ORNL/TM--12239

DE93 003641

ALPHN: A Computer Program for Calculating (α, n) Neutron Production in Canisters of High-Level Waste

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Date Published: October 1992

Prepared for the
U. S. Department of Energy
Office of Civilian Radioactive Waste Management
(Activity No. DB 04 02 11)

Prepared by the
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Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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ABSTRACT

The rate of neutron production from (α,n) reactions in canisters of immobilized high-level waste containing borosilicate glass or glass-ceramic compositions is significant and must be considered when estimating neutron shielding requirements. The personal computer program ALPHN calculates the (α, n) neutron production rate of a canister of vitrified high-level waste. The user supplies the chemical composition of the glass or glass-ceramic and the curies of the alpha-emitting actinides present. The output of the program gives the (α, n) neutron production of each actinide in neutrons per second and the total for the canister. The (α, n) neutron production rates are source terms only; that is, they are production rates within the glass and do not take into account the shielding effect of the glass. For a given glass composition, the user can calculate up to eight cases simultaneously; these cases are based on the same glass composition but contain different quantities of actinides per canister. In a typical application, these cases might represent the same canister of vitrified high-level waste at eight different decay times. Run time for a typical problem containing 20 chemical species, 24 actinides, and 8 decay times was 35 s on an IBM AT personal computer. Results of an example based on an expected canister composition at the Defense Waste Processing Facility are shown.

1. INTRODUCTION

At the end of 1991, about 1005 M curies of high-level waste (HLW) with a thermal output of about 2860 kW were in storage at four sites in the United States: West Valley Demonstration Project (WVDP), Savannah River Site (SRS), Hanford Site (HANF), and Idaho National Engineering Laboratory (INEL). It is estimated that the total quantities of HLW will increase to about 1200 M curies and 3570 kW by the end of year 2020. Under the Nuclear Waste Policy Act, this waste must ultimately be disposed of in a geologic repository. Plans are under way to immobilize the HLW at the four sites in canisters containing borosilicate glass or glass-ceramic mixtures. These canisters will be stored at the sites until a repository becomes available (Salmon 1991).

Among the characteristics needed in the design of shielding for handling canistered HLW are the rates of production of neutrons from spontaneous fission and (α, n) reactions within the canisters. Neutron production from (α, n) reactions takes place as a result of the action of energetic alpha particles from radionuclides such as ^{238}Pu, ^{241}Am, and ^{244}Cm on various light nuclides in the borosilicate glass or glass-ceramic such as ^{29}Si, ^{11}B, and ^{18}O. In vitrified HLW, the rate of neutron production from (α, n) reactions is, in most cases, greater than that from spontaneous fission.

This report describes a computer code for the calculation of the (α, n) neutron production rates of canisters of immobilized HLW. The code is designed for use on a personal computer. An example problem, based on the composition and actinide content of canistered HLW expected to be produced at the SRS, is included.

The Characteristics Data Base, sponsored by DOE's Office of Civilian Radioactive Waste Management, provides a data base of the technical characteristics of spent fuels, high-level waste, and other radioactive wastes that may require long-term isolation (DOE/RW 1992). The ALPHN code was developed as part of the Characteristics Data Base project.

2. ANALYTICAL METHOD

2.1 EXACT SOLUTION

When a single alpha-emitting actinide i emits α-particles of initial energy E_i within a homogeneous mixture of elements j, the rate of production of neutrons by (α, n) reactions within the mixture can be expressed by the following equation (West 1979):

$$Y_{i\,,\,mixture} = \sum_j n_j' \int_0^{E_i} \frac{\sigma_j(E)}{(-dE/dx)_{mixture}}\, dE. \tag{1}$$

In this equation, n'_j is the concentration of component j in atoms/cm^3, $\sigma_j(E)$ is the cross section (cm^2) of component j for the (α, n) reaction at energy E, and

$(-dE/dx)_{mixture}$ is the stopping power of the mixture for α-particles at energy E. The negative sign is used so that the stopping powers will have positive values. With these units, the yield $Y_{i,\ mixture}$ is in neutrons/α-particle. Knowing the rate of emission of α-particles, the yield can be found in neutrons per second. If more than one actinide is present, the total rate of neutron production is the sum of the contributions of the individual actinides.

Direct use of Eq. 1 would require knowledge of the cross sections $\sigma_j(E)$ as functions of energy. These are not, in general, available. However, Eq. 1 can be converted to a form in which the cross sections are eliminated in favor of the thick-target yields of the individual elements, which are available.

The expression given by West for the thick-target yield of neutrons from element j, when receiving α-particles of initial energy E_i, can be expressed as follows:

$$Y_j = n_j \int_o^{E_i} \frac{\sigma_j(E)}{(-dE/dx)_j} \, dE, \tag{2}$$

where n_j and $(-dE/dx)_j$ are the atoms/cm^3 and stopping power of element j in isolation, respectively. Equation 2 can be expressed in the form

$$\frac{dY_j}{dE} = \frac{n_j \sigma_j(E)}{(-dE/dx)_j}, \tag{3}$$

and the cross section $\sigma_j(E)$ can, therefore, be expressed as

$$\sigma_j(E) = \frac{1}{n_j} \left(-\frac{dE}{dx}\right)_j \left(\frac{dY_j}{dE}\right). \tag{4}$$

Replacing the cross section terms in Eq. 1 by means of Eq. 4, the expression for the neutron yield of a mixture becomes

$$Y_{i,mixture} = \sum_j \frac{n_j'}{n_j} \int_o^{E_i} \frac{(-dE/dx)_j \, (dY_j/dE)}{(-dE/dx)_{mixture}} \, dE. \tag{5}$$

Using Bragg's law of the additivity of stopping powers, West derived the following expression for the stopping power of the mixture in terms of the stopping powers of its individual constituents:

$$\left(-\frac{dE}{dx}\right)_{mixture} = \sum_j \frac{n_j'}{n_j}\left(-\frac{dE}{dx}\right)_j. \tag{6}$$

Using this in Eq. 5 gives the following:

$$Y_{i,mixture} = \sum_j \int_0^{E_i} \frac{(n_j'/n_j)\,(-dE/dx)_j\,(dY_j/dE)}{\sum_j (n_j'/n_j)\,(-dE/dx)_j}\,dE. \tag{7}$$

The Northcliffe and Schilling (Northcliffe 1970) tabulations of stopping power are given in the form $(-dE/\rho dx)_j$ and are denoted here by $S_j(E)$; thus

$$\left(-\frac{dE}{dx}\right)_j = \rho_j\,S_j(E). \tag{8}$$

Using this in Eq. 7, and dividing the numerator and denominator by $\rho_{mixture}$, results in the following:

$$Y_{i,mixture} = \sum_j \int_0^{E_i} \frac{(n_j'\rho_j/n_j\rho_{mixture})\,S_j(E)\,(dY_j/dE)}{\sum_j (n_j'\rho_j/n_j\rho_{mixture})\,S_j(E)}\,dE. \tag{9}$$

It can be shown that the fraction $(n'_j\,\rho_j/\,n_j\,\rho_{mixture})$ is identically equal to the mass fraction of element j in the mixture. This is done as follows:

$$\frac{n_j'\,\rho_j}{n_j\,\rho_{mixture}} = \left(\frac{n_j'}{\rho_{mixture}}\right)\left(\frac{\rho_j}{n_j}\right)$$

$$= \left(\frac{atoms\ of\ j\ /\ cm^3\ of\ mixture}{mass\ of\ mixture\ /\ cm^3\ of\ mixture}\right)\left(\frac{mass\ of\ j\ /\ cm^3\ of\ j\ (alone)}{atoms\ of\ j\ /\ cm^3\ of\ j\ (alone)}\right)$$

$$= \left(\frac{atoms\ of\ j}{mass\ of\ mixture}\right)\left(\frac{mass\ of\ j}{atoms\ of\ j}\right)$$

$$= \left(\frac{mass\ of\ j}{mass\ of\ mixture}\right). \tag{10}$$

The validity of Eq. 10 does not require the assumption of perfect additivity of volumes. If an expansion or contraction of volume occurs on mixing, both n'_j and $\rho_{mixture}$ will change by the same ratio, and, therefore, no change in their ratio will occur.

Denoting the mass fraction of j in the mixture by M_j and using Eq. 10 to simplify Eq. 9, the final expression for the mixture yield becomes

$$Y_{i,mixture} = \sum_j \int_0^{E_i} \frac{M_j\, S_j(E)\, (dY_j/dE)}{\sum_j M_j\, S_j(E)}\, dE. \tag{11}$$

Equation 11 represents the exact solution for the mixture yield for a single α-energy E_i. Assuming that data are available giving the thick-target yields Y_j and the stopping powers S_j as functions of energy, the expression on the right side of Eq. 11 can be evaluated by numerical differentiation and integration. Polynomial expressions or other types of functional approximations for Y_j and S_j as functions of E could be used as part of this procedure. The accuracy of the final value of the neutron yield will depend largely on the accuracy of the experimental data on yields and stopping powers, on the validity of the interpolation procedures used in supplying data where no experimental data are available, and on the precision of the numerical procedures.

2.2 WEST'S APPROXIMATE SOLUTION

West developed a simplification of the exact solution that eliminates the need for integration and gives a good approximate value for $Y_{mixture}$ (West 1979). The simplification is based on the observed fact that the stopping powers S_j of many elements vary in a similar manner with respect to energy. West's formulation, in effect, assumes that the stopping power of each element in the mixture can be expressed as

$$S_j(E) = C_j\, g(E), \tag{12}$$

in which C_j is a constant independent of energy for element j, and g(E) is a function of E that is the same for all elements j; that is, g(E) is independent of j. This approximation implies that the stopping powers of any two elements remain in a constant ratio to each other as E varies, this ratio being the ratio of their constants C_j.

To apply Eq. 12 to the simplification of Eq. 11, it is seen that

$$\sum_j M_j\, S_j(E) = \sum_j M_j\, C_j\, g(E), \tag{13}$$

and, since g(E) is independent of j,

$$\sum_j M_j\, S_j(E) = g(E) \sum_j C_j\, M_j. \tag{14}$$

Therefore, using Eq. 12,

$$\frac{M_j\, S_j(E)}{\sum_j M_j\, S_j(E)} = \frac{g(E)\, M_j\, C_j}{g(E) \sum M_j\, C_j} = \frac{M_j\, C_j}{\sum_j M_j\, C_j}. \tag{15}$$

Using Eq. 15 to simplify Eq. 11 results in the following:

$$\begin{aligned} Y_{i,\, mixture} &= \sum_j \int_o^{E_i} \left(\frac{M_j\, C_j}{\sum_j M_j\, C_j} \right) \left(\frac{dY_j}{dE} \right) dE \\ &= \sum_j \left(\frac{M_j\, C_j}{\sum_j M_j\, C_j} \right) \int_o^{E_i} \left(\frac{dY_j}{dE} \right) dE, \end{aligned} \tag{16}$$

which, in view of the fact that Y_j (0) = 0 for all j, reduces to

$$Y_{i,\, mixture} = \frac{\sum_j M_j\, C_j\, Y_j(E_i)}{\sum_j M_j\, C_j}. \tag{17}$$

Assuming the validity of Eq. 12, the C_j terms in Eq. 17 can be replaced by the corresponding S_j terms at an arbitrarily chosen energy E_o, giving

$$Y_{i,\, mixture} = \frac{\sum_j M_j\, S_j(E_o)\, Y_j(E_i)}{\sum_j M_j\, S_j(E_o)}. \tag{18}$$

If the stopping-power approximation given by Eq. 12 were exact, with C_j independent of energy and g(E) independent of j, then any energy could be chosen for E_o, provided that this same energy were used for all S_j. Because Eq. 12 is an approximation, the choice of E_o will have an effect on the error in the final result. In the ALPHN program, the stopping powers S_j are evaluated at the initial α-particle energy E_i. It appears possible that a more advantageous way of choosing E_o might be developed for specific classes of mixtures, such as vitrified high-level waste; however, no attempt was made to do this.

2.3 EXACT SOLUTION USING INTEGRATION BY PARTS

It was proposed by Leal et al. that the method of integration by parts be applied to the equation expressing the exact solution, Eq. 11 in the present discussion (Leal 1991). Integration by parts leads to a result that still requires the application of numerical methods to arrive at the neutron yield. However, as shown by Hermann, the equation resulting from the integration-by-parts approach very clearly shows the relationship between the exact solution and West's approximate solution (Hermann 1992). Integration by parts is based on the fact that if u and v are both functions of a third variable, then

$$d(u\ v) = u\ dv + v\ du, \tag{19}$$

and

$$\int u\ dv = u\ v - \int v\ du. \tag{20}$$

This can be applied to Eq. 11 by defining u and dv as follows:

$$u(E) = \frac{M_j\ S_j(E)}{\sum_j M_j\ S_j(E)} \tag{21}$$

$$dv = \left(\frac{dY_j(E)}{dE}\right) dE. \tag{22}$$

Equation 11 may then be written as

$$Y_{i,\ mixture} = \sum_j \int_o^{E_i} u(E)\ \ dv, \tag{23}$$

and v(E) is obtained from Eq. 22:

$$v(E) = \int dv = Y_j(E). \tag{24}$$

Use of Eq. 20 then gives the following:

$$Y_{i,\,mixture} = \left[\sum_j \frac{M_j\, S_j\, Y_j}{\sum_j M_j\, S_j} \right]_o^{E_i} - \sum_j \int_o^{E_i} Y_j(E) \frac{d\left(\frac{M_j\, S_j(E)}{\sum_j M_j\, S_j(E)}\right)}{dE}\, dE, \tag{25}$$

or, since Y_j (0) = 0 for all j,

$$Y_{i,\,mixture} = \frac{\sum_j M_j\, S_j(E_i)\, Y_j(E_i)}{\sum_j M_j\, S_j(E_i)} - \sum_j \int_o^{E_i} Y_j(E) \frac{d\left(\frac{M_j\, S_j(E)}{\sum_j M_j\, S_j(E)}\right)}{dE}\, dE. \tag{26}$$

The first term on the right side of Eq. 26 is West's approximation for the mixture yield, with the stopping powers S_j evaluated at energy E_i. The second term represents the correction that must be applied to West's approximation to obtain the exact solution. The evaluation of the second term requires the use of procedures such as numerical differentiation and integration, or their mathematical equivalent, as does the evaluation of Eq. 11.

Although the sign of the correction term is negative in the formulation used here, the actual correction to the first term was positive in the applications studied. That is, the neutron yields from vitrified high-level waste predicted by the exact solution are higher than those calculated by West's approximation using stopping powers evaluated at E_i. As discussed later in this report, the magnitude of the correction was quite small (typically about 0.5 to 0.7%) in the cases studied.

If West's approximation were exact, Eq. 12 would be an exact representation of S_j, and Eq. 15 shows that $M_j S_j/\sum M_j S_j$ would then be independent of E. The derivative of $M_j S_j/\sum M_j S_j$ with respect to E would, therefore, be zero, and the second term on the right side of Eq. 26 would vanish, showing that, under these circumstances, Eq. 26 reduces to West's approximation.

2.4 NEUTRON PRODUCTION RATE

To simplify the terminology used here, the total quantity of mixture under discussion is assumed to be one canister.

