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DATA USED IN HEALTH PHYSICS CONSIDERATIONS
FOR PLUTONIUM AND AMERICIUM

by

E. A. Putzier

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

THE DOW CHEMICAL COMPANY
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401
U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT(29-1)-1106

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Printed in USA. Price ~~\$2~~. Available from the Clearinghouse for Federal
Scientific and Technical Information, National Bureau of Standards,
U. S. Department of Commerce, Springfield, Virginia 22151

23 November 1966

RFP-795

UC-41 HEALTH AND SAFETY

TID-4500

CFSTI PRICES

LA 3.00, MH 65

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INTRODUCTION

Information contained in the following pages represents an attempt to put under one cover numerous data which have been used and are used in health physics considerations of plutonium and americium.

NUCLEAR CONSTANTS

Isotope	Radiation	Energy	Abundance
Pu ²³⁸	α	5.495 Mev	72%
	α	5.452 Mev	28%
	α	5.352 Mev	0.09%
	L x-ray	17 kev avg	0.13/ α decay
	γ -ray	45 kev	3.4×10^{-4} / α decay

Radiologic half-life 89.6 yr
 Spontaneous fission half-life 3.8×10^{10} yr
 Specific activity 16.8 c/g
 Specific spontaneous fission rate 1140 f/g/sec
 First daughter product – U²³⁴ (not important to health physics considerations)

Some small amount of hard γ associated with fission.

Isotope	Radiation	Energy	Abundance
Pu ²³⁹	α	5.147 Mev	72.5%
	α	5.134 Mev	16.8%
	α	5.096 Mev	10.7%
	L x-ray	17 kev avg	2.9×10^{-2} / α decay
	γ -ray	39 kev	2×10^{-5} / α decay
	γ -ray	53 kev	7×10^{-5} / α decay
	γ -ray	100 kev	5.5×10^{-5} / α decay
	γ -ray	124 kev	2.5×10^{-5} / α decay
	γ -ray	384 kev	1.5×10^{-5} / α decay

Radiologic half-life 24,400 yr
 Spontaneous fission half-life 5.5×10^{15} yr
 Specific activity 0.062 c/g
 Specific spontaneous fission rate 0.02 f/g/sec
 First daughter product – U²³⁵ (not important to health physics considerations)

Isotope	Radiation	Energy	Abundance
Pu ²⁴⁰	α	5.162 Mev	76%
	α	5.118 Mev	24%
	L x-ray	17 kev avg	0.1/ α decay
	γ -ray	44 kev	10 ⁻⁴ / α decay

Radiologic half-life 6600 yr
 Spontaneous fission half-life 1.2×10^{11} yr
 Specific activity 0.227 c/g
 Specific spontaneous fission rate 460 f/g/sec
 First daughter product – U²³⁶ (not important to health physics considerations)

Some small amount of hard γ associated with fission.

Isotope	Radiation	Energy	Abundance
Pu ²⁴¹	β^-	21 kev max	99+%
	α	4.9 Mev	$4 \times 10^{-3}\%$
	γ -ray	145 kev	2×10^{-6} / α decay

Radiologic half-life 13.2 yr
 Specific activity 113 c/g
 First daughter products – Am²⁴¹ and U²³⁷ (discussed separately)

Isotope	Radiation	Energy	Abundance
Pu ²⁴²	α	4.898 Mev	76%
	α	4.858 Mev	24%

Radiologic half-life 3.8×10^5 yr
 Spontaneous fission half-life 7×10^{10} yr
 Specific activity 3.91×10^{-3} c/g
 Specific spontaneous fission rate 2760 f/g/sec
 First daughter product – U²³⁸ (not important to health physics considerations)

Isotope	Radiation	Energy	Abundance
Am ²⁴¹	α	5.477 Mev	85%
	α	5.435 Mev	12.6%
	α	5.378 Mev	1.7%
	α others		<1%
	L x-ray	17 kev avg	$3.7 \times 10^{-1}/a$ decay
	γ -ray	26 kev	$2.7 \times 10^{-2}/a$ decay
	γ -ray	43 kev	$6 \times 10^{-4}/a$ decay
	γ -ray	60 kev	$3.7 \times 10^{-1}/a$ decay
	γ -ray	99 kev	$2 \times 10^{-4}/a$ decay

