Feb 9, 2000

Problem Set-1

Calculate the Following Parameters for Pu-238

1.) Curies/g of isotope,

2.) Curies needed to generate 1 thermal Watt,

3.) Watts/g of PuO_2,

4.) Watts/cm^3 of PuO_2,

5.) The number of kW_th generated by 1g of PuO_2 for 10 years,

6.) The cost for Pu-238 to generate one kW_eh if the RTG overall efficiency is 5%.

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$T_{1/2}$ = 87.4 years

1 MeV= 1.6021 x 10^{-13} Joule

1 Curie = 3.7 x 10^{10} disintegrations/sec

Density of PuO_2 = 10 g/cc

^{238}Pu in Pu = 80%

Answers to Problem Set #1

1.)

$$1 \text{ g } ^{238}\text{Pu} = \frac{1 \text{ g x } 6.023 \text{ x } 10^{23} \text{ atoms/mole}}{238 \text{ g/mole}}$$

$$= 2.53 \text{ x } 10^{21} \text{ atoms} = N_o$$

Decays/s in 1 g = λN_o

where $\lambda = \ln 2/T_{1/2}$

$$= 0.693/87.4 \text{ x } 3.15 \text{ x } 10^{7}$$

$$= 2.52 \text{ x } 10^{-10} \text{ s}^{-1}$$

Decays/s = $2.53 \text{ x } 10^{21} \bullet 2.52 \text{ x } 10^{-10}$

$$= 6.38 \text{ x } 10^{11}$$

= 17.2 Ci/g of ^{238}**Pu**

2.) If each decay yields a 5.5 MeV alpha particle (or $8.8 \text{ x } 10^{-13}$ **J),**

then, $6.38 \text{ x } 10^{11}$ **decay/s •** $8.8 \text{ x } 10^{-13}$ **J/decay**

or,

0.56 Watt/g of ^{238}**Pu = 1 Watt**

or,

1.79 g ^{238}**Pu = 1 Watt**

or,

30.7 Curies of ^{238}**Pu**

3.) • **Isotopic fraction of ^{238}Pu in Pu is 80%**

• **Pu/PuO_2 = 238/238+32 = 0.881**

• **$^{238}Pu/PuO_2$ = 0.8 x 0.881 = 0.705**

• **Watts/g PuO_2 = 0.705 x 0.56 = 0.395**

4.) • **density of Pu = 19.47 g/cc**

• **density of PuO_2 = 10 g/cc**

• **Watts/cc of PuO_2=0.395 x 10=3.95**

5.)

$$W_t h/g\ PuO_2 \text{ for10 years} = [W_t/g]_0 \int \exp^{-\lambda t}\, dt$$

$$= 0.395 \int \exp^{-\lambda t}\, dt \quad = 0.395\ [\ (\exp^{-\lambda \cdot 10\ y}{}_{-1})]/\lambda$$

since $\lambda = 7.9 \times 10^{-3}\ y^{-1}$

energy/g for 10 y $= 0.395 \bullet 0.07596/7.9 \times 10^{-3}$

$=3.798\ W_t y/g\ PuO_2$

$=33.27\ kW_t h/g\ PuO_2$

6.)

$33.27\ kW_t h/g\ PuO_2 \bullet 0.05\ kW_e h/kW_t h \bullet 1\ g\ PuO_2/0.705\ g\ ^{238}Pu$
• $1\ g\ ^{238}Pu/\$300 = 0\ .00787\ kW_e h/\$$

or, 127 $\$/kW_e h$ per g of ^{238}Pu