From an examination of Eq. 18, it can be seen that the units of $Y_{i,\,mixture}$ are the same as those of the thick-target yields $Y_j(E)$. These yields are customarily given in neutrons per million α-particles and are used in those units by the program. To calculate the neutron production rate in neutrons per second per canister resulting from α-particles of initial energy E_i, the yield $Y_{i,\,mixture}$ must be multiplied by the number of α-curies per canister having initial energy E_i and by the conversion factor 3.7×10^4, which converts α curies to millions of α-particles per second. Thus,

$$N_i = 3.7 \times 10^4 \, A_i \, Y_{i,mixture}, \tag{27}$$

where N_i is the neutron production rate per canister (n/s) due to α-particles of initial energy E_i, and A_i is the number of α-curies per canister of initial energy E_i. The total neutron production rate per canister due to α-emissions from all actinides present is then given by

$$N_{total} = \sum_i N_i . \tag{28}$$

2.5 NOTATION

A_i	α-curies of initial energy E_i, Ci/canister
C_j	constant in approximate expression for stopping power (see Eq. 12)
E	α-energy, MeV
g(E)	function of E in approximate expression for stopping power (see Eq. 12)
M_j	mass fraction of element j in mixture
N_i	neutron production rate due to α-particles of energy E_i, neutrons/s per canister
N_{total}	total neutron production rate, neutrons/s per canister
n_j	atoms of element j per cm^3, in isolation
n'_j	atoms of element j per cm^3 of mixture
S_j	stopping power of element j for α-particles, $(-dE/\rho dx)$, MeV cm^2/g
x	distance of travel through medium, cm
Y_j	thick-target yield for element j when receiving α-particles of initial energy E_i, neutrons/α-particle
$Y_j(E)$	thick-target yield for element j when receiving α-particles of initial energy E, neutrons/α-particle
$Y_{i,\ mixture}$	yield of neutrons from the mixture when receiving α-particles of initial energy E_i, neutrons/α-particle
ρ_j	density of element j in isolation, g/cm^3
$\rho_{mixture}$	density of mixture, g/cm^3
σ	cross section for (α, n) reaction, cm^2/atom

Subscripts:

i	actinide or actinide energy
j	element in mixture

3. COMPUTER PROGRAM

3.1 METHOD

The computer program ALPHN is written in FORTRAN for use with a personal computer. It calculates the (α, n) neutron production rate in a mixture of chemical species receiving α-particles from α-emitting actinides. The user specifies the mass fractions of the chemical species in the mixture and the curies of each actinide. Other basic data (stopping powers and thick-target yields) are supplied by the data library diskette of the program.

The program uses the method of West, which has been described in Sect. 2.2. Equation 18 of that section gives the expression used for the calculation of the neutron yield, $Y_{i,\, mixture}$ for a single α-particle energy E_i. The program assumes that α-emitting actinide i emits α-particles at an energy E_i, the average energy of α emission for that actinide. Approximate average energies were estimated for each actinide from data in Browne et al. (Browne 1986). The total neutron production rate per canister is calculated in the program by means of Eqs. 27 and 28, in which the summation is taken over all actinides i, and actinide i is assumed to emit α-particles with a single average initial energy E_i.

The total mass of mixture is not needed in the calculation of the total rate of neutron production; the only data needed on the mixture are the mass fractions of its components and the α-curies generated by the actinides in the total mass of the mixture, which is assumed to be one canister. The program assumes that the mass of the mixture is large enough to permit the use of thick-target yields, as is usually the case.

The total mixture yield calculated by the program is a source term; that is, it represents the rate of neutron production within the mixture, not the rate of neutron transmission to the outside of the mixture.

The assumption that each actinide emits α-particles with a single initial energy E_i is an approximation, but this approximation is believed to be justified in view of the approximate nature of other quantities used in the program.

3.2 INPUT DATA

3.2.1 Actinides

The program data library makes provision for 47 α-emitting actinides. These are listed in Table 1, which also shows the average α-energy used in the program for each actinide.

Table 1. Actinides available in ALPHN data library[a]

Identification number	Name	Average α energy (MeV)
1	BI211	6.550
2	BI212	6.051
3	PO210	5.304
4	PO212	8.784
5	PO213	8.376
6	PO214	7.686
7	PO215	7.386
8	PO216	6.779
9	PO218	6.001
10	AT217	7.066
11	RN219	6.812
12	RN220	6.288
13	RN222	5.489
14	FR221	6.357
15	RA223	5.697
16	RA224	5.675
17	RA226	4.774
18	AC225	5.750
19	TH227	5.902
20	TH228	5.399
21	TH229	4.862
22	TH230	4.665
23	TH232	4.006
24	PA231	4.923
25	U232	5.306
26	U233	4.814
27	U234	4.773
28	U235	4.378
29	U236	4.479
30	U238	4.194
31	NP237	4.760
32	PU236	5.752
33	PU238	5.500
34	PU239	5.150
35	PU240	5.155
36	PU242	4.890
37	PU244	4.575
38	AM241	5.480
39	AM243	5.266
40	CM242	6.043
41	CM243	5.838
42	CM244	5.800
43	CM245	5.363
44	CM246	5.376
45	CM247	4.948
46	CM248	5.073
47	CF252	5.931

[a]Data taken from Browne 1986 and IDB 1991.

The user prepares an input file, CURIES.IN9, giving the identification number and curies of each actinide present. If more than one case is to be run with the same target mixture composition, the first column of CURIES.IN9 represents the first case, the second column represents the second case, etc. Up to eight cases can be handled in one run. In typical runs, these cases represented different decay times for a canister of vitrified HLW. Formats are discussed in Appendix A.

3.2.2 Chemical Species

For describing the composition of the target mixture, the program makes provision for the use of the 42 chemical species and elements listed in Table 2. These species represent those most commonly used in describing the composition of vitrified HLW.

The user prepares an input file, ALPHN5Z.INP, giving the identification number and mass of each species present. In specifying mass, any quantity proportional to mass can be used (e.g., mass fraction, kg per canister, kg per 100 kg, lb per canister, etc.) The total mass present is not relevant to the calculation of the neutron production rate, except insofar as it affects the total α-curies, which, however, are input separately. Because of this, any mass basis may be used; however, a consistent basis must be used for all species.

When specifying a mixture composition, only the elemental content is significant; the chemical form is not significant. Because of this, species consisting of two or more elements can be specified in various ways at the option of the user. For example, calcium oxide could be entered as two species, Ca and O, or as the single species CaO. Fe_3O_4 could be entered as two species, FeO and O, adjusting the masses of these two species so that the mass of Fe and the mass of O entered agree with the corresponding masses in the Fe_3O_4. The program library stores the necessary elemental compositions of those species in the library that contain more than one element. The program calculates the total mass fraction of oxygen in the mixture by examining the mass fractions of the species that contain oxygen, as well as of elemental oxygen itself.

3.2.3. Data on Stopping Powers and Thick-Target Yields

The program library diskette contains stopping powers for 37 elements and thick-target yields for 10 elements at the α-energies of the 47 α-emitting actinides used in the program. These must be read into memory before using the ALPHN program.

The Northcliffe and Schilling tables give α-particle stopping powers as functions of energy for 12 solid media elements ranging from Be to U and nine gaseous media elements ranging from H to Rn. For elements not listed in the Northcliffe and Schilling tables, estimated stopping powers were obtained using linear interpolation based on atomic number.

Having estimated the stopping powers of the 37 elements specified in the program, linear interpolation with respect to energy was used to estimate stopping powers for these 37 elements at the α-energies of the 47 actinides in the program library.

Table 2. Chemical species used to describe mixture composition

Identification number	Species
1	Al_2O_3
2	B_2O_3
3	CaO
4	Fe_2O_3
5	K_2O
6	Li_2O
7	MgO
8	MnO
9	SiO_2
10	TiO_2
11	Na_2O
12	NiO
13	UO_2
14	O
15	F
16	ZrO_2
17	Cl
18	FeO
19	U_3O_8
20	MnO_2
21	P_2O_5
22	ThO_2
23	CdO
24	Cr_2O_3
25	Ni
26	CeO_2
27	Cs_2O
28	SrO
29	SO_4
30	Ca
31	Be
32	Ag
33	Ba
34	Pb
35	Zn
36	C
37	Ne
38	Eu
39	Ge
40	Ta
41	Ar
42	Cu

Thick-target neutron yields (neutrons per million alphas) as functions of energy were calculated by linear interpolation of values from sources in the literature. The 10 elements or isotopes for which yields are specified are Li (natural), ^{9}Be, B(natural), O (natural), ^{19}F, Mg (natural), ^{27}Al, Si (natural), ^{238}U, and Na (natural). Table 3 lists the thick-target yield data used in the program and the sources from which they were derived. From these data, linear interpolation with respect to energy was used to estimate thick-target yields at the α-energies of the 47 actinides listed in the program.

The interpolations were done in a service program (STPN6C), which produced the file STPN6A.OU3 that contains the stopping powers and yields needed in running the ALPHN program. The file STPN6A.OU3 is on the program library diskette.

3.2.4 Data Supplied in Data Statements

Data supplied within the ALPHN program as data statements include the following:

1. the mass fraction of oxygen in the chemical species that contain oxygen, and

2. the actinide names and α-energies corresponding to the actinide identification numbers in Table 1.

3.3 OUTPUTS

The output file, ALPHN5R.OUT, includes the following:

1. An echo of the input data as interpreted within the program. This shows the number of cases used in the run, the mixture composition, and the α-curies for the actinides in each case. For convenience, the mixture composition table also shows some items calculated within the program.

2. An echo of the basic library data (stopping powers and thick-target yields) for each element in the library at the energy of each actinide in the library. This output is optional and may be printed or suppressed by setting input signals, as discussed in Appendix A.

3. A table showing the final results of the calculation. This shows the (α, n) neutron production rates (neutrons/s) for each case in the run. The production rates are shown for each actinide as well as for the total.

4. Two additional optional tables showing intermediate calculated results. The first of these, with the heading "values of ADDJPY(I,J)," shows the numerators of the expression for the neutron yield (Eq. 18) for each actinide i and each element j. The total of these for each actinide i is also shown; this is the numerator of the expression in Eq. 18 for actinide i. The second table, with the heading "values of ADDJP(I,J)," shows the corresponding denominators for each actinide i and each element j. The total of these for a given actinide is the denominator of Eq. 18 for that actinide. The ratio of the numerator over

Table 3. Thick-target yields of neutrons from various target elements as a function of initial α-energy[a]

Initial α-energy (MeV)	Yield from element or isotope shown, neutrons/10^6α									
	Li(nat)[b]	Be-9	B(nat)	O(nat)	F-19	Mg(nat)	Al-27	Si(nat)	U-238	Na(nat)
1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.00	0.0000	0.0000	0.6000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.50	0.0000	1.0000	1.1000	0.0010	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000
3.00	0.0000	9.7900	1.7200	0.0020	0.1500	0.0000	0.0000	0.0000	0.0000	0.0100
3.50	0.0010	12.9700	3.1500	0.0050	0.3100	0.0000	0.0012	0.0000	0.0010	0.0200
4.00	0.0020	19.8800	6.2380	0.0140	0.8790	0.0770	0.0169	0.0080	0.0059	0.0915
4.50	0.0280	33.2700	10.6300	0.0280	2.1590	0.2630	0.0802	0.0160	0.0107	0.3126
5.00	0.6290	49.4300	15.6400	0.0450	4.3940	0.6440	0.2643	0.0520	0.0164	0.7655
5.50	2.1500	71.8100	20.5900	0.0675	7.7460	1.2620	0.6967	0.1140	0.0236	1.5000
6.00	4.8730	99.1600	25.3500	0.0904	12.2600	2.1410	1.4380	0.2310	0.0321	2.5448
6.50	10.4100	126.2000	29.8500	0.1200	17.9500	3.2500	2.7800	0.3850	0.0416	3.8629
7.00	21.6800	154.8000	33.6200	0.1590	24.8400	4.6000	4.6570	0.6020	0.0520	5.1810
7.50	37.1600	185.5000	38.2100	0.1980	32.9500	6.3520	7.1310	0.8720	0.0631	6.4990
8.00	48.1400	221.3000	42.8000	0.2370	42.1700	8.3490	10.1300	1.2260	0.0742	7.8170
8.50	59.1300	259.1000	47.3900	0.2850	51.3900	10.5500	13.7700	1.6660	0.0853	9.1350

[a]Yields shown were calculated by linear interpolation of values from the literature. Sources: Bair and Gomez del Campo 1979, West and Sherwood 1982, and Marion and Fowler 1960.

[b]The abbreviation "nat" means natural isotopic mixture.

the denominator is also shown for each actinide. This represents the value of Y_i, the yield of neutrons per million alphas for that actinide. When this is multiplied by 3.7E04, it gives the yield for that actinide in neutrons per second per curie of that actinide. These data are useful in identifying the actinides that are the principal contributors to the total neutron production. The first table, "values of ADDJPY(I,J)," shows which of the target elements have the greatest effect on the neutron yield.

4. EXAMPLE PROBLEM

4.1 BASIS

A typical vitrified HLW to be produced at the Defense Waste Processing Facility at the SRS was chosen as the basis for an example of the use of the ALPHN code. The waste, vitrified in borosilicate glass, will be contained in sealed stainless steel canisters about 61 cm in diameter and 300 cm in height. The canister in this example contains 1682 kg of vitrified HLW. A typical elemental composition for the vitrified waste is shown in Table 4. The radionuclide content of the canister at the time of vitrification is shown in Table 5. Total radioactivity is 234,400 Ci and total thermal power is 709W (Baxter 1988).

The object of the calculation is to determine the rate of neutron production per canister. Neutron production rates are desired at times of 0, 10, 100, 1000, 10,000, 100,000, and 1,000,000 years after vitrification.

4.2 PREPARATION OF INPUT DATA

The input file CURIES.IN9, which gives the α-curies of each actinide present at each decay time, was prepared by running the decay portion of the ORIGEN2 program (Croff 1980) at each of the desired decay times using the radionuclide composition shown in Table 5 as input. The ORIGEN2 output contains much more information than is needed for input to ALPHN and was edited to prepare the file CURIES.IN9, which contains only the α-curies of each actinide. This file is shown as Table 6.

The other input file needed is ALPHN5Z.INP, which gives the elemental composition of the vitrified HLW-glass mixture. As mentioned in Sect. 3.2.2, any mass basis can be used for this file. Because the composition data were available as mass percent, the mass of each species present was entered as kilograms per hundred kilograms of mixture. This file is shown as Table 7.

Details of the formats used for both input files are given in Appendix A.

4.3 OUTPUT

The main portions of the output are discussed here; the complete output is listed in Appendix B.

Table 4. Savannah River Site: chemical composition of HLW glass[a]

Component	Water-free wt %
Ag	0.05
Al_2O_3	3.96
B_2O_3	10.28
$BaSO_4$	0.14
$Ca_3(PO_4)_2$	0.07
CaO	0.85
$CaSO_4$	0.08
Cr_2O_3	0.12
Cs_2O	0.08
CuO	0.19
Fe_2O_3	7.04
FeO	3.12
K_2O	3.58
Li_2O	3.16
MgO	1.36
MnO	2.00
Na_2O	11.00
Na_2SO_4	0.36
NaCl	0.19
NaF	0.07
NiO	0.93
PbS	0.07
SiO_2	45.57
ThO_2	0.21
TiO_2	0.99
U_3O_8	2.20
Zeolite	1.67
ZnO	0.08
Others	0.58
Total	100.00

[a]Source: Baxter 1988.

