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SPECIFIC ACTIVITIES OF HIGHLY IRRADIATED PLUTONIUM

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Specific activities of individual plutonium isotopes and the specific activity of the average of the last H-240 plutonium products were calculated. The results of these calculations indicate the following.

The total alpha, beta, and gamma emission rates from one gram of evaporator stream plutonium would be:

Alpha Emission Rate - 4.04×10^{9} α's/gm-sec

Beta Emission Rate - 9.24×10^{10} β's/gm-sec

Gamma Emission Rate - 2.83×10^{8} γ's/gm-sec

The predominant γ-energies would be:

I	0.056 - 0.060 Mev	1.4×10^{8} γ's/gm-sec
II	0.180 - 0.209 Mev	8.5×10^{7} γ's/gm-sec
III	0.120 - 0.149 Mev	2.6×10^{7} γ's/gm-sec
IV	0.150 - 0.179 Mev	1.3×10^{7} γ's/gm-sec
	Total these groups	2.64×10^{8} γ's/gm-sec

The above four groups constitute 93% of the total gamma emission rate.

Table I - ISOTOPIC ACTIVITY

Isotope	$T_{1/2}$	α's or β^-'s /sec/gm	SF's /sec/gm
Pu-238	89.6y	6.21×10^{11} α	1.14×10^{3}
Pu-239	24,400y	2.27×10^{9} α	1.01×10^{-2}
Pu-240	6,600y	8.37×10^{9} α	4.25×10^{2}
Pu-241	13.2y	4.17×10^{12} β	---
Pu-242	3.8×10^{5}y	1.44×10^{8} α	7.6×10^{2}
U-237	6.75d	3.01×10^{15}	---
Am-241	462y	1.19×10^{11} α	3.93
Cm-242	162.5d	1.23×10^{14} α	7.6×10^{6}

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The α, β and γ emissions from these isotopes are as follows:

Table II

Pu-238	α	5.495	Mev	(72%)
		5.452	Mev	(28%)
		5.352	Mev	(0.09%)
	γ	0.0438	Mev	(0.038%, e/γ, 740)
		0.099	Mev	(8×10^{-3}% e/γ 11)
		0.150	Mev	(1×10^{-3}%)
		0.203	Mev	(4×10^{-6}%)
		0.760	Mev	(5×10^{-5}%)
		0.810	Mev	(e/γ large)
		0.875	Mev	(2×10^{-5}%)
Pu-239	α	5.147	Mev	(72.5%)
		5.134	Mev	(16.8%)
		5.096	Mev	(10.7%)
		5.064	Mev	(0.037%)
		4.999	Mev	(0.013%)
		4.917	Mev	(0.005%)
	γ	0.0385	Mev	(2×10^{-3}%)
		0.0520	Mev	(7×10^{-3}%)
Pu-240	α	5.162	Mev	(76%)
		5.118	Mev	(24%)
		5.014	Mev	(0.1%)
	γ	0.04528	Mev	(~4×10^{-3}%/EDA)
Pu-241	α	4.893	Mev	(4×10^{-3}%)
	β	0.021	Mev	(99 + %)
	γ	0.145	Mev	(7% of α)
Pu-242	α	4.898	Mev	(76%)
		4.858	Mev	(25%)
	γ	0.045	Mev	(???)

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Table II contd

U-237	β	0.249	Mev	(74%)
		0.084	Mev	(26%)
	γ	E		
	1	0.0264	Mev	
	2	0.0332	Mev	
	3	0.0435	Mev	
	4	0.0596	Mev	(36%)
	5	0.0648	Mev	(2.3%)
	6	0.1139	Mev	
	7	0.1646	Mev	(3.6%)
	8	0.2079	Mev	(24%)
	9	0.2342	Mev	
	10	0.2675	Mev	(0.86%)
	11	0.3323	Mev	(1.4%)
	12	0.3353	Mev	(0.2%)
	13	0.3685	Mev	
	14	0.371	Mev	
Am-241	α	5.534	Mev	(0.35%)
		5.500	Mev	(0.23%)
		5.477	Mev	(85%)
		5.435	Mev	(12.6%)
		5.378	Mev	(1.7%)
		5.311	Mev	(1.2×10^{-2}%)
	γ	0.02636	Mev	(3.3%)
		0.03320	Mev	(0.2%)
		0.04346	Mev	(0.24%)
		0.05957	Mev	(40%)
		0.103	Mev	(0.04%)
		0.113	Mev	(3×10^{-3}%)
		0.130	Mev	(5×10^{-3}%)
		0.159	Mev	(4×10^{-4}%)
		0.210	Mev	(8×10^{-4}%)
		0.27	Mev	(10^{-4}%)
		0.33	Mev	(3×10^{-4}%)
		0.37	Mev	(2×10^{-4}%)
Cm-242	α	6.110	Mev	(73.7%)
		6.066	Mev	(26.3%)
	γ	0.04403	Mev	(0.039%)
		0.1018	Mev	(3.5×10^{-3}%)
		0.1576	Mev	(2.3×10^{-3}%)

