Radioactivity + Nuclear Reactions

A Physics

1. Radium-226 has an atomic no. 88, and a half life of 1620 y, and emits alpha (α) particles with average energies of 7.65×10^{-13} J each.

$c_{light} = 3 \times 10^{8}$ m/s

$m_p = m_n = 1u = 1.661 \times 10^{-27}$ kg

$m_e = 9.11 \times 10^{-31}$ kg

$N_A = 6 \times 10^{23}$

Calculate ... (a) no. of protons and neutrons in a Radium nucleus (1)

(b) the no. of Ra nuclei in 1g of radium-226. (2)

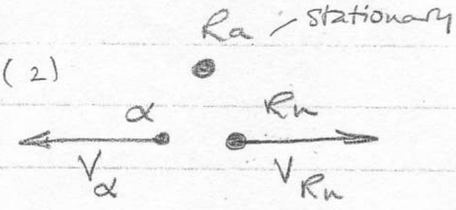
(c) the decay constant of Ra-226 (2).

(d) the activity (in Bq) of 1g of Ra-226 (2)

(e) the speed of the α-particles (2)

(f) the momentum of the α-particles. (2)

(g) Radium decays into a Radon (Rn) nucleus. Write the nuclear reaction (2)



(h) Explain why the α and Rn. nuclei must fly away from each other. Which moves faster, and why? (4)

(i) Using a previous answer, calculate the speed of the Radon nuclei. (2)

(j) Ra-226 is used to provide back-up power in satellites – typical power requirement is 25 W. Calculate the no. of radium atoms needed to provide 25 W power (2)

(k) Calculate the needed mass of radium. (2) $\boxed{23}$

2 Uranium-239 is a short-lived isotope produced when U-238 absorbs a neutron – this is quite common in nuclear reactors. (U has 92 protons!)

a) Write the nuclear reaction for this. (1)

b) The U-239 decays to neptunium Np by emitting a Beta (β) particle. Write the nuclear reaction. (2)

c) The energy released is 2.2×10^{-14} J for each decay. In what form is energy released? (1)

d) Calculate the speed of the emitted Beta per decay. (2) $\boxed{6}$

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Radioactivity + Nuclear Reactions — Answers — A Physics

1. (a) $^{226}_{88}Ra$ 88p (1) + 226 − 88 = 138 n (1)

(b) 226 g ≡ 6×10^{23} nuclei so 1g ≡ 2.65×10^{21} nuclei

units!!

(c) $\ln 2 = T_{1/2}\,\lambda$ (1) → $\lambda = \ln 2 / t_{1/2} = \ln 2 / 1620 = 4.28\times10^{-4}\,y^{-1} = 1.36\times10^{-11}\,s^{-1}$ (1)

(d) $dN/dt = A = -\lambda N$ (1) $= 1.36\times10^{-11}\times2.65\times10^{21} = 3.595\times10^{10}$ Bq (1)

(e) energy = KE = $\frac{1}{2}mv^2$ (1) $m_\alpha = 2p+2n = 6.644\times10^{-27}$ kg

$v_\alpha^2 = \dfrac{2\times KE}{m_\alpha} = 2\times7.65\times10^{-13}/6.644\times10^{-27} = 2.303\times10^{14}\,(m/s)^2$

so $V_\alpha = 1.52\times10^{7}$ m/s (1) ($< 3\times10^{8}$!!)

(f) momentum = mV (1) $= 6.644\times10^{-27}\times1.52\times10^{7} =$

$= 1.008\times10^{-19}$ kg m s^{-1} (1)

(g) $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$ ← or ($^{4}_{2}\alpha$) (1) (1)

(h) Momentum of system constant (1) Initial momentum of Ra is zero (1) so momentum of α and Rn together is zero ... α moves faster (1) because its mass is less (1)

(i) $m_{Rn}V_{Rn} = m_\alpha V_\alpha$ (1) → $V_{Rn} = \dfrac{V_\alpha\times m_\alpha}{m_{Rn}} = 1.52\times10^{7}\times\dfrac{4}{222} = 2.74\times10^{5}$ m/s (1)

(j) 25 W = 25 J/s. So in 1sec need $25/7.65\times10^{-13} = 3.27\times10^{13}$ decays/sec (1)

1g of Ra = 2.65×10^{21} nuclei gives 3.595×10^{10} decays/sec

so no. of Ra atoms needed $= \dfrac{3.27\times10^{13}}{3.595\times10^{10}}\times2.65\times10^{21} = 2.41\times10^{24}$ atoms (1)

(k) mass needed is $\dfrac{3.27\times10^{13}}{3.595\times10^{10}} = 909$ grams (1) [23]

2. a) $^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{92}U$ (1)

(b) $^{239}_{92}U \rightarrow {}^{239}_{93}Np$ (1) $+ {}^{0}_{-1}e$ (1)

(c) Energy released as k.E. (1)

(d) $\frac{1}{2}m_e v^2 = 2.2\times10^{-14}$

so $v^2 = 2\times2.2\times10^{-14}/9.11\times10^{-31} = 4.82\times10^{16}$

so $V = 2.2\times10^{8}$ m/s

hmm... slower than light speed!

RN Jan '01

+ May '04

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