Table 5. Savannah River Site: radionuclide content per HLW canister[a]

Radionuclide	Mass (g/canister)	Radioactivity (Ci/canister)	Thermal power (W/canister)
^{51}Cr	0.1008E-20	0.9312E-16	0.1996E-19
^{60}Co	0.1502E+00	0.1699E+03	0.2619E+01
^{59}Ni	0.3163E+00	0.2397E-01	0.9519E-06
^{63}Ni	0.4824E-01	0.2975E+01	0.3000E-03
^{79}Se	0.2439E+01	0.1699E+00	0.4232E-04
^{87}Rb	0.9961E+01	0.8719E-06	0.7278E-09
^{89}Sr	0.1470E-08	0.4267E-04	0.1473E-06
^{90}Sr	0.3426E+03	0.4675E+05	0.5426E+02
^{90}Y	0.8795E-01	0.4786E+05	0.2653E+03
^{91}Y	0.3085E-07	0.7568E-03	0.2715E-05
^{93}Zr	0.4443E+03	0.1117E+01	0.1298E-03
^{95}Zr	0.4680E-06	0.1005E-01	0.5084E-04
^{94}Nb	0.5147E-03	0.9646E-04	0.9830E-06
^{95}Nb	0.5407E-06	0.2115E-01	0.1013E-03
^{95m}Nb	0.3272E-09	0.1247E-03	0.1730E-06
^{99}Tc	0.1816E+03	0.3079E+01	0.1545E-02
^{103}Ru	0.5217E-12	0.1684E-07	0.5827E-10
^{106}Ru	0.6729E+00	0.2252E+04	0.1339E-00
^{103m}Rh	0.5028E-15	0.1636E-07	0.3761E-11
^{106}Rh	0.6346E-06	0.2259E+04	0.2167E+02
^{107}Pd	0.2863E+02	0.1473E-01	0.8732E-06
^{110m}Ag	0.2647E-04	0.1258E+00	0.2098E-02
^{113}Cd	0.1472E+00	0.5009E-13	0.8420E-16
^{115m}Cd	0.4763E-13	0.1213E-08	0.4518E-11
^{121m}Sn	0.1336E-02	0.7902E-01	0.1581E-03
^{123}Sn	0.3101E-04	0.2549E+00	0.7951E-03
^{126}Sn	0.1556E+02	0.4415E+00	0.5508E-03
^{124}Sb	0.4071E-11	0.7123E-07	0.9445E-09
^{125}Sb	0.8226E+00	0.8496E+03	0.2656E+01
^{126}Sb	0.7365E-06	0.6159E-01	0.1138E-02
^{126m}Sb	0.5619E-08	0.4415E+00	0.5622E-02
^{126m}Te	0.1532E-01	0.2760E+03	0.2320E+00
^{127}Te	0.4555E-07	0.1202E+00	0.1622E-03

Table 5. Savannah River Site: radionuclide content per HLW canister[a](continued)

Radionuclide	Mass (g/canister)	Radioactivity (Ci/canister)	Thermal power (W/canister)
^{128m}Te	0.1302E-04	0.1228E+00	0.6597E-04
^{129}Te	0.1457E-18	0.3053E-11	0.1089E-13
^{129m}Te	0.1576E-15	0.4749E-11	0.8316E-14
^{134}Cs	0.2606E+00	0.3372E+03	0.3433E+01
^{135}Cs	0.8633E+02	0.9943E-01	0.3319E-04
^{136}Cs	0.1068E-43	0.7838E-39	0.1066E-41
^{137}Cs	0.4989E+03	0.4341E+05	0.4802E+02
^{136m}Ba	0.3195E-49	0.8607E-38	0.1040E-40
^{137m}Ba	0.7724E-04	0.4155E+05	0.1632E+03
^{140}Ba	0.1404E-40	0.1024E-35	0.2853E-38
^{140}La	0.7734E-42	0.4304E-36	0.7205E-38
^{141}Ce	0.1260E-14	0.3591E-10	0.5250E-13
^{142}Ce	0.4005E+03	0.9609E-05	0.0000E+00
^{144}Ce	0.3093E+01	0.9869E+04	0.6547E+01
^{143}Pr	0.1780E-38	0.1198E-33	0.2291E-37
^{144}Pr	0.1306E-03	0.9869E+04	0.7255E+02
^{144m}Pr	0.6545E-06	0.1187E+03	0.4063E-01
^{144}Nd	0.4110E+03	0.4860E-09	0.0000E+00
^{147}Nd	0.1570E-48	0.1261E-43	0.3038E-46
^{147}Pm	0.2609E+02	0.2419E+05	0.8679E+01
^{148}Pm	0.4243E-15	0.6975E-10	0.5364E-12
^{148m}Pm	0.4722E-13	0.1009E-08	0.1277E-10
^{147}Sm	0.8796E+02	0.2000E-05	0.2738E-07
^{148}Sm	0.1916E+02	0.5788E-11	0.6901E-13
^{149}Sm	0.7420E+01	0.1781E-11	0.0000E+00
^{151}Sm	0.9418E+01	0.2478E+03	0.2906E-01
^{152}Eu	0.2132E-01	0.3688E+01	0.2790E-01
^{154}Eu	0.2295E+01	0.6196E+03	0.5543E+01
^{155}Eu	0.1021E+01	0.4749E+03	0.3455E+00
^{156}Eu	0.9489E-36	0.5231E-31	0.5392E-33
^{160}Tb	0.9923E-10	0.1120E-05	0.9110E-08
^{208}Tl	0.3829E-11	0.1128E-02	0.2645E-04

Table 5. Savannah River Site: radionuclide content per HLW canister[a] (continued)

Radionuclide	Mass (g/canister)	Radioactivity (Ci/canister)	Thermal power (W/canister)
^{232}U	0.6256E-03	0.1339E-01	0.4301E-03
^{233}U	0.1636E-03	0.1584E-05	0.4605E-07
^{234}U	0.5485E+01	0.3428E-01	0.9875E-03
^{235}U	0.7278E+02	0.1573E-03	0.4122E-05
^{236}U	0.1742E+02	0.1128E-02	0.3054E-04
^{238}U	0.3122E+05	0.1050E-01	0.2663E-03
^{236}Np	0.1323E-05	0.1744E-07	0.3514E-10
^{237}Np	0.1263E+02	0.8904E-02	0.2722E-03
^{236}Pu	0.2297E-03	0.1221E+00	0.4249E-02
^{237}Pu	0.7401E-15	0.8941E-11	0.3292E-14
^{238}Pu	0.8667E+02	0.1484E+04	0.4919E+02
^{239}Pu	0.2076E+03	0.1291E+02	0.3979E+00
^{240}Pu	0.3809E+02	0.8681E+01	0.2704E+00
^{241}Pu	0.1620E+02	0.1670E+04	0.5176E-01
^{242}Pu	0.3206E+01	0.1224E-01	0.3616E-03
^{241}Am	0.3210E+01	0.1102E+02	0.3661E+00
^{242}Am	0.1776E-07	0.1436E-01	0.1628E-04
^{242m}Am	0.1488E-02	0.1447E-01	0.5709E-05
^{243}Am	0.2902E-01	0.5788E-02	0.1860E-03
^{242}Cm	0.1057E-04	0.3495E-01	0.1288E-02
^{243}Cm	0.1078E-03	0.5565E-02	0.2039E-03
^{244}Cm	0.1329E+01	0.1076E+03	0.3763E+01
^{245}Cm	0.3910E-04	0.6715E-05	0.2225E-06
^{246}Cm	0.1739E-05	0.5342E-06	0.1747E-07
^{247}Cm	0.7116E-08	0.6604E-12	0.2107E-13
^{248}Cm	0.1614E-09	0.6864E-12	0.8533E-13
Totals	0.3427E+05	0.2344E+06	0.7093E+03

[a]Quantities shown are for sludge-precipitate glass and are based on Baxter 1988, assuming sludge aged an average of 5 years and supernate aged an average of 15 years, with a canister load of 3,710 lb of glass (1,682 kg). Radionuclide contents are at the time of filling canister.

Table 6. Input file CURIES.IN9 for example problem[a]

```
03   0.000E-012.250E-138.359E-101.436E-067.680E-043.697E-022.901E-015.814E-02
05   0.000E-011.482E-101.651E-093.351E-082.829E-063.120E-046.933E-031.689E-02
06   0.000E-016.955E-119.351E-092.902E-067.680E-043.697E-022.901E-015.814E-02
09   0.000E-016.956E-119.353E-092.902E-067.682E-043.697E-022.902E-015.815E-02
10   0.000E-011.515E-101.688E-093.425E-082.891E-063.189E-047.087E-031.727E-02
13   0.000E-016.958E-119.355E-092.903E-067.684E-043.698E-022.902E-015.816E-02
14   0.000E-011.515E-101.688E-093.425E-082.891E-063.189E-047.087E-031.727E-02
17   0.000E-016.958E-119.355E-092.903E-067.684E-043.698E-022.902E-015.816E-02
18   0.000E-011.515E-101.688E-093.425E-082.891E-063.189E-047.087E-031.727E-02
21   0.000E-011.515E-101.688E-093.425E-082.891E-063.189E-047.087E-031.727E-02
22   0.000E-013.275E-074.931E-061.788E-044.473E-034.758E-022.877E-015.812E-02
26   1.584E-061.623E-061.983E-065.812E-066.913E-059.209E-047.765E-031.717E-02
27   3.429E-023.848E-027.475E-023.251E-015.654E-015.516E-014.297E-014.319E-02
28   1.574E-041.574E-041.575E-041.577E-041.699E-042.679E-045.740E-045.983E-04
30   1.050E-021.050E-021.050E-021.050E-021.050E-021.050E-021.050E-021.050E-02
31   8.907E-038.911E-038.979E-031.057E-021.958E-022.230E-022.166E-021.618E-02
33   1.484E+031.473E+031.372E+036.737E+025.507E-014.468E-220.000E-010.000E-01
34   1.291E+011.291E+011.291E+011.287E+011.254E+019.680E+007.245E-014.626E-12
35   8.683E+008.693E+008.768E+008.880E+008.078E+003.111E+002.228E-042.235E-15
36   1.225E-021.225E-021.225E-021.224E-021.222E-021.203E-021.024E-022.042E-03
38   1.102E+011.362E+013.191E+015.793E+011.379E+011.042E-051.931E-092.691E-41
40   3.496E-021.675E-021.138E-027.545E-031.246E-041.877E-220.000E-010.000E-01
42   1.076E+021.035E+027.336E+012.341E+002.575E-155.234E-214.781E-202.239E-19
44   5.342E-075.342E-075.335E-075.265E-074.614E-071.234E-072.317E-130.000E-01
99
```

[a]The actinides are identified by the two-digit numbers in the first column. The next eight columns give the α-curies of each actinide in the eight cases of the example problem. The signal "99" indicates the end of the file.

Table 7. Input file ALPHN5Z.INP for example problem[a]

```
ALPHN5Z.IN4 SRP GLASS FOR (ALPHA,N) CALCULATION
TABLE 9-DWPF.  (ALPHA,N) NEUTRON SOURCES
IN DECAY OF SRP HLW
BASED  ON ONE CANISTER, SLUDGE + SUPERNATE GLASS (1682 KG/CANISTER).
  8  1  1  1  1
 IMMOBLZN   1.0YR   10.0YR   100.0YR 1000.0YR  10.0KYR 100.0KYR  1.0MYR
  1  8  7       4.36
  2  3  3      10.28
  3 11  0       1.06
  4 14  0       7.04
 18 14  0       3.12
  5 10  0       3.58
  6  1  1       3.16
  7  7  6       1.36
  8 13  0       2.00
  9  9  8      47.69
 10 12  0       0.99
 11  6 10      12.23
 12 15  0       0.93
 19 16  0       2.20
9999
```

[a]The mass percentages shown were derived from the composition data of Table 4. The differences between the two tables are due to the zeolite and to the combining of various species to obtain totals for elements such as calcium and sodium.

As described in Sect. 3.3, the output begins by echoing the mixture composition, the number of cases to be run, the α-curies of each actinide in each case, and the library data (stopping powers and thick-target yields) for each element at the energy of each actinide.

As already mentioned, the mixture composition table shows some items calculated within the program. These include the indexes MSTP(N) and KYL(N) used to locate the stopping power and yield data for the various elements in the program library. Also shown are the masses or mass fractions of elements contained in the species of the mixture.

The main results are shown in Table 8, which gives the calculated neutron production rates by actinides for each case (decay time) in the run. The total neutron production rate per canister was 6.411E+07 neutrons/s at the time of immobilization and decayed to 2.578E+04 neutrons/s at 1 M years after immobilization. As can be seen from the table, a number of the α-emitting daughters of the original actinides were not present in significant quantities at the time of vitrification but appeared subsequently as a result of decay of the parent actinides. Some of these daughters contribute significantly to (α, n) neutron production at long decay times. In constructing Table 8, any actinide or daughter that is present in a nonzero quantity in at least one case (one decay time) is shown in all cases, even if its quantity in those cases is zero.

5. VERIFICATION AND VALIDATION

In the application of quality assurance to computer codes, verification means confirming that the computer code gets the results that the mathematical model predicts; in other words, that the code performs the calculations properly. Validation means showing that the results predicted by the mathematical model are in agreement with those of real-world experiments.

Some degree of verification was obtained by comparing the results of ALPHN with those obtained from ORIGEN-S (Croff 1980, Hermann 1987, Hermann 1990, Parks 1990) on the same example problem. The two codes were written independently, and both use West's method. For the Savannah River HLW glass, the neutron production rates were 6.41E07 and 6.38E07 neutrons/s for ALPHN and ORIGEN-S, respectively. This is a difference of about 0.5%.

Validation of the ORIGEN-S code by comparing its results with those of experiments conducted at Savannah River Laboratory (SRL) (Pellarin 1986) has been previously reported (Hermann 1992). The experiments used a glass composition containing a uniformly distributed known amount of ^{238}Pu. The total (α, n) neutron source predicted by ORIGEN-S was 2% greater than the average of three samples measured at SRL. Because ALPHN has been shown to give results within 0.5% of those of ORIGEN-S, the SRL experiments can be taken as some degree of validation of ALPHN.

Table 8. Results of example problem: neutron production rates.

TABLE 9-DWPF. (ALPHA,N) NEUTRON SOURCES
IN DECAY OF SRS HLW

BASED ON ONE CANISTER, SLUDGE + SUPERNATE GLASS (1682 KG/CANISTER).

NEUTRONS/S

	IMMOBLZN	1.0YR	10.0YR	100.0YR	1000.0YR	10.0KYR	100.0KYR	1.0MYR
PO210	0.000E-01	7.737E-09	2.875E-05	4.938E-02	2.641E+01	1.271E+03	9.976E+03	1.999E+03
PO213	0.000E-01	2.364E-05	2.633E-04	5.345E-03	4.512E-01	4.977E+01	1.106E+03	2.694E+03
PO214	0.000E-01	8.738E-06	1.175E-03	3.646E-01	9.648E+01	4.645E+03	3.645E+04	7.304E+03
PO218	0.000E-01	3.693E-06	4.965E-04	1.541E-01	4.078E+01	1.963E+03	1.541E+04	3.087E+03
AT217	0.000E-01	1.432E-05	1.596E-04	3.238E-03	2.733E-01	3.015E+01	6.701E+02	1.633E+03
RN222	0.000E-01	2.697E-06	3.627E-04	1.125E-01	2.979E+01	1.434E+03	1.125E+04	2.255E+03
FR221	0.000E-01	9.902E-06	1.103E-04	2.239E-03	1.890E-01	2.084E+01	4.632E+02	1.129E+03
RA226	0.000E-01	1.581E-06	2.126E-04	6.597E-02	1.746E+01	8.404E+02	6.595E+03	1.322E+03
AC225	0.000E-01	6.976E-06	7.773E-05	1.577E-03	1.331E-01	1.468E+01	3.263E+02	7.952E+02
TH229	0.000E-01	3.706E-06	4.129E-05	8.379E-04	7.072E-02	7.801E+00	1.734E+02	4.225E+02
TH230	0.000E-01	6.737E-03	1.014E-01	3.678E+00	9.201E+01	9.787E+02	5.918E+03	1.196E+03
U233	3.725E-02	3.817E-02	4.664E-02	1.367E-01	1.626E+00	2.166E+01	1.826E+02	4.038E+02
U234	7.788E+02	8.739E+02	1.698E+03	7.383E+03	1.284E+04	1.253E+04	9.759E+03	9.809E+02
U235	2.436E+00	2.436E+00	2.438E+00	2.441E+00	2.629E+00	4.146E+00	8.884E+00	9.260E+00
U238	1.335E+02	1.335E+02	1.335E+02	1.[illegible]E+02	1.335E+02	1.335E+02	1.335E+02	1.335E+02
NP237	2.000E+02	2.001E+02	2.016E+02	2.374E+02	4.397E+02	5.008E+02	4.864E+02	3.633E+02
PU238	5.791E+07	5.748E+07	5.354E+07	2.629E+07	2.149E+04	1.744E-17	0.000E-01	0.000E-01
PU239	3.969E+05	3.969E+05	3.969E+05	3.957E+05	3.855E+05	2.976E+05	2.227E+04	1.422E-07
PU240	2.680E+05	2.683E+05	2.706E+05	2.740E+05	2.493E+05	9.601E+04	6.876E+00	6.897E-11
PU242	3.065E+02	3.065E+02	3.065E+02	3.062E+02	3.057E+02	3.010E+02	2.562E+02	5.109E+01
AM241	4.248E+05	5.251E+05	1.230E+06	2.233E+06	5.316E+05	4.017E-01	7.444E-05	0.000E-01
CM242	1.907E+03	9.136E+02	6.207E+02	4.116E+02	6.796E+00	1.024E-17	0.000E-01	0.000E-01
CM244	5.105E+06	4.911E+06	3.481E+06	1.111E+05	1.222E-10	2.483E-16	2.268E-15	1.062E-14
CM246	1.929E-02	1.929E-02	1.926E-02	1.901E-02	1.666E-02	4.455E-03	8.365E-09	0.000E-01
TOTAL	6.411E+07	6.358E+07	5.892E+07	2.931E+07	1.202E+06	4.184E+05	1.214E+05	2.578E+04

****

As part of the verification procedure, the example problem discussed in Sect. 4 was calculated using temporary computer programs written to solve Eqs. 11 and 26 by numerical methods. These programs were not highly refined; energies were divided into 0.5 MeV intervals, and interpolations were linear. The results, however, were almost identical. For this example, the method based on Eq. 11 gave a neutron production rate of 6.456E+07 neutrons/s per canister at the time of immobilization; the method based on Eq. 26 gave 6.455E+07 neutrons/s. This is about 0.7% higher than the 6.411E+07 neutrons/s calculated by West's method. Similar calculations using data projected for HLW at WVDP, HANF, and INEL showed that the exact method gave results about 0.6 to 1.2% higher than West's method. However, it cannot be assumed from these results that West's method can be applied with similar accuracy to all mixtures.