Radiologic half-life 462 yr

Specific activity 3.22 c/g

First daughter product — Np²³⁷ (not important to health physics considerations of Am²⁴¹ chain)

Isotope	Radiation	Energy	Abundance
U ²³⁷	β^-	250 kev max	74%
	β^-	84 kev max	26%
	γ -ray	59 kev	$3.6 \times 10^{-1}/a$ decay
	γ -ray	65 kev	$2.3 \times 10^{-2}/a$ decay
	γ -ray	165 kev	$3.6 \times 10^{-2}/a$ decay
	γ -ray	208 kev	$2.4 \times 10^{-1}/a$ decay
	γ -ray	268 kev	$8.6 \times 10^{-3}/a$ decay
	γ -ray	332 kev	$1.6 \times 10^{-2}/a$ decay

Radiologic half-life 6.7 days

Specific activity 8.2×10^4 c/gFirst daughter product — Np²³⁷ (not important for health physics considerations of Pu²⁴¹ chain)

CHANGING ACTIVITY IN A MIXTURE OF Pu ISOTOPES

The decay of Pu²⁴¹ to Am²⁴¹ and U²³⁷ has a decided influence on the over-all x- and γ -activity of a mixture of plutonium isotopes and to a lesser extent an influence on the α specific activity of the mixture. This influence can be predicted if the plutonium isotopic analysis of the mixture is known and the existing amount of U²³⁷ and Am²⁴¹ is known. The actual abundances of x- and γ -rays for a mixture consisting of 94.5% Pu²³⁹, 5% Pu²⁴⁰ and 0.5% Pu²⁴¹ with respect to time are shown in Figures 1 and 2. Values for other isotopic ratios would be in direct proportion to the isotopic ratios cited on these graphs. Figure 3 shows the changing α activity of the same mixture with time. Again, values for other isotopic ratios would be in direct proportion to the isotopic ratios exhibited on these graphs. The very small α activity contribution from Pu²⁴¹ is ignored.

GAMMA DOSE RATES FROM "SEMI-INFINITE" THICK PURE METAL SLABS

1. Pu²³⁸
 - L x-ray surface dose rate 980 Rad/hr
 - 45-kev γ surface dose rate 2 Rad/hr
2. Pu²³⁹
 - L x-ray surface dose rate 0.61 Rad/hr
 - γ radiations surface dose rate 0.056 Rad/hr
3. Pu²⁴⁰
 - L x-ray surface dose rate 14 Rad/hr

44-kev γ -ray surface dose rate

8 mrad/hr

Hard γ -ray associated with fission
-- surface dose rate

0.062 Rad/hr

of Pu^{241} , obtain the surface dose rate factor from Figure 10 and multiply by the appropriate time factor from Figure 9 (time < 35 days, however, from the practical standpoint $35 < t < 1$ year, the value from Figure 10 may be used without a time factor; for $t > 1$ year, this value should be multiplied by

$$\frac{0.693 t}{e^{13.2}}$$

4. Pu^{241} + daughters (Am^{241} and U^{237})Surface dose rate from L x-rays from Am^{241} growth: $t < 2$ years230 $(4.64 \times 10^{-4} t)$ Rad/hr t in daysFor all t 230 $[3.33 (e^{-1.5 \times 10^{-3} t} - e^{-5.24 \times 10^{-2} t})]$ Rad/hr t in yearsSurface dose rate from γ -rays from Am^{241} growth: $t < 2$ years221 $(4.64 \times 10^{-4} t)$ Rad/hr t in daysFor all t 221 $[3.33 (e^{-1.5 \times 10^{-3} t} - e^{-5.24 \times 10^{-2} t})]$ Rad/hr t in yearsSurface dose rate from γ -rays from U^{237} growth:For $t < 40$ days24 $(1 - e^{-0.102 t})$ Rad/hr t in daysFor $t > 40$ days24 $e^{-\frac{0.693 t}{13.2 \times 365}}$ Rad/hr t in days

Each of the above radiation levels is from a slab of metal of a single, initially pure isotope of Pu. Therefore, the values for a mixture must be weighted according to the isotopic make-up of the mixture. Figures 4 through 10 may be used for making a quick estimate of the surface dose rate from a slab of plutonium metal if the isotopic make-up and age since purification are known. Values for the contributions to the surface dose rate from Pu^{238} , Pu^{239} and Pu^{240} may be taken directly from Figures 4, 5, and 6, respectively. To obtain the contribution from the Am^{241} daughter of Pu^{241} , obtain the surface dose rate factor from Figure 8 and multiply by the appropriate time factor from Figure 7 (time < 2 years). To obtain the contribution from the U^{237} daughter

with t in years). The five values may be added to estimate the gamma surface dose rate from the mixture.

