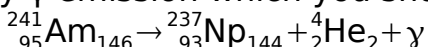


Smoke detectors use $^{241}_{95}\text{Am}_{146}$ to provide ionization radiation. Let's investigate some properties of smoke detectors. Note that some data for this comes from <http://www.nndc.bnl.gov/chart/reCenter.jsp?z=95&n=146> which you may use for this problem.

(a) it is found that $^{241}_{95}\text{Am}_{146}$ is unstable against α decay (this is essentially the only decay mode it experiences). Write a balanced equation showing this decay. Note that this reaction is accompanied by γ emission which you should also show.



(b) Show, using the binding energy calculation, that this decay is unstable against α decay. Express your results in MeV.

If you refer to the site:

<http://www.nndc.bnl.gov/masses/mass.mas03>

You can find the atomic masses for the various parts of the reaction. (They are in μu (which I use μ as amu) For example, you'll find for $^{241}_{95}\text{Am}_{146}$ the following:

51	146	95	241	Am	52936.008	1.829	7543.272	0.008	B-	-767.417	1.172	241	056829.144	1.963
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Looking across you will see the mass as 241 056829.144 μu which is 241.056829144 μu .

Use the conversion 1 μu =931.494 MeV.

0	2	2	4	He	2424.91565	0.00006	7073.915	0.000	B-	-22898.270	212.132	4	002603.25415	0.00006
51	144	93	237	Np	44873.275	1.833	7574.982	0.008	B-	-220.032	1.298	237	048173.444	1.967

$$B = (4.00260325415 + 237.04813744 - 241.056829144) = -0.00608844585 \mu$$

$$\Rightarrow B = -5.67135 \text{ MeV}$$

(c) Go to the site:

http://www.nndc.bnl.gov/nudat2/indx_sigma.jsp

Enter your nucleus as 241Am and choose the mode of decay to be alpha. From this, obtain the half life of 432.6 yr (indicate that you have done this step by saying so).

Calculate the decay constant (in yr^{-1}) for $^{241}_{95}\text{Am}_{146}$.

$$\tau_{1/2} = \frac{\ln(2)}{\lambda} \Rightarrow \lambda = \ln\left(\frac{2}{\tau_{1/2}}\right) = \frac{0.0016/\text{yr}}{3.18} \times 10^{-11}/\text{sec}$$

Suppose you have initially 0.29×10^{-6} g of Americium dioxide (the form in smoke detectors). We want to calculate its activity in Bq. In order to do this, it is necessary to calculate the atomic weight of AmO_2 which is 273.05569 g/mole or μ . Since the atomic weight of Am is 241.056829144, the percentage of Am which is active is about 88.3%. Show then that the initial amount of Am in a typical smoke detector is about 0.256 μg . You need this to answer the following question.

After a period of 5 years, how much $^{241}_{95}\text{Am}_{146}$ remains (in μg)?

$$N = N_0 e^{-\lambda t} = (0.256 \mu\text{g}) e^{-50.0016} = 0.254 \mu\text{g}$$

Calculate the initial activity (R_0) of the radiation in the smoke detector in Bq. In order to do this, you need to calculate the number of atoms present.

Do this in the following way:

(a) show that about 0.001062 μmoles of ${}^{241}_{95}\text{Am}_{146}$ are present.

$$n = 0.256 \mu\text{g} \times \left(\frac{1 \text{ mole}}{241.0568 \text{ g}} \right) = 0.001064 \mu\text{m}$$

(b) show that the number of nuclei present is about 6.393×10^{14} .

This is given by:

$$n = N_A \left(\frac{\text{Number}}{\text{mole}} \right) \times m_A \left(\frac{\mu\text{g}}{\text{mole}} \right) = 6.3932 \times 10^{14}$$

(c) now calculate the activity in Bq. You may use the approximation that the number of seconds in a year is about $\pi \times 10^7$ s.

$$R_0 = \lambda N_0 \Rightarrow R_0 = \frac{0.0016}{\pi \times 10^7} = 6.393 \times 10^{-14} = 32559 \text{ Bq}$$

(d) What is the activity after 5 years in Bq?

How many 5 year old smoke detectors would be required to obtain an activity of 1 Ci?
 $32559 \times n = 3.7 \times 10^{10}$ so $n = 1.11 \times 10^6$