6. CONCLUSIONS

The ALPHN program appears to be an adequate tool for characterizing the (α, n) neutron source term in immobilized HLW. In the examples studied, the error introduced by the use of West's approximate method appears to be within the range of precision needed for deriving (α, n) sources for shielding analyses. Calculations by the exact method gave results about 0.6 to 1.2% higher than the approximate method.

Although the ALPHN program was written primarily because of the need for characterizing canisters of immobilized HLW, it can be used in other applications. As one example, the code was recently used to investigate the rate of (α, n) neutron production in a tank of molten fuel salt from the Molten Salt Reactor Experiment. This was done in connection with an evaluation of the adequacy of the neutron shielding.

The usefulness of the ALPHN program could be improved by providing for the calculation of energy spectra of the (α, n) neutrons produced, as is done in the ORIGEN-S program.

Improvements could also be made in the interpolation procedures used in supplying stopping powers and thick-target yields as functions of energy. Because of the shape of the yield curves for the most significant target elements in vitrified HLW in the energy range of interest, it appears likely that a polynomial fit of the yield data would give rates of neutron production lower than those obtained by linear interpolation.

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APPENDIX A

FORMATS FOR INPUT DATA

APPENDIX A. FORMATS FOR INPUT DATA

1. FORMAT FOR INPUT FILE ALPHN5Z.INP

The input file ALPHN5Z.INP is shown in Table 7.
The READ and FORMAT statements for file ALPHN5Z.INP are shown in Table A.1.

This file contains the following data:

Line 1: Description of problem (line must appear, even if blank)

Line 2-4: Three lines of description used as headings for the output table (user's option, but lines must appear even if blank)

Line 5: Number of cases in this run (NTMAX)
IOUT1 If zero, table of stopping powers is suppressed
IOUT2 If zero, table of thick-target yields is suppressed
IOUT3 If zero, preview of table of actinides that will appear in final results is suppressed
IOUT4 If zero, tables of ADDJPY (I,J) and ADDJP (I,J) are suppressed.

Line 6: Column headings for each case, used when all cases appear as a single table of output. Typically, these headings give the decay time for each case.

Line 7: and subsequent give the composition of the mixture. One line is used for each species present; it gives the identification number of the species and the mass (or mass fraction) of that species in the mixture. The end of the file is signalled by putting 9999 in the space where the identification number of the next species would normally appear.

2. FORMAT FOR INPUT FILE CURIES.IN9

The file CURIES.IN9 gives the α-curies of each actinide for each case in the run. Each actinide constitutes a single line of data. The data are read by iterative application of the following statement: READ (25,410) IK, (DUMCUR(NTM), NTM = 1, NTMAX)

The format statement used is as follows: 410 FORMAT (1X, I2, 4X, 8E9.0)

IK is the two-digit identification number of the actinide (its number in the list of 47 actinides; see Table 1)

DUMCUR(NTM) is the α-curies of actinide IK in case number NTM

NTMAX is the total number of cases (maximum of 8). The value of NTMAX was read from file ALPHN5Z.INP before reading file CURIES.IN9.

The READ statement is read until the number 99 is read in the position where IK would normally appear. This signals the end of the file.

Table A.1. ALPHN program statements used to read input file ALPHN5Z.INP

READ statements:

```
C*
      READ (14,415)(TITLE(N),N=1,15)
C*    THESE HEADINGS ARE FOR THE ALPHA,N TABLE:
      READ(14,415)(HEAD1(K),K=1,15)
      READ(14,415)(HEAD2(K),K=1,15)
      READ(14,415)(HEAD3(K),K=1,15)
C*
C*    READ NUMBER OF CASES FOR THIS GLASS COMPOSITION.
      READ(14,401)NTMAX,IOUT1,IOUT2,IOUT3,IOUT4
      READ(14,416)(HEAD(NT),NT=1,NTMAX)
C*
C*    READ GLASS COMPOSITION DATA:
C*
      DO 14 N=1,40
      READ(14,402,END=16)NX,KG(N)
      IF(NX.EQ.9999)GO TO 16
      NMAX=N
      NID(N)=NX
      MSTP(N)=IMSTP(NX)
      KYL(N)= IKYL(NX)
      KGO2(N)=KG(N)*FACO2(NID(N))
      KGMET(N)=KG(N) - KGO2(N)
      TOTO2=TOTO2 + KGO2(N)
      TOTKG=TOTKG + KG(N)
      TOTMET=TOTMET + KGMET(N)
      WRITE(15,501)N,NX,MSTP(N),KYL(N),NAME(NID(N)),KG(N),KGMET(N),
     1   KGO2(N)
   14 CONTINUE
   16 CONTINUE
C*
```

FORMAT statements:

```
C*
  401 FORMAT(6I4)
  402 FORMAT(I4,11X,2F20.0)
  415 FORMAT(15A5)
  416 FORMAT(8(1X,A8))
  500 FORMAT(' ',2X,15A5,/)
  501 FORMAT(' ',I4,I5,I7,I8,6X,A5,3(4X,F15.4))
C*
```

APPENDIX B

OUTPUT OF EXAMPLE PROBLEM

APPENDIX B. OUTPUT OF EXAMPLE PROBLEM

The output of the example problem is listed in the following pages. This was printed with the command PRINT ALPHN5R.OUT. In this example, none of the auxiliary outputs were suppressed.

INPUT DATA: SRS-DWPF GLASS (ALPHA,N) CALCULATION

NUMBER OF CASES = 8

IMMOBLZN 1.0YR 10.0YR 100.0YR 1000.0YR 10.0KYR 100.0KYR 1.0MYR

COMPOSITION OF MIXTURE

N	NX	MSTP(N)	KYL(N)		MASS	MASS METAL	MASS OXYGEN
1	1	8	7	AL2O3	4.3600	2.3121	2.0479
2	2	3	3	B2O3	10.2800	3.1899	7.0901
3	3	11	0	CAO	1.0600	0.7607	0.2993
4	4	14	0	FE2O3	7.0400	4.9266	2.1134
5	18	14	0	FEO	3.1200	2.4252	0.6948
6	5	10	0	K2O	3.5800	2.9700	0.6100
7	6	1	1	LI2O	3.1600	1.4700	1.6900
8	7	7	6	MGO	1.3600	0.8199	0.5401
9	8	13	0	MNO	2.0000	1.5500	0.4500
10	9	9	8	SIO2	47.6900	22.2951	25.3949
11	10	28	0	TIO2	0.9900	0.5900	0.4000
12	11	6	10	NA2O	12.2300	9.0698	3.1602
13	12	15	0	NIO	0.9300	0.7300	0.2000
14	19	16	9	U3O8	2.2000	1.8656	0.3344
TOTAL					100.0000	54.9748	45.0252

INPUT DATA: ALPHA CURIES

		IMMOBLZN	1.0YR	10.0YR	100.0YR	1000.0YR	10.0KYR	100.0KYR	1.0MYR
3	PO210	0.000E-01	2.250E-13	8.359E-10	1.436E-06	7.680E-04	3.697E-02	2.901E-01	5.814E-02
5	PO213	0.000E-01	1.482E-10	1.651E-09	3.351E-08	2.829E-06	3.120E-04	6.933E-03	1.689E-02
6	PO214	0.000E-01	6.955E-11	9.351E-09	2.902E-06	7.680E-04	3.697E-02	2.901E-01	5.814E-02
9	PO218	0.000E-01	6.956E-11	9.353E-09	2.902E-06	7.682E-04	3.697E-02	2.902E-01	5.815E-02
10	AT217	0.000E-01	1.515E-10	1.688E-09	3.425E-08	2.891E-06	3.189E-04	7.087E-03	1.727E-02
13	RN222	0.000E-01	6.958E-11	9.355E-09	2.903E-06	7.684E-04	3.698E-02	2.902E-01	5.816E-02
14	FR221	0.000E-01	1.515E-10	1.688E-09	3.425E-08	2.891E-06	3.189E-04	7.087E-03	1.727E-02
17	RA226	0.000E-01	6.958E-11	9.355E-09	2.903E-06	7.684E-04	3.698E-02	2.902E-01	5.816E-02
18	AC225	0.000E-01	1.515E-10	1.688E-09	3.425E-08	2.891E-06	3.189E-04	7.087E-03	1.727E-02
21	TH229	0.000E-01	1.515E-10	1.688E-09	3.425E-08	2.891E-06	3.189E-04	7.087E-03	1.727E-02
22	TH230	0.000E-01	3.275E-07	4.931E-06	1.788E-04	4.473E-03	4.758E-02	2.877E-01	5.812E-02
26	U233	1.584E-06	1.623E-06	1.983E-06	5.812E-06	6.913E-05	9.209E-04	7.765E-03	1.717E-02
27	U234	3.429E-02	3.848E-02	7.475E-02	3.251E-01	5.654E-01	5.516E-01	4.297E-01	4.319E-02
28	U235	1.574E-04	1.574E-04	1.575E-04	1.577E-04	1.699E-04	2.679E-04	5.740E-04	5.983E-04
30	U238	1.050E-02	1.050E-02	1.050E-02	1.050E-02	1.050E-02	1.050E-02	1.050E-02	1.050E-02
31	NP237	8.907E-03	8.911E-03	8.979E-03	1.057E-02	1.958E-02	2.230E-02	2.166E-02	1.618E-02
33	PU238	1.484E+03	1.473E+03	1.372E+03	6.737E+02	5.507E-01	4.468E-22	0.000E-01	0.000E-01
34	PU239	1.291E+01	1.291E+01	1.291E+01	1.287E+01	1.254E+01	9.680E+00	7.245E-01	4.626E-12

35	PU240	8.683E+00	8.693E+00	8.768E+00	8.880E+00	8.078E+00	3.111E+00	2.228E-04	2.235E-15
36	PU242	1.225E-02	1.225E-02	1.225E-02	1.224E-02	1.222E-02	1.203E-02	1.024E-02	2.042E-03
38	AM241	1.102E+01	1.362E+01	3.191E+01	5.793E+01	1.379E+01	1.042E-05	1.931E-09	2.691E-41
40	CM242	3.496E-02	1.675E-02	1.138E-02	7.545E-03	1.246E-04	1.877E-22	0.000E-01	0.000E-01
42	CM244	1.076E+02	1.035E+02	7.336E+01	2.341E+00	2.575E-15	5.234E-21	4.781E-20	2.239E-19
44	CM246	5.342E-07	5.342E-07	5.335E-07	5.265E-07	4.614E-07	1.234E-07	2.317E-13	0.000E-01
	TOTAL	1.624E+03	1.612E+03	1.499E+03	7.561E+02	3.558E+01	1.362E+01	2.979E+00	5.245E-01

LIBRARY DATA: STOPPING POWER, MEV/(MG CM2)

		LI-7	BE-9	B-11	O-16	F-19	NA-23	MG-27
1	BI211	0.6246	0.6398	0.6550	0.6172	0.5854	0.5526	0.5291
2	BI212	1.2751	1.3598	1.4445	1.4865	1.4079	1.1212	1.0396
3	PO210	0.7231	0.7480	0.7729	0.7282	0.6882	0.6419	0.6108
4	PO212	0.4391	0.4341	0.4290	0.4040	0.3877	0.3821	0.3738
5	PO213	0.5197	0.5316	0.5434	0.5147	0.4907	0.4660	0.4482
6	PO214	0.5554	0.5681	0.5808	0.5491	0.5222	0.4953	0.4756
7	PO215	0.5737	0.5870	0.6004	0.5671	0.5389	0.5104	0.4897
8	PO216	0.6107	0.6254	0.6401	0.6036	0.5727	0.5411	0.5184
9	PO218	0.6663	0.6853	0.7042	0.6634	0.6282	0.5900	0.5634
10	AT217	0.5932	0.6073	0.6213	0.5863	0.5567	0.5266	0.5048
11	RN219	0.6087	0.6233	0.6379	0.6015	0.5708	0.5394	0.5168
12	RN220	0.6441	0.6610	0.6778	0.6386	0.6052	0.5700	0.5451
13	RN222	0.7080	0.7313	0.7546	0.7109	0.6722	0.6281	0.5981
14	FR221	0.6387	0.6551	0.6714	0.6326	0.5996	0.5651	0.5406
15	RA223	0.6910	0.7126	0.7341	0.6916	0.6543	0.6126	0.5840
16	RA224	0.6928	0.7146	0.7363	0.6937	0.6562	0.6143	0.5855
17	RA226	0.7737	0.8048	0.8358	0.7890	0.7454	0.6886	0.6529
18	AC225	0.6867	0.7078	0.7289	0.6867	0.6498	0.6087	0.5804
19	TH227	0.6744	0.6942	0.7140	0.6726	0.6367	0.5974	0.5701
20	TH228	0.7153	0.7394	0.7635	0.7193	0.6800	0.6348	0.6043
21	TH229	0.7637	0.7934	0.8230	0.7763	0.7333	0.6793	0.6446
22	TH230	0.7862	0.8189	0.8517	0.8047	0.7603	0.7001	0.6632
23	TH232	0.8617	0.9047	0.9477	0.8998	0.8508	0.7700	0.7259
24	PA231	0.7567	0.7854	0.8142	0.7676	0.7250	0.6728	0.6388
25	U232	0.7229	0.7478	0.7727	0.7279	0.6880	0.6418	0.6106
26	U233	0.7691	0.7996	0.8300	0.7832	0.7399	0.6843	0.6491
27	U234	0.7738	0.8049	0.8360	0.7891	0.7455	0.6887	0.6530
28	U235	0.8190	0.8562	0.8934	0.8460	0.7996	0.7305	0.6905
29	U236	0.8075	0.8431	0.8787	0.8314	0.7857	0.7198	0.6809
30	U238	0.8401	0.8801	0.9202	0.8725	0.8248	0.7500	0.7080
31	NP237	0.7753	0.8066	0.8378	0.7910	0.7473	0.6900	0.6542
32	PU236	0.6866	0.7077	0.7287	0.6865	0.6496	0.6085	0.5803
33	PU238	0.7071	0.7303	0.7536	0.7099	0.6713	0.6273	0.5974
34	PU239	0.7356	0.7619	0.7882	0.7425	0.7015	0.6534	0.6212
35	PU240	0.7352	0.7615	0.7877	0.7420	0.7011	0.6531	0.6209
36	PU242	0.7605	0.7897	0.8190	0.7723	0.7295	0.6763	0.6419
37	PU244	0.7965	0.8306	0.8648	0.8176	0.7726	0.7096	0.6718
38	AM241	0.7087	0.7321	0.7555	0.7118	0.6730	0.6288	0.5988