NEUTRON RADIATION FROM Pu

The neutron radiation value (ngs) from pure plutonium metal depends primarily on the spontaneous fission rates of the isotopes which make up the mixture. Specific neutron yields are as follows:

Pu^{238}	3420 neutrons/g/sec
Pu^{239}	Negligible
Pu^{240}	1380 neutrons/g/sec
Pu^{242}	2580 neutrons/g/sec

The ngs value for the plutonium mixtures common to Rocky Flats operations is, for practical purposes, dependent on the Pu^{240} content only. Figure 11 is a plot of ngs versus percent Pu^{240} in the mixture.

The neutron dose rate at the surface of a Pu sphere can be shown to be $\frac{1}{2}na$ where a is the radius of the sphere and n is the number of neutrons emitted per unit volume. For fission neutrons, $1 \text{ n/cm}^2/\text{sec} = 0.115 \text{ mrem/hr}$.

Neutrons may also be produced by the α -n nuclear reaction when Pu and certain light nuclei are combined as mixtures or compounds. Observed neutron yields from polonium alpha particles bombarding thick targets are shown in Table I. Yields from plutonium alpha particles may vary slightly from these, e.g., Rocky Flats has observed about $6 \text{ n}/10^6 \alpha$ for PuF_4 . As a rule of thumb, PuF_4 consisting of 94.5% Pu^{238} , 5% Pu^{240} and 0.5% Pu^{241} yields about $1.5 \times 10^7 \text{ n/sec/kg}$ (wt. is of Pu). The increasing α activity with an increasing percentage of Pu^{240} results in greater neutron yields. This is shown in Figure 12. Increased neutron yield because of Am^{241} growth is negligible up to several years after purification. For the above-mentioned mixture, there would be about a 2½% increase at 4 years after purification.

THE GROWTH OF AMERICIUM FROM Pu^{241}

For different applications it may be convenient to express the growth of Am^{241} from Pu^{241} in different ways. Three methods which are commonly used are shown in Figure 13

TABLE I

NEUTRON YIELDS FROM POLONIUM α PARTICLES
ON THICK TARGETS*

Target	Observed Neutron Yield/ $10^6 \alpha$		
	Roberts (observed)	Roberts (corrected)	Breen and Hertz (actual sources)
Li ₂ CO ₃	0.66		
Li		2.6	1.0
Be	72	80	59
B	21	24	15
C	0.09	0.11	
N ₂	0.01	0.01	
O ₂	0.061	0.07	
CF ₂	7.5		
CaF ₂	5.0		2.8
F ₂		12	
Na	1.3	1.5	1.1
Mg	1.2	1.4	0.80
Al	0.64	0.74	0.53
Si	0.15	0.16	
HgCl	0.04		
Cl ₂		0.11	
A	0.30	0.38	

* Marion, J. B., and Fowler, J. L., Editors, *Fast Neutron Physics*, Chapter I A, Interscience Publishers, Inc., New York, 1960.

as curies of Am/g of Pu²⁴¹ with respect to time; grams of Am²⁴¹/g of Pu²⁴¹ with respect to time; and ppm of Am²⁴¹ in a Pu mixture with respect to time. In the last case, 1% Pu²⁴¹ is assumed to be in the mixture. The plot also assumes that at 0 time, the mixture is void of Am²⁴¹. For a quick calculation the product 1.44t where t is in days and < 2

years yields the ppm growth of Am²⁴¹ for a mixture containing 1% Pu²⁴¹. Values for other initial percentages of Pu²⁴¹ would be in direct proportion to the values on the graph.

Of interest also is the decreasing percentage of Pu²⁴¹ with time. Assuming unity at time 0, Figure 14 is a plot of the portion of Pu²⁴¹ remaining as time increases.

