelectric generators for satellites and automatic weather stations, for example) point up the need for accurate knowledge of the rate of heat production of such materials.

Promethium-147, which is readily available from uranium fission products and has a convenient half-life of 2.67 years[1], is one of the most attractive isotopes for use in radioactive heat

*Research sponsored by the USAEC under contract with the Union Carbide Corporation.

[1] F. P. ROBERTS, E. J. WHEELWRIGHT and W. Y. MATSUMOTO, "The Half-Life of Promethium-147," USAEC Rpt. HW-77296, General Electric, Hanford Atomic Products Operation (April 1963).