39	AM243	0.7262	0.7515	0.7767	0.7317	0.6915	0.6448	0.6134
40	CM242	0.6630	0.6817	0.7003	0.6598	0.6248	0.5871	0.5607
41	CM243	0.6796	0.6999	0.7203	0.6785	0.6422	0.6021	0.5745
42	CM244	0.6827	0.7033	0.7240	0.6821	0.6455	0.6050	0.5770
43	CM245	0.7183	0.7427	0.7671	0.7227	0.6831	0.6375	0.6067
44	CM246	0.7172	0.7415	0.7658	0.7214	0.6819	0.6365	0.6058
45	CM247	0.7539	0.7822	0.8106	0.7640	0.7216	0.6702	0.6364
46	CM248	0.7876	0.8206	0.8535	0.8065	0.7620	0.7015	0.6645
47	CF252	0.6720	0.6916	0.7111	0.6699	0.6342	0.5952	0.5682

		AL-27	SI-28	K-39	CA-40	CR-52	MN-55	FE-56
1	BI211	0.5056	0.4964	0.4506	0.4414	0.4080	0.4004	0.3929
2	BI212	0.9580	0.9343	0.8155	0.7917	0.7115	0.6951	0.6788
3	PO210	0.5796	0.5681	0.5110	0.4996	0.4593	0.4506	0.4419
4	PO212	0.3654	0.3606	0.3366	0.3319	0.3115	0.3061	0.3007
5	PO213	0.4304	0.4231	0.3867	0.3795	0.3527	0.3466	0.3405
6	PO214	0.4560	0.4480	0.4085	0.4006	0.3716	0.3650	0.3584
7	PO215	0.4691	0.4608	0.4196	0.4114	0.3812	0.3743	0.3675
8	PO216	0.4956	0.4867	0.4421	0.4332	0.4007	0.3933	0.3860
9	PO218	0.5368	0.5267	0.4761	0.4660	0.4297	0.4217	0.4136
10	AT217	0.4831	0.4745	0.4315	0.4229	0.3915	0.3843	0.3772
11	RN219	0.4942	0.4853	0.4409	0.4320	0.3996	0.3923	0.3849
12	RN220	0.5201	0.5105	0.4625	0.4529	0.4182	0.4104	0.4026
13	RN222	0.5682	0.5571	0.5017	0.4906	0.4514	0.4429	0.4343
14	FR221	0.5161	0.5066	0.4592	0.4498	0.4154	0.4076	0.3999
15	RA223	0.5554	0.5447	0.4913	0.4806	0.4426	0.4343	0.4259
16	RA224	0.5568	0.5460	0.4924	0.4817	0.4435	0.4352	0.4268
17	RA226	0.6172	0.6047	0.5419	0.5293	0.4854	0.4759	0.4665
18	AC225	0.5522	0.5416	0.4887	0.4781	0.4404	0.4321	0.4238
19	TH227	0.5428	0.5325	0.4811	0.4708	0.4339	0.4258	0.4176
20	TH228	0.5737	0.5625	0.5062	0.4950	0.4552	0.4466	0.4380
21	TH229	0.6099	0.5975	0.5358	0.5234	0.4802	0.4710	0.4617
22	TH230	0.6264	0.6136	0.5494	0.5366	0.4917	0.4821	0.4725
23	TH232	0.6818	0.6674	0.5952	0.5807	0.5302	0.5194	0.5085
24	PA231	0.6047	0.5925	0.5316	0.5194	0.4767	0.4675	0.4584
25	U232	0.5794	0.5680	0.5109	0.4995	0.4592	0.4505	0.4418
26	U233	0.6139	0.6014	0.5391	0.5266	0.4830	0.4737	0.4643
27	U234	0.6173	0.6048	0.5419	0.5294	0.4854	0.4760	0.4666
28	U235	0.6505	0.6369	0.5693	0.5558	0.5084	0.4983	0.4881
29	U236	0.6420	0.6287	0.5623	0.5490	0.5025	0.4926	0.4826
30	U238	0.6659	0.6519	0.5821	0.5681	0.5192	0.5087	0.4982
31	NP237	0.6184	0.6058	0.5428	0.5302	0.4862	0.4767	0.4673
32	PU236	0.5520	0.5415	0.4886	0.4780	0.4403	0.4320	0.4237
33	PU238	0.5675	0.5565	0.5012	0.4901	0.4510	0.4424	0.4339
34	PU239	0.5890	0.5773	0.5187	0.5070	0.4658	0.4570	0.4481
35	PU240	0.5887	0.5770	0.5185	0.5068	0.4656	0.4568	0.4479
36	PU242	0.6075	0.5952	0.5338	0.5216	0.4786	0.4694	0.4602
37	PU244	0.6339	0.6209	0.5557	0.5426	0.4970	0.4872	0.4774
38	AM241	0.5687	0.5576	0.5022	0.4911	0.4518	0.4433	0.4347
39	AM243	0.5819	0.5704	0.5129	0.5014	0.4609	0.4522	0.4434

40	CM242	0.5343	0.5243	0.4741	0.4641	0.4280	0.4200	0.4120
41	CM243	0.5468	0.5363	0.4843	0.4739	0.4366	0.4284	0.4202
42	CM244	0.5491	0.5386	0.4862	0.4757	0.4383	0.4300	0.4218
43	CM245	0.5759	0.5646	0.5080	0.4967	0.4568	0.4481	0.4395
44	CM246	0.5751	0.5638	0.5074	0.4961	0.4562	0.4476	0.4389
45	CM247	0.6027	0.5905	0.5299	0.5177	0.4753	0.4662	0.4570
46	CM248	0.6275	0.6146	0.5503	0.5375	0.4925	0.4828	0.4732
47	CF252	0.5411	0.5308	0.4797	0.4694	0.4327	0.4246	0.4165

		NI-58	U-238	ZR	CL	AG-47	BA-56	P-15
1	BI211	0.3778	0.1814	0.3184	0.4392	0.2938	0.2611	0.4873
2	BI212	0.6461	0.2774	0.5401	1.0201	0.5034	0.4304	0.9105
3	PO210	0.4244	0.1995	0.3566	0.5078	0.3308	0.2914	0.5567
4	PO212	0.2900	0.1472	0.2470	0.3072	0.2237	0.2040	0.3558
5	PO213	0.3282	0.1619	0.2763	0.3766	0.2561	0.2289	0.4158
6	PO214	0.3452	0.1686	0.2908	0.3972	0.2690	0.2398	0.4401
7	PO215	0.3538	0.1720	0.2981	0.4083	0.2755	0.2454	0.4526
8	PO216	0.3712	0.1788	0.3129	0.4308	0.2888	0.2568	0.4778
9	PO218	0.3975	0.1890	0.3347	0.4678	0.3094	0.2739	0.5166
10	AT217	0.3630	0.1756	0.3059	0.4201	0.2825	0.2514	0.4659
11	RN219	0.3703	0.1784	0.3121	0.4295	0.2881	0.2562	0.4764
12	RN220	0.3870	0.1850	0.3260	0.4524	0.3011	0.2671	0.5009
13	RN222	0.4173	0.1967	0.3507	0.4971	0.3251	0.2868	0.5460
14	FR221	0.3845	0.1840	0.3240	0.4487	0.2991	0.2654	0.4971
15	RA223	0.4093	0.1936	0.3442	0.4852	0.3187	0.2815	0.5340
16	RA224	0.4101	0.1939	0.3449	0.4865	0.3194	0.2821	0.5353
17	RA226	0.4477	0.2084	0.3758	0.5468	0.3492	0.3063	0.5921
18	AC225	0.4072	0.1928	0.3425	0.4822	0.3171	0.2802	0.5310
19	TH227	0.4014	0.1905	0.3378	0.4734	0.3124	0.2764	0.5222
20	TH228	0.4207	0.1981	0.3536	0.5023	0.3279	0.2890	0.5512
21	TH229	0.4432	0.2067	0.3721	0.5384	0.3456	0.3035	0.5852
22	TH230	0.4532	0.2104	0.3805	0.5571	0.3535	0.3098	0.6007
23	TH232	0.4869	0.2230	0.4089	0.6198	0.3799	0.3310	0.6529
24	PA231	0.4401	0.2055	0.3695	0.5326	0.3432	0.3015	0.5803
25	U232	0.4243	0.1995	0.3565	0.5077	0.3307	0.2913	0.5566
26	U233	0.4456	0.2076	0.3741	0.5430	0.3476	0.3050	0.5890
27	U234	0.4477	0.2084	0.3759	0.5468	0.3492	0.3063	0.5922
28	U235	0.4678	0.2159	0.3929	0.5843	0.3650	0.3190	0.6234
29	U236	0.4627	0.2139	0.3885	0.5748	0.3609	0.3158	0.6154
30	U238	0.4772	0.2194	0.4008	0.6019	0.3723	0.3249	0.6380
31	NP237	0.4484	0.2086	0.3764	0.5481	0.3497	0.3067	0.5932
32	PU236	0.4071	0.1928	0.3425	0.4820	0.3170	0.2802	0.5309
33	PU238	0.4169	0.1966	0.3504	0.4965	0.3248	0.2865	0.5454
34	PU239	0.4304	0.2018	0.3614	0.5167	0.3355	0.2953	0.5656
35	PU240	0.4302	0.2017	0.3613	0.5164	0.3354	0.2952	0.5653
36	PU242	0.4418	0.2061	0.3709	0.5357	0.3445	0.3026	0.5829
37	PU244	0.4578	0.2121	0.3844	0.5657	0.3571	0.3127	0.6079
38	AM241	0.4176	0.1969	0.3510	0.4976	0.3254	0.2870	0.5465
39	AM243	0.4259	0.2001	0.3578	0.5100	0.3320	0.2924	0.5589
40	CM242	0.3960	0.1884	0.3334	0.4655	0.3081	0.2729	0.5142

41	CM243	0.4038	0.1915	0.3398	0.4771	0.3144	0.2780	0.5259
42	CM244	0.4053	0.1921	0.3410	0.4793	0.3155	0.2790	0.5281
43	CM245	0.4221	0.1986	0.3547	0.5044	0.3290	0.2899	0.5533
44	CM246	0.4216	0.1984	0.3543	0.5036	0.3286	0.2896	0.5525
45	CM247	0.4388	0.2051	0.3684	0.5303	0.3422	0.3007	0.5784
46	CM248	0.4539	0.2107	0.3811	0.5583	0.3540	0.3102	0.6017
47	CF252	0.4002	0.1901	0.3369	0.4718	0.3115	0.2757	0.5206

		S-16	CS-55	CU-29	PB-82	TH-90	ZN-30	TI-22
1	BI211	0.4781	0.2647	0.3717	0.1985	0.1848	0.3655	0.4231
2	BI212	0.8867	0.4385	0.6331	0.3071	0.2834	0.6201	0.7442
3	PO210	0.5453	0.2958	0.4174	0.2185	0.2033	0.4104	0.4767
4	PO212	0.3510	0.2062	0.2854	0.1610	0.1500	0.2809	0.3223
5	PO213	0.4086	0.2319	0.3234	0.1766	0.1648	0.3185	0.3649
6	PO214	0.4322	0.2431	0.3399	0.1843	0.1717	0.3347	0.3848
7	PO215	0.4443	0.2488	0.3483	0.1880	0.1752	0.3428	0.3949
8	PO216	0.4689	0.2604	0.3653	0.1957	0.1822	0.3593	0.4154
9	PO218	0.5065	0.2779	0.3910	0.2070	0.1926	0.3845	0.4458
10	AT217	0.4573	0.2549	0.3573	0.1921	0.1789	0.3515	0.4057
11	RN219	0.4675	0.2597	0.3643	0.1952	0.1818	0.3584	0.4142
12	RN220	0.4913	0.2709	0.3807	0.2025	0.1885	0.3744	0.4337
13	RN222	0.5349	0.2910	0.4104	0.2155	0.2005	0.4035	0.4685
14	FR221	0.4877	0.2692	0.3782	0.2014	0.1875	0.3719	0.4308
15	RA223	0.5234	0.2857	0.4025	0.2120	0.1973	0.3957	0.4593
16	RA224	0.5246	0.2862	0.4033	0.2124	0.1976	0.3966	0.4603
17	RA226	0.5796	0.3111	0.4401	0.2283	0.2123	0.4325	0.5042
18	AC225	0.5204	0.2843	0.4005	0.2112	0.1965	0.3938	0.4569
19	TH227	0.5120	0.2804	0.3947	0.2086	0.1941	0.3881	0.4502
20	TH228	0.5400	0.2933	0.4138	0.2169	0.2018	0.4068	0.4725
21	TH229	0.5728	0.3082	0.4357	0.2265	0.2106	0.4283	0.4988
22	TH230	0.5879	0.3147	0.4455	0.2306	0.2145	0.4377	0.5110
23	TH232	0.6385	0.3364	0.4781	0.2445	0.2273	0.4694	0.5518
24	PA231	0.5682	0.3061	0.4327	0.2252	0.2095	0.4254	0.4950
25	U232	0.5451	0.2957	0.4173	0.2185	0.2033	0.4103	0.4766
26	U233	0.5765	0.3097	0.4381	0.2275	0.2116	0.4306	0.5017
27	U234	0.5796	0.3111	0.4401	0.2283	0.2124	0.4325	0.5043
28	U235	0.6099	0.3241	0.4597	0.2367	0.2200	0.4515	0.5287
29	U236	0.6021	0.3208	0.4547	0.2345	0.2181	0.4466	0.5225
30	U238	0.6240	0.3302	0.4688	0.2405	0.2236	0.4603	0.5401
31	NP237	0.5806	0.3115	0.4408	0.2286	0.2126	0.4332	0.5050
32	PU236	0.5203	0.2843	0.4004	0.2111	0.1964	0.3937	0.4569
33	PU238	0.5343	0.2907	0.4100	0.2153	0.2003	0.4031	0.4680
34	PU239	0.5539	0.2997	0.4232	0.2211	0.2057	0.4161	0.4835
35	PU240	0.5536	0.2996	0.4230	0.2210	0.2056	0.4159	0.4833
36	PU242	0.5707	0.3072	0.4343	0.2259	0.2101	0.4269	0.4970
37	PU244	0.5948	0.3176	0.4499	0.2325	0.2162	0.4420	0.5165
38	AM241	0.5355	0.2912	0.4107	0.2156	0.2006	0.4038	0.4689
39	AM243	0.5474	0.2968	0.4188	0.2192	0.2039	0.4118	0.4784
40	CM242	0.5042	0.2768	0.3895	0.2064	0.1920	0.3830	0.4441
41	CM243	0.5155	0.2821	0.3972	0.2097	0.1951	0.3905	0.4531
42	CM244	0.5176	0.2830	0.3986	0.2103	0.1957	0.3919	0.4547