FISSION PRODUCT IMPURITIES ASSOCIATED
WITH Pu OPERATIONS

Traces of Ru¹⁰³-Rh¹⁰³ are sometimes found as impurities in Pu. The effective half-life for these isotopes is about 40 days. Gamma energies average about 500 kev. Found more commonly are the impurities Zr⁹⁵-Nb⁹⁵. Both Zr⁹⁵ and Nb⁹⁵ contribute gammas of average energy 750 kev. Zr⁹⁵ decays into Nb⁹⁵ with a 65-day half-life and Nb⁹⁵ in turn decays to stable Mo⁹⁵ with a 35-day half-life. The combined activity changing with time, therefore, cannot be represented by a simple exponential. Figure 15 shows this relationship assuming the original activity of Nb⁹⁵ is 0. The equation of this plot is

$$A = e^{-\frac{0.693t}{65}} + \frac{7}{6} \left(e^{-\frac{0.693t}{65}} - e^{-\frac{0.693t}{35}} \right)$$

with t in days.

SHIELDING DATA FOR MATERIALS COMMON
TO Pu AND Am²⁴¹ OPERATIONS

Table II lists the percent transmission through materials common to glovebox construction for the various γ energies usually encountered.

TABLE II

PERCENT TRANSMISSION OF GAMMAS THROUGH SEVERAL MATERIALS

Energy Mev	Pb Gloves*		Pb Glass 4.8 Sp. Gr.**				Safety Glass**				Plexiglas**		Lead**			Steel**		
	30-Ga	50-Ga	1/4"	1/2"	3/4"	1"	1/4"	1/2"	3/4"	1"	1/2"	1"	1/16"	1/8"	1/4"	1/8"	1/4"	1/2"
0.017	1	0	1.3	0.0			13				40	15	0.0			0		
0.060	85	45	1.5	0.0			75	55	42	32	81	68	0.0			0		
0.100	78	29	5.4	0.0			84	70	58	49	82	71	35.0	10.0	1.0	45	20	3.5
0.200	96	82	33	14.0	5.4	2.2	88	76	67	60	87	76	47.0	25.0	5.0	82	67	45.0
0.380	99	96	69	47.0	31.0	21.0	90	84	75	68	90	86	70.0	56.0	30.0	82	68	47.0
0.510	-100	97	75	60.0	45	35							80.0	70.0	50.0			
0.750	-100	98	81	66	52	45	94	87	80	75	90	86	85.0	78.0	62.0	85	74	56.0
1.27	-100	-100	87	74	61	52							88	85	72	90	79	61.0
2.1	-100	-100	90	80	73	64							92	87	76	90	80	64.0

* 30-Gage gloves -0.04 mm Pb equivalent

50-Gage gloves -0.20 mm Pb equivalent

** Moulthrop, H. A., *Data on Gamma Shielding of Special Plutonium Samples*, Z Plant Radiation Study, Interim Report No. 5 - Part II, HW-61755, Part 2, October 22, 1959.

SHIPPING CONSIDERATIONS

Shipping regulations for radioactive materials are well documented. In shipping plutonium, the curie value is highly dependent on the isotopic mixture. Figures 16, 17 and 18 may be used to calculate the curie value of a given shipment if one knows the number of grams of mixture in the shipment and the isotopic abundance of the shipment.

ACTIVITY VERSUS PARTICLE SIZE

It is sometimes of interest to know the relationship of activity to the size of a particle. Figure 19 shows activity versus particle size assuming spherical particles of pure compound.

THE EFFECT OF ISOTOPIC MIXTURES ON BODY BURDEN AND RADIOACTIVITY CONCENTRATION GUIDES FOR AIR AND WATER

Because both α and β activity are associated with the isotopes of plutonium, α activity by itself is not always sufficient to evaluate body burden and air and water levels relative to guides set down by official agencies. The β activity of Pu^{241} is of such low energy that it is difficult to measure. It therefore is practical to adjust the α activity values to account for a calculated β activity for a given isotopic mixture. Figures 20, 21 and 22 show adjusted α values to account for Pu^{241} β activity in given isotopic mixtures.

RELATIONSHIP OF AIR CONCENTRATION, TIME OF EXPOSURE, BODY BURDEN ACCUMULATION AND BIOASSAY

Figure 23 shows the relationship between time of exposure, air concentration and accumulated body burden. The plot assumes the air-borne contamination to be of respirable size and that 25% is retained and contributes to the systemic body burden. Figure 24 relates urine activity with systemic body burden assuming an acute exposure. In general chronic exposures may be considered as a series of acute exposures. This graph (Figure 24) is based on the formula $D_r = 435 u t^{.76}$ where u is the 24-hour urine sample activity, D_r is the body burden activity in the same units, and t is the time in days.

