Nuclear Physics

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a) $^{87}_{37}Rb \rightarrow ^{87}_{38}Sr + ^{0}_{-1}\beta$

$\therefore$ Beta decay.

b) $^{222}_{86}Rn \rightarrow ^{4}_{2}He + ^{218}_{84}Po$

$\therefore$ Polonium-218

c) $^{1}_{1}H + ^{7}_{3}Li \rightarrow ^{4}_{2}He + ^{4}_{2}He$

$\therefore$ Lithium-7

d) $^{4}_{2}\alpha + ^{9}_{4}Be \rightarrow ^{12}_{6}C + ^{1}_{0}n + \gamma$

$\therefore$ neutron.

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① A) i: Rest mass of reactants/parent nuclei.

$$m_p = 1.67262 \times 10^{-27} + 11.648 \times 10^{-27}$$
$$= 13.32062 \times 10^{-27} \text{ kg.}$$

ii: Rest mass of products/daughter nuclei.

$$m_d = 2 \times 6.64466 \times 10^{-27}$$
$$= 13.28932 \times 10^{-27} \text{ kg}$$

B) $\Delta m = (13.32062 - 13.28932) \times 10^{-27}$

$= 3.13 \times 10^{-29}$ kg (mass deficit)

c) $E = \Delta mc^2 = 3.13 \times 10^{-29} \times (3.00 \times 10^8)^2$

$= 2.817 \times 10^{-12}$ J

D) Mass-energy is lost by the nucleons in the reaction and this released as energy.

② The Smoke Detector

a) $94 = 95 + a$

$\therefore a = -1$

$241 = 241 + b$

$\therefore b = 0$

b) mass # = 0
atomic # = -1 $\therefore$ X must be an electron.
(Beta decay)

c) Δm = mass of parent nuclei − mass of daughter nuclei

$= 4.00284 \times 10^{-25} - 3.93628 \times 10^{-25} - 6.64466 \times 10^{-27}$

$= 1.134 \times 10^{-29}$ kg

$E = \Delta m c^2 = 1.134 \times 10^{-29} \times (3.00 \times 10^8)^2$

$= 1.0206 \times 10^{-12}$ J

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a) Uranium-235

i: # of Protons = 92

\# of Neutrons = 235 − 92 = 143

ii: Mass of components $= 92 \times 1.67262 \times 10^{-27} + 143 \times 1.67493 \times 10^{-27}$

$= (1.5388104 + 2.3951499) \times 10^{-25}$

$= 393.39603 \times 10^{-27}$ kg

iii: mass deficit, Δm = mass of components − mass of nucleus.

$= 393.39603 \times 10^{-27} - 390.2480 \times 10^{-27}$

$= 3.14803 \times 10^{-27}$ kg

iv: Total Binding Energy:

$E = \Delta m c^2$

$= 3.14803 \times 10^{-27} \times (3.00 \times 10^8)^2$

$= 2.833227 \times 10^{-10}$ J

b) Iron-56 (26 protons & 30 neutrons)

Binding Energy: $E = \Delta m c^2$

Δm = mass of components − mass of nucleus

$= (26 \times 1.67262 \times 10^{-27}) + (30 \times 1.67493 \times 10^{-27}) - 92.908 \times 10^{-27}$

$= 43.48812 \times 10^{-27} + 50.2479 \times 10^{-27} - 92.908 \times 10^{-27}$

$= 0.82802 \times 10^{-27}$ kg

$\therefore BE = \Delta m c^2$

$= 0.82802 \times 10^{-27} \times (3 \times 10^8)^2$

$= \underline{0.745218 \times 10^{-10} \text{ J}}$

The total binding energy of Uranium 235 is greater than Iron 56. However, the nucleus of Uranium 235 is also significantly larger than Iron 56 and is less stable. The stability of a nucleus is shown by the binding energy per nucleon

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① a) i: Uranium 235

Total binding energy: 2.833227×10^{-10} J

Binding energy per nucleon $= \frac{2.833227 \times 10^{-10}}{235}$

$= 1.205629 \times 10^{-12}$ J

BE/n in eV $= \frac{1.205629 \times 10^{-12}}{1.6 \times 10^{-19}}$

$= \underline{7.535 \text{ MeV}}$

ii: Iron 56:

BE/n in eV $= \frac{0.745218 \times 10^{-10}}{56 \times 1.6 \times 10^{-19}}$

$= \underline{8.317 \text{ MeV}}$

B) Iron 56 has a higher binding energy per nucleon than Uranium 235 and therefore Iron 56 is more stable.