43	CM245	0.5420	0.2943	0.4151	0.2175	0.2024	0.4082	0.4741
44	CM246	0.5412	0.2939	0.4146	0.2173	0.2022	0.4077	0.4735
45	CM247	0.5663	0.3053	0.4315	0.2247	0.2090	0.4242	0.4935
46	CM248	0.5889	0.3151	0.4461	0.2309	0.2147	0.4383	0.5117
47	CF252	0.5104	0.2797	0.3937	0.2082	0.1937	0.3871	0.4490

		C-6	NE-10	EU-63	GE-32	TA-73	AR-18	SR
1	BI211	0.6701	0.5535	0.2356	0.3533	0.2140	0.4229	0.3271
2	BI212	1.5292	1.3293	0.3735	0.5942	0.3338	0.9760	0.5536
3	PO210	0.7979	0.6482	0.2608	0.3963	0.2356	0.4877	0.3665
4	PO212	0.4240	0.3713	0.1886	0.2718	0.1734	0.2981	0.2532
5	PO213	0.5552	0.4668	0.2077	0.3088	0.1899	0.3637	0.2845
6	PO214	0.5935	0.4953	0.2172	0.3242	0.1984	0.3832	0.2991
7	PO215	0.6137	0.5107	0.2220	0.3318	0.2025	0.3936	0.3065
8	PO216	0.6548	0.5418	0.2319	0.3474	0.2109	0.4149	0.3215
9	PO218	0.7232	0.5930	0.2463	0.3714	0.2232	0.4499	0.3438
10	AT217	0.6354	0.5271	0.2273	0.3401	0.2069	0.4049	0.3144
11	RN219	0.6525	0.5401	0.2314	0.3466	0.2104	0.4137	0.3207
12	RN220	0.6946	0.5718	0.2407	0.3617	0.2183	0.4354	0.3350
13	RN222	0.7780	0.6335	0.2569	0.3897	0.2323	0.4776	0.3605
14	FR221	0.6878	0.5666	0.2393	0.3594	0.2171	0.4319	0.3328
15	RA223	0.7557	0.6170	0.2526	0.3822	0.2286	0.4664	0.3537
16	RA224	0.7581	0.6188	0.2531	0.3830	0.2290	0.4676	0.3544
17	RA226	0.8669	0.7018	0.2730	0.4173	0.2463	0.5246	0.3862
18	AC225	0.7500	0.6128	0.2515	0.3803	0.2277	0.4635	0.3520
19	TH227	0.7338	0.6008	0.2484	0.3749	0.2250	0.4552	0.3471
20	TH228	0.7876	0.6407	0.2588	0.3929	0.2339	0.4825	0.3634
21	TH229	0.8527	0.6904	0.2707	0.4134	0.2442	0.5167	0.3824
22	TH230	0.8844	0.7159	0.2758	0.4222	0.2488	0.5344	0.3910
23	TH232	0.9906	0.8018	0.2929	0.4519	0.2639	0.5938	0.4196
24	PA231	0.8429	0.6824	0.2691	0.4106	0.2428	0.5112	0.3797
25	U232	0.7976	0.6480	0.2607	0.3962	0.2356	0.4876	0.3664
26	U233	0.8604	0.6966	0.2719	0.4155	0.2453	0.5210	0.3845
27	U234	0.8670	0.7019	0.2730	0.4173	0.2463	0.5247	0.3863
28	U235	0.9306	0.7532	0.2832	0.4351	0.2554	0.5602	0.4034
29	U236	0.9143	0.7401	0.2806	0.4306	0.2530	0.5511	0.3990
30	U238	0.9602	0.7772	0.2880	0.4434	0.2596	0.5768	0.4114
31	NP237	0.8691	0.7036	0.2733	0.4179	0.2466	0.5258	0.3868
32	PU236	0.7498	0.6127	0.2515	0.3803	0.2276	0.4634	0.3519
33	PU238	0.7768	0.6326	0.2567	0.3893	0.2321	0.4771	0.3601
34	PU239	0.8144	0.6605	0.2640	0.4018	0.2384	0.4961	0.3715
35	PU240	0.8139	0.6601	0.2639	0.4016	0.2383	0.4959	0.3714
36	PU242	0.8482	0.6867	0.2699	0.4121	0.2436	0.5142	0.3812
37	PU244	0.8989	0.7276	0.2781	0.4263	0.2508	0.5425	0.3949
38	AM241	0.7790	0.6342	0.2571	0.3900	0.2325	0.4781	0.3608
39	AM243	0.8020	0.6513	0.2616	0.3977	0.2363	0.4898	0.3677
40	CM242	0.7190	0.5898	0.2455	0.3700	0.2225	0.4477	0.3425
41	CM243	0.7406	0.6059	0.2497	0.3772	0.2261	0.4587	0.3491
42	CM244	0.7447	0.6089	0.2505	0.3786	0.2268	0.4608	0.3504
43	CM245	0.7915	0.6435	0.2596	0.3942	0.2346	0.4845	0.3646
44	CM246	0.7901	0.6425	0.2593	0.3937	0.2343	0.4838	0.3641

45	CM247	0.8390	0.6792	0.2684	0.4095	0.2423	0.5090	0.3787
46	CM248	0.8865	0.7176	0.2761	0.4228	0.2491	0.5356	0.3915
47	CF252	0.7307	0.5985	0.2478	0.3739	0.2244	0.4537	0.3461

		CD	CE
1	BI211	0.2902	0.2538
2	BI212	0.4953	0.4141
3	PO210	0.3264	0.2827
4	PO212	0.2215	0.1996
5	PO213	0.2531	0.2229
6	PO214	0.2657	0.2334
7	PO215	0.2722	0.2388
8	PO216	0.2853	0.2497
9	PO218	0.3054	0.2660
10	AT217	0.2791	0.2445
11	RN219	0.2845	0.2491
12	RN220	0.2973	0.2595
13	RN222	0.3208	0.2782
14	FR221	0.2953	0.2580
15	RA223	0.3146	0.2733
16	RA224	0.3152	0.2738
17	RA226	0.3444	0.2968
18	AC225	0.3130	0.2720
19	TH227	0.3084	0.2684
20	TH228	0.3235	0.2804
21	TH229	0.3410	0.2941
22	TH230	0.3487	0.3001
23	TH232	0.3745	0.3201
24	PA231	0.3386	0.2922
25	U232	0.3263	0.2826
26	U233	0.3428	0.2956
27	U234	0.3444	0.2968
28	U235	0.3599	0.3088
29	U236	0.3559	0.3057
30	U238	0.3671	0.3144
31	NP237	0.3449	0.2972
32	PU236	0.3129	0.2720
33	PU238	0.3205	0.2780
34	PU239	0.3310	0.2863
35	PU240	0.3309	0.2862
36	PU242	0.3399	0.2932
37	PU244	0.3522	0.3028
38	AM241	0.3211	0.2785
39	AM243	0.3276	0.2836
40	CM242	0.3042	0.2651
41	CM243	0.3103	0.2699
42	CM244	0.3115	0.2708
43	CM245	0.3246	0.2812
44	CM246	0.3242	0.2809
45	CM247	0.3376	0.2915
46	CM248	0.3492	0.3005
47	CF252	0.3075	0.2677

LIBRARY BATA: THICK-TARGET NEUTRON YIELDS FOR ALPHA EMITTERS PER 10**6 ALPHAS

		LI(NAT)	BE-9	B(NAT)	O(NAT)	F-19	MG(NAT)	AL-27	SI(NAT)	U238-O2	NA(NAT)
1	BI211	11.5483	129.0886	30.2308	0.1239	18.6459	3.3863	2.9696	0.4069	0.0427	3.9960
2	BI212	0.0000	0.3480	1.1219	0.0003	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000
3	PO210	1.5538	63.0370	18.6496	0.0587	6.4320	1.0197	0.5272	0.0897	0.0208	1.2121
4	PO212	65.3811	280.6006	50.0008	0.3123	56.6343	11.8019	15.8404	1.9163	0.0916	9.8847
5	PO213	56.3979	249.7029	46.2489	0.2731	49.0979	10.0028	12.8651	1.5566	0.0825	8.8073
6	PO214	41.2468	198.8248	39.9184	0.2125	36.3817	7.0953	8.2472	1.0038	0.0672	6.9896
7	PO215	33.6430	178.5250	37.1672	0.1891	31.1074	5.9539	6.5689	0.8107	0.0606	6.1996
8	PO216	16.6874	142.1302	31.9499	0.1417	21.7877	4.0020	3.8255	0.5059	0.0474	4.5971
9	PO218	4.8841	99.2141	25.3590	0.0905	12.2714	2.1432	1.4407	0.2313	0.0321	2.5474
10	AT217	23.7141	158.8340	34.2231	0.1641	25.9057	4.8302	4.9821	0.6375	0.0535	5.3542
11	RN219	17.4470	144.0578	32.2040	0.1444	22.2521	4.0929	3.9520	0.5205	0.0481	4.6859
12	RN220	8.0601	114.7242	27.9402	0.1074	15.5352	2.7793	2.2105	0.3196	0.0376	3.3035
13	RN222	2.1171	71.3266	20.4831	0.0670	7.6736	1.2487	0.6874	0.1127	0.0234	1.4841
14	FR221	8.8275	118.4720	28.5639	0.1115	16.3238	2.9330	2.3965	0.3410	0.0389	3.4862
15	RA223	3.2240	82.5968	22.4673	0.0765	9.5263	1.6087	0.9891	0.1601	0.0270	1.9121
16	RA224	3.1036	81.3880	22.2570	0.0755	9.3268	1.5698	0.9563	0.1550	0.0266	1.8659
17	RA226	0.3575	42.1289	13.3765	0.0373	3.3842	0.4719	0.1811	0.0357	0.0138	0.5609
18	AC225	3.5120	85.4905	22.9710	0.0790	10.0039	1.7017	1.0675	0.1725	0.0279	2.0226
19	TH227	4.3404	93.8104	24.4189	0.0859	11.3771	1.9691	1.2930	0.2081	0.0304	2.3404
20	TH228	1.8434	67.2982	19.5921	0.0630	7.0702	1.1374	0.6095	0.1015	0.0221	1.3519
21	TH229	0.4631	44.9698	14.2572	0.0403	3.7771	0.5388	0.2135	0.0421	0.0148	0.6405
22	TH230	0.2265	38.6060	12.2843	0.0336	2.8970	0.3888	0.1410	0.0279	0.0126	0.4621
23	TH232	0.0023	20.0300	6.2872	0.0142	0.8933	0.0791	0.0176	0.0081	0.0060	0.0940
24	PA231	0.5364	46.9414	14.8685	0.0424	4.0498	0.5853	0.2359	0.0465	0.0155	0.6958
25	U232	1.5614	63.1489	18.6744	0.0588	6.4488	1.0228	0.5294	0.0900	0.0208	1.2157
26	U233	0.4055	43.4217	13.7773	0.0387	3.5630	0.5023	0.1959	0.0386	0.0143	0.5971
27	U234	0.3564	42.0998	13.3675	0.0373	3.3802	0.4712	0.1808	0.0357	0.0138	0.5601
28	U235	0.0217	30.0162	9.5627	0.0246	1.8480	0.2178	0.0648	0.0141	0.0095	0.2589
29	U236	0.0269	32.7157	10.4482	0.0274	2.1060	0.2553	0.0776	0.0157	0.0105	0.3034
30	U238	0.0121	25.0887	7.9465	0.0194	1.3769	0.1494	0.0415	0.0111	0.0078	0.1775
31	NP237	0.3410	41.6861	13.2392	0.0369	3.3230	0.4614	0.1761	0.0347	0.0137	0.5485
32	PU236	3.5229	85.5999	22.9900	0.0790	10.0220	1.7052	1.0705	0.1730	0.0279	2.0268
33	PU238	2.1500	71.8100	20.5900	0.0675	7.7460	1.2620	0.6967	0.1140	0.0236	1.5000
34	PU239	1.0853	56.1440	17.1250	0.0518	5.3996	0.8294	0.3940	0.0706	0.0186	0.9859
35	PU240	1.1002	56.3633	17.1735	0.0520	5.4325	0.8355	0.3983	0.0712	0.0186	0.9930
36	PU242	0.4969	45.8780	14.5388	0.0413	3.9027	0.5603	0.2238	0.0441	0.0151	0.6660
37	PU244	0.1183	35.6972	11.3825	0.0306	2.4947	0.3202	0.1079	0.0214	0.0116	0.3806
38	AM241	2.0895	70.9193	20.3930	0.0666	7.6126	1.2374	0.6795	0.1115	0.0233	1.4708
39	AM243	1.4370	61.3183	18.2694	0.0570	6.1746	0.9723	0.4940	0.0849	0.0202	1.1557
40	CM242	5.3536	101.5071	25.7406	0.0930	12.7539	2.2373	1.5545	0.2444	0.0329	2.6592
41	CM243	3.9907	90.2986	23.8078	0.0830	10.7975	1.8562	1.1978	0.1931	0.0293	2.2063
42	CM244	3.7838	88.2200	23.4460	0.0812	10.4544	1.7894	1.1415	0.1842	0.0287	2.1269
43	CM245	1.7336	65.6824	19.2347	0.0613	6.8282	1.0928	0.5783	0.0970	0.0216	1.2989
44	CM246	1.7740	66.2777	19.3664	0.0619	6.9174	1.1092	0.5898	0.0987	0.0218	1.3184
45	CM247	0.5659	47.7332	15.1140	0.0432	4.1593	0.6040	0.2450	0.0482	0.0158	0.7179
46	CM248	0.2112	38.1956	12.1570	0.0332	2.8402	0.3791	0.1363	0.0270	0.0124	0.4506
47	CF252	4.4961	95.3748	24.6912	0.0872	11.6353	2.0193	1.3354	0.2148	0.0309	2.4002

ACTINIDES IN THIS CALCULATION (ZERO INDICATES ACTINIDE IS NOT PRESENT)

1	BI211	0
2	BI212	0
3	PO210	1
4	PO212	0
5	PO213	1
6	PO214	1
7	PO215	0
8	PO216	0
9	PO218	1
10	AT217	1
11	RN219	0
12	RN220	0
13	RN222	1
14	FR221	1
15	RA223	0
16	RA224	0
17	RA226	1
18	AC225	1
19	TH227	0
20	TH228	0
21	TH229	1
22	TH230	1
23	TH232	0
24	PA231	0
25	U232	0
26	U233	1
27	U234	1
28	U235	1
29	U236	0
30	U238	1
31	NP237	1
32	PU236	0
33	PU238	1
34	PU239	1
35	PU240	1
36	PU242	1
37	PU244	0
38	AM241	1
39	AM243	0
40	CM242	1
41	CM243	0
42	CM244	1
43	CM245	0
44	CM246	1
45	CM247	0
46	CM248	0
47	CF252	0

*************** MAIN RESULTS FOR THIS PROBLEM ***

TABLE 9-DWPF. (ALPHA,N) NEUTRON SOURCES
IN DECAY OF SRS HLW

BASED ON ONE CANISTER, SLUDGE + SUPERNATE GLASS (1682 KG/CANISTER).