EVALUATION OF Pu-CONTAMINATED WOUNDS

Evaluation of the amount of Pu in a wound is complicated by factors such as lack of knowledge of isotopic ratios, age of contaminant, depth of contaminant, dispersion of contaminant, geometry of the wound count compared to geometry of the standard source and possible other factors. The remaining graphs (Figures 25 through 31), some of which are specific to the Rocky Flats wound counter, show the effects of these factors and may be used to minimize these errors for a given contaminated wound evaluation. The final graph merely shows how the tissue dose might vary for a deposit of one microgram if dispersed uniformly throughout spherical volumes of tissue of different diameters.

REFERENCES

1. *Los Alamos Handbook of Radiation Monitoring*, U.S. AEC report LA-1835 (3rd edition) compiled and edited by J. E. Dummer, Jr., November 1958.
2. Roesch, W. C., *Surface Dose from Plutonium*, U.S. AEC report HW-51317, July 1957.
3. *Reviews of Modern Physics*, 30, No. 2, Part II, April 1958.

ILLUSTRATIONS

Figure 1. X- AND GAMMA-RAY ACTIVITY VERSUS TIME FOR STATED ISOTOPIC MIXTURE

Figure 2. X- AND GAMMA-RAY ACTIVITY VERSUS TIME FOR STATED ISOTOPIC MIXTURE

Figure 3. ALPHA ACTIVITY VERSUS TIME FOR STATED ISOTOPIC MIXTURE

Figure 4. SURFACE DOSE RATE CONTRIBUTION - Pu²³⁸

Figure 5. SURFACE DOSE RATE CONTRIBUTION - Pu^{239}

Figure 6. SURFACE DOSE RATE CONTRIBUTION - Pu^{240}

Figure 7. Am^{241} GROWTH FACTOR (use with Figure 8)

Figure 8. SURFACE DOSE RATE FACTOR Am^{241}

Figure 9. U^{237} GROWTH FACTOR (use with Figure 10)

Figure 10. SURFACE DOSE RATE FACTOR U^{237}

Figure 11. NEUTRONS PER GRAM PER SECOND VERSUS PERCENT Pu^{240} IN MIXTURE

Figure 12. NEUTRON PER GRAM PER SECOND FOR PuF_4 VERSUS PERCENT Pu^{240} IN MIXTURE

Figure 13. Am^{241} CONTENT IN MIXTURE CONTAINING ONE PERCENT Pu^{241} VERSUS TIME

Figure 14. RELATIVE Pu^{241} CONTENT IN A MIXTURE VERSUS TIME

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Figure 16. ACTIVITY CONTRIBUTION OF Pu^{239} PER GRAM OF MIXTURE

Figure 17. ACTIVITY CONTRIBUTION OF Pu^{240} PER GRAM OF MIXTURE

Figure 18. ACTIVITY CONTRIBUTION OF Pu^{241} PER GRAM OF MIXTURE

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Figure 20. Pu ALPHA EMITTER MPBB ADJUSTMENT VERSUS Pu^{241} CONTENT IN MIXTURE

Figure 21. RADIOACTIVITY AIR CONCENTRATION GUIDE ADJUSTMENT VERSUS Pu^{241} CONTENT IN MIXTURE

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Figure 23. BODY BURDEN ACCUMULATION VERSUS EXPOSURE TIME FOR GIVEN Pu AIR CONCENTRATIONS

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Figure 28. OBSERVED COUNT RATE FOR L X-RAYS FROM 1 μ g SOURCE FOR VARYING DISTANCES FROM CRYSTAL

Figure 29. CORRECTION FACTOR FOR ROCKY FLATS WOUND COUNTER, 1 μ g PEDESTAL SOURCE - 3/4-in. APERTURE

Figure 30. CORRECTION FACTOR FOR ROCKY FLATS WOUND COUNTER, 1 μ g FLAT SOURCE - 3/4-in. APERTURE

Figure 31. DOSE RATE FROM Pu WOUND DEPOSIT VERSUS DIAMETER OF AFFECTED TISSUE VOLUME