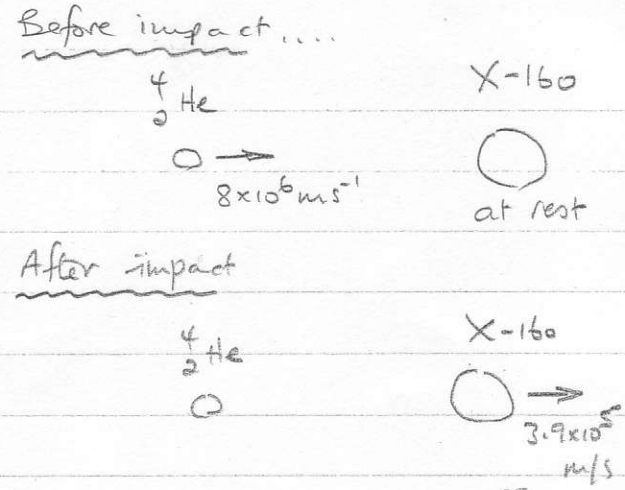
Momentum and Atomic Nuclei.



1. A helium nucleus collides with a stationary nucleus (X), mass number 160. After the collision, X is moving with a velocity of 3.9×10^5 ms^{-1}.

a). What is the principle of the conservation of momentum? (1)

b) What is an "elastic collision"? (2)

$m_{proton} = m_{neutron} = 1.66\times10^{-27}$ kg.

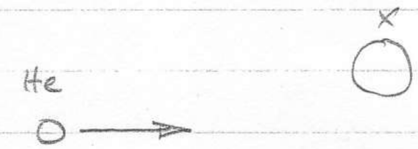
c) What is the mass of the He nucleus? (1)

d) What is the velocity of the He nucleus after collision, and in which direction? (3)

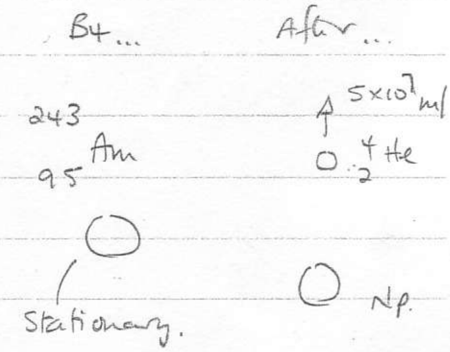
(e) Show that the collision is elastic. (2)

(f) Explain how a collision between two nuclei can be elastic whereas collisions between large objects (like cars and footballers) are not. (4)

(g) Copy the diagram and sketch the motions of the 2 nuclei here. (2)



2. An Americium nucleus decays (explodes) into 2 fragments; a He nucleus and a Neptunium nucleus



a) Calculate the mass of the Np nucleus (2)

b) Calculate the velocity of the Np nucleus (2)

c) It is observed that the He and Np nuclei fly apart along a straight line. Explain why this must always happen when a stationary nucleus decays. (2)

d) Can you explain why the ratio of velocities of fragments must be in inverse proportion to their masses (2)

e) Calculate the energy released by the decay of the Am nucleus.

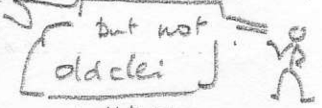
(f) Nuclear reactions like this are sometimes used to provide energy for satellites and space probes. How many Am nuclei must decay per second to produce a power of 5 W? (2)

2/12

1/5

TJW
08.03

Momentum + Atomic Nuclei* Answers A2 Phys.



1. a) Principle: Total momentum of an isolated system is constant ... Total momentum before event / collision / explosion = p_{total} after

b) Elastic collision ... no energy lost (1) ... $E_{before} = E_{after}$ ... no contact (1) /1

c) ^4_2He ... mass $= 4 \times 1.66 \times 10^{-27} = \underline{6.64 \times 10^{-27}}$ kg (1) /1

d) $p_{before} = p_{after}$ .... $p_{He} + 0 = p_{He} + p_X$

$(6.64 \times 10^{-27} \times 8 \times 10^6) + 0 = (p_{He})_{after} + 160 \times 1.66 \times 10^{-27} \times 3.9 \times 10^5$

so $(p_{He})_{after} = \underset{(He)}{5.312 \times 10^{-20}} - \underset{(X)}{1.036 \times 10^{-19}} = \underline{-5.046 \times 10^{-20}}$ kg m s^{-1} (1)

So $v_{He}(after) = -5.046 \times 10^{-20} / 6.64 \times 10^{-27} = \underline{-7.60 \times 10^6}$ m/s (1) $\longleftarrow$ (1)

(the He nucleus rebounds with nearly its original velocity).

e) Hmm... if elastic $E_{before} = E_{after}$.