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The approximate composition of the last material processed from H-240 would be as follows:

Pu-238	200-500 ppm
Pu-239	83.6%
Pu-240	13.8%
Pu-241	2.2%
Pu-242	0.4%
Am-241 (In Feed)	~1.0% (/EDA from MTR Pu Run Data Comparison)
Cm-242 (In Feed)	~0.03%(/EDA from MTR Pu Run Data Comparison)

It is doubtful that more than 2% of the Am or Cm present in the feed could have appeared in the evaporator stream. Only one check (on a Savannah River run) was made on the evaporator stream before further purification and in this case the Am + Cm alpha pulse rate was less than 20% of the total alpha.

Thus, one gram of plutonium with the additional contamination would have an alpha activity as follows:

Table III

				Act. α's/gm-Sec
Pu-238	350×10^{-6}	$\times 6.21 \times 10^{11}$	=	2.180×10^{8}
Pu-239	0.836	$\times 2.27 \times 10^{9}$	=	19.000×10^{8}
Pu-240	0.138	$\times 8.37 \times 10^{9}$	=	11.550×10^{8}
Pu-242	0.004	$\times 1.44 \times 10^{8}$	=	0.006×10^{8}
Am-241	0.01×0.02	$\times 1.19 \times 10^{11}$	=	0.24×10^{8}
Cm-242	0.0003×0.02	$\times 1.23 \times 10^{14}$	=	7.40×10^{8}
Total Pu				32.736×10^{8}
Total Non Pu				7.64×10^{8}
Total				40.38×10^{8}

The α-curie levels would be as follows:

Pu isotopes only	0.0885 curies/gm Pu Mix
Total isotopes	0.109 curies/gm Mix

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It is anticipated that in addition to the above activities there would be equilibrium between Pu-241 and U-237 with some additional Am-241 being formed from the Pu-241 β^- decay. However, since there is uncertainty on the Am-241 estimate we can assume that the Am-241 content is probably a maximum. The Pu-241 β^- activity would be

$$0.022 \times 4.17 \times 10^{12} = 9.20 \times 10^{10}\ \beta^-\text{'s/Am-Pu/sec (2.5 curies/gm)}$$

The U-237 β^- activity would be

$$0.022 \times 4 \times 10^{-3} \times 4.17 \times 10^{12} = 3.7 \times 10^{8}\ \beta^-\text{'s/gm-Pu/sec (0.01 curies/gm)}$$

The gamma activity of the Pu isotopes and Am + Cm that can be estimated is as follows:

Table IV. Gamma Emissions from Pu Mix

	γ's/gm-sec Pu Mix	γ's/gm-Pu-sec due to Am + Cm
0.025-0.030	-	7.8×10^5
0.031-0.035	-	4.8×10^4
0.036-0.040	3.8×10^4	-
0.041-0.045	1.3×10^5	3.44×10^5
0.046-0.050	-	-
0.051-0.055	1.3×10^5	-
0.056-0.060	1.3×10^8	9.52×10^6
0.061-0.065	8.5×10^6	-
0.095-0.100	1.8×10^4	-
0.101-0.105	-	3.6×10^4
0.111-0.115	-	7.2×10^2
0.120-0.149	2.6×10^7	1.2×10^3
0.150-0.179	1.3×10^7	1.7×10^4
0.180-0.209	8.5×10^7	-
0.210-0.239	-	1.9×10^2
0.240-0.269	3.2×10^6	-
0.270-0.299	-	2.4×10^1
0.300-0.329	-	-

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Table IV cont'd

	γ's/gm-sec Pu Mix	γ's/gm-Pu-sec due to Am + Cm
0.330-0.359	6.0×10^{6}	7.2×10^{1}
0.360-0.389	-	4.8×10^{1}
0.390-0.419	-	-
0.750-0.779	1.1×10^{2}	-
0.780-0.809	-	-
0.810-0.839	?	-
0.840-0.869	-	-
0.870-0.899	4.4×10^{1}	-
Total γ Emissions	2.72×10^{8}	1.08×10^{7}

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