NEUTRONS/SEC

	IMMOBLZN	1.0YR	10.0YR	100.0YR	1000.0YR	10.0KYR	100.0KYR	1.0MYR
PO210	0.000E-01	7.737E-09	2.875E-05	4.938E-02	2.641E+01	1.271E+03	9.976E+03	1.999E+03
PO213	0.000E-01	2.364E-05	2.633E-04	5.345E-03	4.512E-01	4.977E+01	1.106E+03	2.694E+03
PO214	0.000E-01	8.738E-06	1.175E-03	3.646E-01	9.648E+01	4.645E+03	3.645E+04	7.304E+03
PO218	0.000E-01	3.693E-06	4.965E-04	1.541E-01	4.078E+01	1.963E+03	1.541E+04	3.087E+03
AT217	0.000E-01	1.432E-05	1.596E-04	3.238E-03	2.733E-01	3.015E+01	6.701E+02	1.633E+03
RN222	0.000E-01	2.697E-06	3.627E-04	1.125E-01	2.979E+01	1.434E+03	1.125E+04	2.255E+03
FR221	0.000E-01	9.902E-06	1.103E-04	2.239E-03	1.890E-01	2.084E+01	4.632E+02	1.129E+03
RA226	0.000E-01	1.581E-06	2.126E-04	6.597E-02	1.746E+01	8.404E+02	6.595E+03	1.322E+03
AC225	0.000E-01	6.976E-06	7.773E-05	1.577E-03	1.331E-01	1.468E+01	3.263E+02	7.952E+02
TH229	0.000E-01	3.706E-06	4.129E-05	8.379E-04	7.072E-02	7.801E+00	1.734E+02	4.225E+02
TH230	0.000E-01	6.737E-03	1.014E-01	3.678E+00	9.201E+01	9.787E+02	5.918E+03	1.196E+03
U233	3.725E-02	3.817E-02	4.664E-02	1.367E-01	1.626E+00	2.166E+01	1.826E+02	4.038E+02
U234	7.788E+02	8.739E+02	1.698E+03	7.383E+03	1.284E+04	1.253E+04	9.759E+03	9.809E+02
U235	2.436E+00	2.436E+00	2.438E+00	2.441E+00	2.629E+00	4.146E+00	8.884E+00	9.260E+00
U238	1.335E+02	1.335E+02	1.335E+02	1.335E+02	1.335E+02	1.335E+02	1.335E+02	1.335E+02
NP237	2.000E+02	2.001E+02	2.016E+02	2.374E+02	4.397E+02	5.008E+02	4.864E+02	3.633E+02
PU238	5.791E+07	5.748E+07	5.354E+07	2.629E+07	2.149E+04	1.744E-17	0.000E-01	0.000E-01
PU239	3.969E+05	3.969E+05	3.969E+05	3.957E+05	3.855E+05	2.976E+05	2.227E+04	1.422E-07
PU240	2.680E+05	2.683E+05	2.706E+05	2.740E+05	2.493E+05	9.601E+04	6.876E+00	6.897E-11
PU242	3.065E+02	3.065E+02	3.065E+02	3.062E+02	3.057E+02	3.010E+02	2.562E+02	5.109E+01
AM241	4.248E+05	5.251E+05	1.230E+06	2.233E+06	5.316E+05	4.017E-01	7.444E-05	0.000E-01
CM242	1.907E+03	9.136E+02	6.207E+02	4.116E+02	6.796E+00	1.024E-17	0.000E-01	0.000E-01
CM244	5.105E+06	4.911E+06	3.481E+06	1.111E+05	1.222E-10	2.483E-16	2.268E-15	1.062E-14
CM246	1.929E-02	1.929E-02	1.926E-02	1.901E-02	1.666E-02	4.455E-03	8.365E-09	0.000E-01
TOTAL	6.411E+07	6.358E+07	5.892E+07	2.931E+07	1.202E+06	4.184E+05	1.214E+05	2.578E+04

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VALUES OF ADDJPY(I,J)

	KG	BI211	BI212	PO210	PO212	PO213	PO214
AL2O3	2.31	0.3471E+01	0.0000E+00	0.7065E+00	0.1338E+02	0.1280E+02	0.8695E+01
B2O3	3.19	0.6316E+02	0.5169E+01	0.4598E+02	0.6842E+02	0.8017E+02	0.7396E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.1060E+02	0.0000E+00	0.1652E+01	0.4220E+02	0.4309E+02	0.3368E+02
MGO	0.82	0.1469E+01	0.0000E+00	0.5107E+00	0.3617E+01	0.3676E+01	0.2767E+01
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.4503E+01	0.0000E+00	0.1136E+01	0.1541E+02	0.1468E+02	0.1003E+02
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.2003E+02	0.0000E+00	0.7057E+01	0.3426E+02	0.3722E+02	0.3140E+02
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.1445E-01	0.0000E+00	0.7741E-02	0.2515E-01	0.2492E-01	0.2114E-01
O2	45.03	0.3443E+01	0.2008E-01	0.1925E+01	0.5681E+01	0.6329E+01	0.5254E+01
TOTAL		0.1067E+03	0.5190E+01	0.5897E+02	0.1830E+03	0.1980E+03	0.1658E+03

	KG	PO215	PO216	PO218	AT217	RN219	RN220
AL2O3	2.31	0.7125E+01	0.4384E+01	0.1788E+01	0.5565E+01	0.4516E+01	0.2658E+01
B2O3	3.19	0.7118E+02	0.6524E+02	0.5696E+02	0.6783E+02	0.6553E+02	0.6041E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.2837E+02	0.1498E+02	0.4784E+01	0.2068E+02	0.1561E+02	0.7632E+01
MGO	0.82	0.2391E+01	0.1701E+01	0.9901E+00	0.1999E+01	0.1734E+01	0.1242E+01
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.8329E+01	0.5490E+01	0.2716E+01	0.6744E+01	0.5632E+01	0.3638E+01
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.2870E+02	0.2256E+02	0.1363E+02	0.2557E+02	0.2292E+02	0.1708E+02
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.1945E-01	0.1581E-01	0.1132E-01	0.1753E-01	0.1601E-01	0.1298E-01
O2	45.03	0.4828E+01	0.3851E+01	0.2703E+01	0.4332E+01	0.3911E+01	0.3088E+01
TOTAL		0.1509E+03	0.1182E+03	0.8359E+02	0.1327E+03	0.1199E+03	0.9576E+02

	KG	RN222	FR221	RA223	RA224	RA226	AC225
AL2O3	2.31	0.9031E+00	0.2860E+01	0.1270E+01	0.1231E+01	0.2584E+00	0.1363E+01
B2O3	3.19	0.4930E+02	0.6117E+02	0.5261E+02	0.5228E+02	0.3566E+02	0.5341E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.2203E+01	0.8288E+01	0.3275E+01	0.3161E+01	0.4066E+00	0.3545E+01
MGO	0.82	0.6124E+00	0.1300E+01	0.7703E+00	0.7536E+00	0.2526E+00	0.8098E+00
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.1400E+01	0.3851E+01	0.1944E+01	0.1887E+01	0.4813E+00	0.2083E+01
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.8455E+01	0.1787E+02	0.1062E+02	0.1040E+02	0.3503E+01	0.1117E+02
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.8587E-02	0.1335E-01	0.9752E-02	0.9622E-02	0.5365E-02	0.1004E-01
O2	45.03	0.2145E+01	0.3176E+01	0.2382E+01	0.2358E+01	0.1325E+01	0.2443E+01
TOTAL		0.6503E+02	0.9853E+02	0.7289E+02	0.7207E+02	0.4190E+02	0.7483E+02

	KG	TH227	TH228	TH229	TH230	TH232	PA231
AL2O3	2.31	0.1623E+01	0.8085E+00	0.3011E+00	0.2042E+00	0.2774E-01	0.3298E+00
B2O3	3.19	0.5562E+02	0.4772E+02	0.3743E+02	0.3337E+02	0.1901E+02	0.3862E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.4303E+01	0.1938E+01	0.5199E+00	0.2618E+00	0.2913E-02	0.5967E+00
MGO	0.82	0.9205E+00	0.5636E+00	0.2848E+00	0.2114E+00	0.4708E-01	0.3066E+00
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.2471E+01	0.1273E+01	0.5608E+00	0.3817E+00	0.1205E+00	0.6143E+00
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.1268E+02	0.7784E+01	0.3946E+01	0.2934E+01	0.6565E+00	0.4246E+01
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.1080E-01	0.8168E-02	0.5707E-02	0.4946E-02	0.2496E-02	0.5942E-02
O2	45.03	0.2601E+01	0.2040E+01	0.1409E+01	0.1217E+01	0.5753E+00	0.1465E+01
TOTAL		0.8023E+02	0.6213E+02	0.4446E+02	0.3859E+02	0.2044E+02	0.4618E+02

	KG	U232	U233	U234	U235	U236	U238
AL2O3	2.31	0.7092E+00	0.2781E+00	0.2580E+00	0.9746E-01	0.1152E+00	0.6389E-01
B2O3	3.19	0.4603E+02	0.3648E+02	0.3565E+02	0.2725E+02	0.2929E+02	0.2333E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.1659E+01	0.4585E+00	0.4054E+00	0.2613E-01	0.3193E-01	0.1494E-01
MGO	0.82	0.5121E+00	0.2673E+00	0.2523E+00	0.1233E+00	0.1425E+00	0.8673E-01
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.1140E+01	0.5176E+00	0.4814E+00	0.2002E+00	0.2201E+00	0.1613E+00
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.7077E+01	0.3706E+01	0.3499E+01	0.1715E+01	0.1981E+01	0.1207E+01
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.7741E-02	0.5538E-02	0.5365E-02	0.3826E-02	0.4190E-02	0.3193E-02
O2	45.03	0.1927E+01	0.1365E+01	0.1325E+01	0.9370E+00	0.1026E+01	0.7621E+00
TOTAL		0.5906E+02	0.4307E+02	0.4187E+02	0.3036E+02	0.3281E+02	0.2563E+02

	KG	NP237	PU236	PU238	PU239	PU240	PU242
AL2O3	2.31	0.2518E+00	0.1366E+01	0.9142E+00	0.5366E+00	0.5421E+00	0.3144E+00
B2O3	3.19	0.3538E+02	0.5344E+02	0.4950E+02	0.4306E+02	0.4315E+02	0.3798E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.3886E+00	0.3556E+01	0.2235E+01	0.1174E+01	0.1189E+01	0.5555E+00
MGO	0.82	0.2475E+00	0.8114E+00	0.6182E+00	0.4225E+00	0.4254E+00	0.2949E+00
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.4687E+00	0.2089E+01	0.1414E+01	0.9087E+00	0.9159E+00	0.5852E+00
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.3433E+01	0.1119E+02	0.8534E+01	0.5843E+01	0.5882E+01	0.4085E+01
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.5332E-02	0.1004E-01	0.8656E-02	0.7002E-02	0.6999E-02	0.5806E-02
O2	45.03	0.1314E+01	0.2442E+01	0.2158E+01	0.1732E+01	0.1737E+01	0.1436E+01
TOTAL		0.4149E+02	0.7490E+02	0.6538E+02	0.5368E+02	0.5385E+02	0.4526E+02

	KG	PU244	AM241	AM243	CM242	CM243	CM244
AL2O3	2.31	0.1581E+00	0.8935E+00	0.6646E+00	0.1920E+01	0.1514E+01	0.1449E+01
B2O3	3.19	0.3140E+02	0.4915E+02	0.4526E+02	0.5750E+02	0.5470E+02	0.5415E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.1385E+00	0.2177E+01	0.1534E+01	0.5218E+01	0.3987E+01	0.3797E+01
MGO	0.82	0.1764E+00	0.6075E+00	0.4890E+00	0.1029E+01	0.8744E+00	0.8466E+00
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.2962E+00	0.1386E+01	0.1080E+01	0.2857E+01	0.2309E+01	0.2212E+01
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.2450E+01	0.8388E+01	0.6759E+01	0.1416E+02	0.1205E+02	0.1167E+02
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.4590E-02	0.8559E-02	0.7541E-02	0.1156E-01	0.1047E-01	0.1029E-01
O2	45.03	0.1126E+01	0.2134E+01	0.1878E+01	0.2763E+01	0.2536E+01	0.2494E+01
TOTAL		0.3575E+02	0.6474E+02	0.5768E+02	0.8546E+02	0.7798E+02	0.7663E+02

	KG	CM245	CM246	CM247	CM248	CF252
AL2O3	2.31	0.7700E+00	0.7843E+00	0.3414E+00	0.1978E+00	0.1671E+01
B2O3	3.19	0.4707E+02	0.4731E+02	0.3908E+02	0.3310E+02	0.5601E+02
CAO	0.76	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FE2O3	4.93	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
FEO	2.43	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
K2O	2.97	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LI2O	1.47	0.1831E+01	0.1870E+01	0.6272E+00	0.2445E+00	0.4442E+01
MGO	0.82	0.5436E+00	0.5510E+00	0.3152E+00	0.2066E+00	0.9408E+00
MNO	1.55	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SIO2	22.30	0.1221E+01	0.1241E+01	0.6346E+00	0.3700E+00	0.2542E+01
TIO2	0.59	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
NA2O	9.07	0.7510E+01	0.7611E+01	0.4364E+01	0.2867E+01	0.1296E+02
NIO	0.73	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
U3O8	1.87	0.8003E-02	0.8069E-02	0.6046E-02	0.4874E-02	0.1096E-01
O2	45.03	0.1995E+01	0.2011E+01	0.1486E+01	0.1206E+01	0.2630E+01
TOTAL		0.6094E+02	0.6138E+02	0.4685E+02	0.3819E+02	0.8120E+02

VALUES OF ADDJP(I,J)

	KG	BI211	BI212	PO210	PO212	PO213	PO214
AL2O3	2.31	0.1169E+01	0.2215E+01	0.1340E+01	0.8448E+00	0.9951E+00	0.1054E+01
B2O3	3.19	0.2089E+01	0.4608E+01	0.2465E+01	0.1368E+01	0.1733E+01	0.1853E+01
CAO	0.76	0.3358E+00	0.6022E+00	0.3800E+00	0.2525E+00	0.2887E+00	0.3047E+00
FE2O3	4.93	0.1936E+01	0.3344E+01	0.2177E+01	0.1481E+01	0.1678E+01	0.1766E+01
FEO	2.43	0.9529E+00	0.1646E+01	0.1072E+01	0.7293E+00	0.8258E+00	0.8692E+00
K2O	2.97	0.1338E+01	0.2422E+01	0.1518E+01	0.9997E+00	0.1148E+01	0.1213E+01
LI2O	1.47	0.9182E+00	0.1874E+01	0.1063E+01	0.6455E+00	0.7640E+00	0.8165E+00
MGO	0.82	0.4338E+00	0.8524E+00	0.5008E+00	0.3065E+00	0.3675E+00	0.3900E+00
MNO	1.55	0.6206E+00	0.1077E+01	0.6984E+00	0.4745E+00	0.5372E+00	0.5658E+00
SIO2	22.30	0.1107E+02	0.2083E+02	0.1267E+02	0.8040E+01	0.9433E+01	0.9988E+01
TIO2	0.59	0.2496E+00	0.4391E+00	0.2813E+00	0.1902E+00	0.2153E+00	0.2270E+00
NA2O	9.07	0.5012E+01	0.1017E+02	0.5822E+01	0.3466E+01	0.4227E+01	0.4492E+01
NIO	0.73	0.2758E+00	0.4716E+00	0.3098E+00	0.2117E+00	0.2396E+00	0.2520E+00
U3O8	1.87	0.3384E+00	0.5175E+00	0.3722E+00	0.2746E+00	0.3020E+00	0.3145E+00
O2	45.03	0.2779E+02	0.6693E+02	0.3279E+02	0.1819E+02	0.2317E+02	0.2472E+02
TOTAL		0.5453E+02	0.1180E+03	0.6345E+02	0.3747E+02	0.4593E+02	0.4883E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.1957E+01	0.4398E-01	0.9294E+00	0.4883E+01	0.4311E+01	0.3395E+01