$E_{before} = E_{He} + 0 = \frac{1}{2} m_{He} v_{He}^2 = \frac{1}{2} \times 6.64 \times 10^{-27} \times (8 \times 10^6)^2 = 2.12 \times 10^{-13}$ J (1)

$E_{after} = E_{He} + E_X = \left[\frac{1}{2} \times 6.64 \times 10^{-27} \times (7.6 \times 10^6)^2\right] + \left[\frac{1}{2} \times 160 \times 1.66 \times 10^{-27} \times (3.9 \times 10^5)^2\right]$ (1)

$= 1.918 \times 10^{-13} + 2.020 \times 10^{-14} = 2.12 \times 10^{-13}$ ∴ ELASTIC!

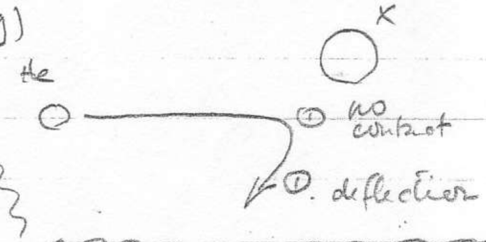
f) nuclei ... v. small mass ... large positive charges ... strong repulsive forces (1) ... don't touch (1) (make contact

organise the answer!

footballs ... atoms come into contact (1) ... set them vibrating (1) ...

gain heat energy ... some k.E transferred to heat ... inelastic

(g)



2. a) $M_{Am} = 243 \times 1.66 \times 10^{-27} = \underline{4.034 \times 10^{-25}}$ kg

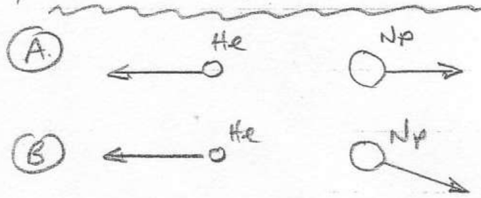
b) p before $= 0 = p$ after .... so $p_{He} = p_{Np}$ (1)

$4 \times 1.66 \times 10^{-27} \times 5 \times 10^7 = 239 \times 1.66 \times 10^{-27} \times v \longleftarrow {}^{239}_{93}Np.$

So $v_{Np} = \underline{8.37 \times 10^5}$ m s^{-1} (1)

c) Think ... in (A) when $p_{He} = p_{Np}$, then $p_{system} = 0$ which is what it should be. (1)

in (B) p_{system} can never $= 0$ 'cos the velocity of Np has a downward component, which He can't balance. (1)



d) Use symbols $p_{system} = 0$ ... so $p_{He} = p_{Np}$ ... so $m_{He} v_{He} = m_{Np} v_{Np}$

so ratio of fragment velocities $v_{He}/v_{Np} = m_{Np}/m_{He}$ — inverse ratio of masses

e) E released $= KE_{He} + KE_{Np} = \left[\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times (5 \times 10^7)^2\right] + \left[\frac{1}{2} \times 239 \times 1.66 \times 10^{-27} \times (8.37 \times 10^5)^2\right]$

$= \underline{8.30 \times 10^{-12} + 1.390 \times 10^{-13}}$ (1) $= \underline{8.43 \times 10^{-12}}$ J (1)

f) 5 W = 5 J/s ... 1 decay produces 8.43×10^{-12} J

so... for 5 J/s (1) there must be $\frac{5}{8.43 \times 10^{-12}} = \underline{5.92 \times 10^{11}}$ decays/sec

TN.

09.03. phew!

Q $\boxed{1}$ /15 $\boxed{2}$ /12.