	KG	PO215	PO216	PO218	AT217	RN219	RN220
AL2O3	2.31	0.1085E+01	0.1146E+01	0.1241E+01	0.1117E+01	0.1143E+01	0.1203E+01
B2O3	3.19	0.1915E+01	0.2042E+01	0.2246E+01	0.1982E+01	0.2035E+01	0.2162E+01
CAO	0.76	0.3129E+00	0.3295E+00	0.3545E+00	0.3217E+00	0.3286E+00	0.3445E+00
FE2O3	4.93	0.1811E+01	0.1902E+01	0.2038E+01	0.1858E+01	0.1896E+01	0.1983E+01
FEO	2.43	0.8913E+00	0.9361E+00	0.1003E+01	0.9148E+00	0.9335E+00	0.9764E+00
K2O	2.97	0.1246E+01	0.1313E+01	0.1414E+01	0.1282E+01	0.1309E+01	0.1374E+01
LI2O	1.47	0.8434E+00	0.8977E+00	0.9795E+00	0.8720E+00	0.8948E+00	0.9468E+00
MGO	0.82	0.4015E+00	0.4251E+00	0.4620E+00	0.4139E+00	0.4237E+00	0.4470E+00
MNO	1.55	0.5802E+00	0.6096E+00	0.6536E+00	0.5957E+00	0.6081E+00	0.6361E+00
SIO2	22.30	0.1027E+02	0.1085E+02	0.1174E+02	0.1058E+02	0.1082E+02	0.1138E+02
TIO2	0.59	0.2330E+00	0.2451E+00	0.2630E+00	0.2394E+00	0.2444E+00	0.2559E+00
NA2O	9.07	0.4629E+01	0.4908E+01	0.5351E+01	0.4776E+01	0.4892E+01	0.5170E+01
NIO	0.73	0.2583E+00	0.2710E+00	0.2902E+00	0.2650E+00	0.2703E+00	0.2825E+00
U3O8	1.87	0.3209E+00	0.3336E+00	0.3526E+00	0.3276E+00	0.3328E+00	0.3451E+00
O2	45.03	0.2553E+02	0.2718E+02	0.2987E+02	0.2640E+02	0.2708E+02	0.2875E+02
TOTAL		0.5033E+02	0.5339E+02	0.5826E+02	0.5194E+02	0.5321E+02	0.5626E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.2999E+01	0.2214E+01	0.1435E+01	0.2555E+01	0.2253E+01	0.1702E+01

	KG	RN222	FR221	RA223	RA224	RA226	AC225
AL2O3	2.31	0.1314E+01	0.1193E+01	0.1284E+01	0.1287E+01	0.1427E+01	0.1277E+01
B2O3	3.19	0.2407E+01	0.2142E+01	0.2342E+01	0.2349E+01	0.2666E+01	0.2325E+01
CAO	0.76	0.3732E+00	0.3421E+00	0.3656E+00	0.3664E+00	0.4026E+00	0.3637E+00
FE2O3	4.93	0.2140E+01	0.1970E+01	0.2098E+01	0.2103E+01	0.2298E+01	0.2088E+01
FEO	2.43	0.1053E+01	0.9698E+00	0.1033E+01	0.1035E+01	0.1131E+01	0.1028E+01
K2O	2.97	0.14[illegible]E+01	0.1364E+01	0.1459E+01	0.1462E+01	0.1609E+01	0.1451E+01
LI2O	1.47	0.104[illegible]E+01	0.9389E+00	0.1016E+01	0.1018E+01	0.1137E+01	0.1009E+01
MGO	0.82	0.4904E+00	0.4433E+00	0.4788E+00	0.4801E+00	0.5353E+00	0.4759E+00
MNO	1.55	0.6865E+00	0.6318E+00	0.6732E+00	0.6746E+00	0.7376E+00	0.6698E+00
SIO2	22.30	0.1242E+02	0.1129E+02	0.1214E+02	0.1217E+02	0.1348E+02	0.1208E+02
TIO2	0.59	0.2764E+00	0.2542E+00	0.2710E+00	0.2716E+00	0.2975E+00	0.2696E+00
NA2O	9.07	0.5697E+01	0.5125E+01	0.5556E+01	0.5572E+01	0.6245E+01	0.5521E+01
NIO	0.73	0.3046E+00	0.2807E+00	0.2988E+00	0.2994E+00	0.3268E+00	0.2972E+00
U3O8	1.87	0.3670E+00	0.3433E+00	0.3612E+00	0.3617E+00	0.3888E+00	0.3597E+00
O2	45.03	0.3201E+02	0.2848E+02	0.3114E+02	0.3123E+02	0.3552E+02	0.3092E+02
TOTAL		0.6207E+02	0.5578E+02	0.6052E+02	0.6069E+02	0.6821E+02	0.6013E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.1048E+01	0.1767E+01	0.1204E+01	0.1188E+01	0.6142E+00	0.1244E+01

	KG	TH227	TH228	TH229	TH230	TH232	PA231
AL2O3	2.31	0.1255E+01	0.1326E+01	0.1410E+01	0.1448E+01	0.1576E+01	0.1398E+01
B2O3	3.19	0.2278E+01	0.2435E+01	0.2625E+01	0.2717E+01	0.3023E+01	0.2597E+01
CAO	0.76	0.3581E+00	0.3765E+00	0.3981E+00	0.4082E+00	0.4417E+00	0.3951E+00
FE2O3	4.93	0.2057E+01	0.2158E+01	0.2275E+01	0.2328E+01	0.2505E+01	0.2258E+01
FEO	2.43	0.1013E+01	0.1062E+01	0.1120E+01	0.1146E+01	0.1233E+01	0.1112E+01
K2O	2.97	0.1429E+01	0.1503E+01	0.1591E+01	0.1632E+01	0.1768E+01	0.1579E+01
LI2O	1.47	0.9914E+00	0.1052E+01	0.1123E+01	0.1156E+01	0.1267E+01	0.1112E+01
MGO	0.82	0.4675E+00	0.4955E+00	0.5285E+00	0.5438E+00	0.5952E+00	0.5238E+00
MNO	1.55	0.6600E+00	0.6922E+00	0.7300E+00	0.7473E+00	0.8051E+00	0.7246E+00
SIO2	22.30	0.1187E+02	0.1254E+02	0.1332E+02	0.1368E+02	0.1488E+02	0.1321E+02
TIO2	0.59	0.2656E+00	0.2788E+00	0.2943E+00	0.3015E+00	0.3256E+00	0.2921E+00
NA2O	9.07	0.5418E+01	0.5757E+01	0.6161E+01	0.6350E+01	0.6984E+01	0.6102E+01
NIO	0.73	0.2930E+00	0.3071E+00	0.3235E+00	0.3308E+00	0.3554E+00	0.3213E+00
U3O8	1.87	0.3554E+00	0.3696E+00	0.3856E+00	0.3925E+00	0.4160E+00	0.3834E+00
O2	45.03	0.3028E+02	0.3239E+02	0.3495E+02	0.3623E+02	0.4051E+02	0.3456E+02
TOTAL		0.5900E+02	0.6274E+02	0.6724E+02	0.6941E+02	0.7669E+02	0.6657E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.1360E+01	0.9903E+00	0.6612E+00	0.5560E+00	0.2665E+00	0.6937E+00

	KG	U232	U233	U234	U235	U236	U238
AL2O3	2.31	0.1340E+01	0.1419E+01	0.1427E+01	0.1504E+01	0.1484E+01	0.1540E+01
B2O3	3.19	0.2465E+01	0.2648E+01	0.2667E+01	0.2850E+01	0.2803E+01	0.2935E+01
CAO	0.76	0.3799E+00	0.4006E+00	0.4027E+00	0.4228E+00	0.4176E+00	0.4321E+00
FE2O3	4.93	0.2177E+01	0.2287E+01	0.2299E+01	0.2405E+01	0.2378E+01	0.2454E+01
FEO	2.43	0.1071E+01	0.1126E+01	0.1132E+01	0.1184E+01	0.1170E+01	0.1208E+01
K2O	2.97	0.1517E+01	0.1601E+01	0.1609E+01	0.1691E+01	0.1670E+01	0.1729E+01
LI2O	1.47	0.1063E+01	0.1131E+01	0.1138E+01	0.1204E+01	0.1187E+01	0.1235E+01
MGO	0.82	0.5007E+00	0.5322E+00	0.5354E+00	0.5662E+00	0.5583E+00	0.5805E+00
MNO	1.55	0.6983E+00	0.7342E+00	0.7378E+00	0.7724E+00	0.7635E+00	0.7885E+00
SIO2	22.30	0.1266E+02	0.1341E+02	0.1348E+02	0.1420E+02	0.1402E+02	0.1453E+02
TIO2	0.59	0.2812E+00	0.2960E+00	0.2976E+00	0.3120E+00	0.3083E+00	0.3187E+00
NA2O	9.07	0.5821E+01	0.6206E+01	0.6246E+01	0.6625E+01	0.6528E+01	0.6802E+01
NIO	0.73	0.3097E+00	0.3253E+00	0.3268E+00	0.3415E+00	0.3378E+00	0.3483E+00
U3O8	1.87	0.3722E+00	0.3873E+00	0.3888E+00	0.4028E+00	0.3991E+00	0.4093E+00
O2	45.03	0.3277E+02	0.3526E+02	0.3553E+02	0.3809E+02	0.3743E+02	0.3928E+02
TOTAL		0.6343E+02	0.6777E+02	0.6822E+02	0.7257E+02	0.7146E+02	0.7460E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.9311E+00	0.6356E+00	0.6138E+00	0.4183E+00	0.4591E+00	0.3435E+00

	KG	NP237	PU236	PU238	PU239	PU240	PU242
AL2O3	2.31	0.1430E+01	0.1276E+01	0.1312E+01	0.1362E+01	0.1361E+01	0.1405E+01
B2O3	3.19	0.2672E+01	0.2324E+01	0.2404E+01	0.2514E+01	0.2513E+01	0.2613E+01
CAO	0.76	0.4033E+00	0.3636E+00	0.3728E+00	0.3857E+00	0.3855E+00	0.3968E+00
FE2O3	4.93	0.2302E+01	0.2087E+01	0.2138E+01	0.2208E+01	0.2207E+01	0.2267E+01
FEO	2.43	0.1133E+01	0.1028E+01	0.1052E+01	0.1087E+01	0.1086E+01	0.1116E+01
K2O	2.97	0.1612E+01	0.1451E+01	0.1489E+01	0.1541E+01	0.1540E+01	0.1585E+01
LI2O	1.47	0.1140E+01	0.1009E+01	0.1039E+01	0.1081E+01	0.1081E+01	0.1118E+01
MGO	0.82	0.5364E+00	0.4758E+00	0.4898E+00	0.5093E+00	0.5091E+00	0.5263E+00
MNO	1.55	0.7389E+00	0.6696E+00	0.6857E+00	0.7083E+00	0.7080E+00	0.7276E+00
SIO2	22.30	0.1351E+02	0.1207E+02	0.1241E+02	0.1287E+02	0.1286E+02	0.1327E+02
TIO2	0.59	0.2980E+00	0.2696E+00	0.2761E+00	0.2853E+00	0.2852E+00	0.2932E+00
NA2O	9.07	0.6258E+01	0.5519E+01	0.5689E+01	0.5926E+01	0.5923E+01	0.6134E+01
NIO	0.73	0.3273E+00	0.2972E+00	0.3043E+00	0.3142E+00	0.3140E+00	0.3225E+00
U3O8	1.87	0.3892E+00	0.3597E+00	0.3668E+00	0.3765E+00	0.3763E+00	0.3845E+00
O2	45.03	0.3561E+02	0.3091E+02	0.3196E+02	0.3343E+02	0.3341E+02	0.3477E+02
TOTAL		0.6836E+02	0.6011E+02	0.6199E+02	0.6460E+02	0.6456E+02	0.6693E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.6069E+00	0.1246E+01	0.1055E+01	0.8310E+00	0.8341E+00	0.6762E+00

	KG	PU244	AM241	AM243	CM242	CM243	CM244
AL2O3	2.31	0.1466E+01	0.1315E+01	0.1345E+01	0.1235E+01	0.1264E+01	0.1270E+01
B2O3	3.19	0.2759E+01	0.2410E+01	0.2478E+01	0.2234E+01	0.2298E+01	0.2309E+01
CAO	0.76	0.4127E+00	0.3736E+00	0.3814E+00	0.3530E+00	0.3605E+00	0.3618E+00
FE2O3	4.93	0.2352E+01	0.2142E+01	0.2184E+01	0.2030E+01	0.2070E+01	0.2078E+01
FEO	2.43	0.1158E+01	0.1054E+01	0.1075E+01	0.9992E+00	0.1019E+01	0.1023E+01
K2O	2.97	0.1650E+01	0.1492E+01	0.1523E+01	0.1408E+01	0.1438E+01	0.1444E+01
LI2O	1.47	0.1171E+01	0.1042E+01	0.1068E+01	0.9746E+00	0.9990E+00	0.1004E+01
MGO	0.82	0.5508E+00	0.4910E+00	0.5030E+00	0.4597E+00	0.4711E+00	0.4731E+00
MNO	1.55	0.7552E+00	0.6871E+00	0.7009E+00	0.6510E+00	0.6640E+00	0.6665E+00
SIO2	22.30	0.1384E+02	0.1243E+02	0.1272E+02	0.1169E+02	0.1196E+02	0.1201E+02
TIO2	0.59	0.3048E+00	0.2767E+00	0.2823E+00	0.2620E+00	0.2673E+00	0.2683E+00
NA2O	9.07	0.6436E+01	0.5703E+01	0.5848E+01	0.5325E+01	0.5461E+01	0.5487E+01
NIO	0.73	0.3342E+00	0.3048E+00	0.3109E+00	0.2891E+00	0.2948E+00	0.2959E+00
U3O8	1.87	0.3957E+00	0.3673E+00	0.3733E+00	0.3515E+00	0.3573E+00	0.3584E+00
O2	45.03	0.3681E+02	0.3205E+02	0.3294E+02	0.2971E+02	0.3055E+02	0.3071E+02
TOTAL		0.7040E+02	0.6214E+02	0.6374E+02	0.5797E+02	0.5947E+02	0.5976E+02

RATIO OF TOTJPY TO TOTJP

RATIO(I)	0.5078E+00	0.1042E+01	0.9049E+00	0.1474E+01	0.1311E+01	0.1282E+01

	KG	CM245	CM246	CM247	CM248	CF252
AL2O3	2.31	0.1332E+01	0.1330E+01	0.1394E+01	0.1451E+01	0.1251E+01
B2O3	3.19	0.2447E+01	0.2443E+01	0.2586E+01	0.2723E+01	0.2268E+01
CAO	0.76	0.3778E+00	0.3774E+00	0.3938E+00	0.4089E+00	0.3571E+00
FE2O3	4.93	0.2165E+01	0.2162E+01	0.2251E+01	0.2331E+01	0.2052E+01
FEO	2.43	0.1066E+01	0.1064E+01	0.1108E+01	0.1148E+01	0.1010E+01
K2O	2.97	0.1509E+01	0.1507E+01	0.1574E+01	0.1634E+01	0.1425E+01
LI2O	1.47	0.1056E+01	0.1054E+01	0.1108E+01	0.1158E+01	0.9879E+00
MGO	0.82	0.4975E+00	0.4967E+00	0.5218E+00	0.5449E+00	0.4659E+00
MNO	1.55	0.6946E+00	0.6938E+00	0.7226E+00	0.7483E+00	0.6581E+00
SIO2	22.30	0.1259E+02	0.1257E+02	0.1317E+02	0.1370E+02	0.1183E+02
TIO2	0.59	0.2797E+00	0.2794E+00	0.2912E+00	0.3019E+00	0.2649E+00
NA2O	9.07	0.5782E+01	0.5773E+01	0.6079E+01	0.6362E+01	0.5398E+01
NIO	0.73	0.3081E+00	0.3077E+00	0.3203E+00	0.3313E+00	0.2921E+00
U3O8	1.87	0.3705E+00	0.3701E+00	0.3826E+00	0.3931E+00	0.3547E+00
O2	45.03	0.3254E+02	0.3248E+02	0.3440E+02	0.3631E+02	0.3016E+02
TOTAL		0.6301E+02	0.6291E+02	0.6630E+02	0.6955E+02	0.5878E+02
RATIO(I)		0.9672E+00	0.9758E+00	0.7067E+00	0.5492E+00	0.1381E+01

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