Nuclear Physics Summary

Subject: Date:

1) Which aspects of the α particle scattering experiment suggested the existence of a small dense nucleus within an atom?
Pg 1 – 3

2) Define a) Nucleon no. (mass no.)
b) proton no. (atomic no.)
c) Isotope

3) Mass-energy equivalance $E = mc^2$ to explain mass defect

4) Fission & Fusion *

5) Using concept of mass-energy in analysing nuclear processes.*
Pg 11 Eg. 7

Radioactivity *

6) Know difference between 3 types of decay: α, β, γ

a) α decay: ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

b) β decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$

c) γ decay: ${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \gamma$

7) Need to apply conservation of mass-energy & conservation of linear momentum to determine if reaction is possible & to calculate velocity of products. Pg 11 Eg 7

8) Radioactive Decay Law: $N = N_0 e^{-\lambda t}$ or $A = A_0 e^{-\lambda t}$

- N is the no. of nuclides remaining after time t
- $A = \lambda N$

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9) Define a) Activity
b) Half life
c) Decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

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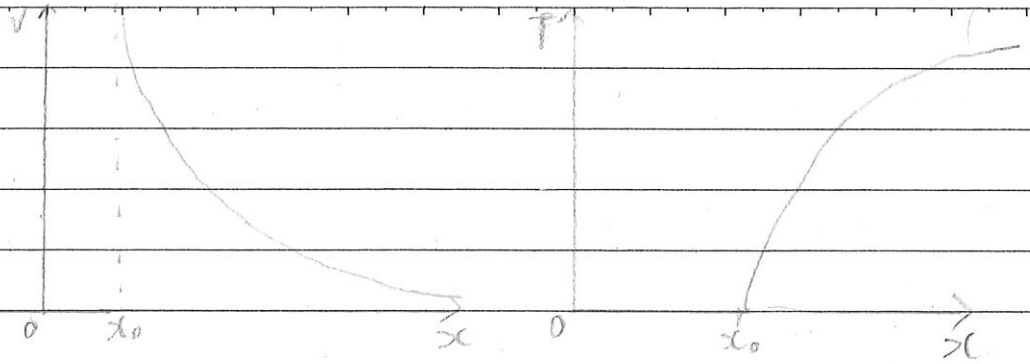
1a i)



1bi) Electrostatic potential energy.

1bii)

$$\text{Energy} = 1.0 \times 1.6 \times 10^{-19} \times 10^{6}$$
$$= 1.6 \times 10^{-13}\ J$$

1biii) ~~When K.E = 0J,~~ $\cancel{-\frac{GMm}{r} = 4.8 \times 1.6 \times 10^{-19} \times 10^{6}}$

$$\frac{Qq}{4\pi\varepsilon_0 d} = 4.8 \times 1.6 \times 10^{-13} \quad \cancel{= -\frac{6.67\times(6.63\times10^{-27})(3.297\times10^{-25})(6.69\times10^{-27})}{4.8\times1.6\times10^{-19}\times10^{6}}}$$

$$d = \frac{Qq}{4\pi\varepsilon_0(4.8\times1.6\times10^{-13})} =$$

$$=$$

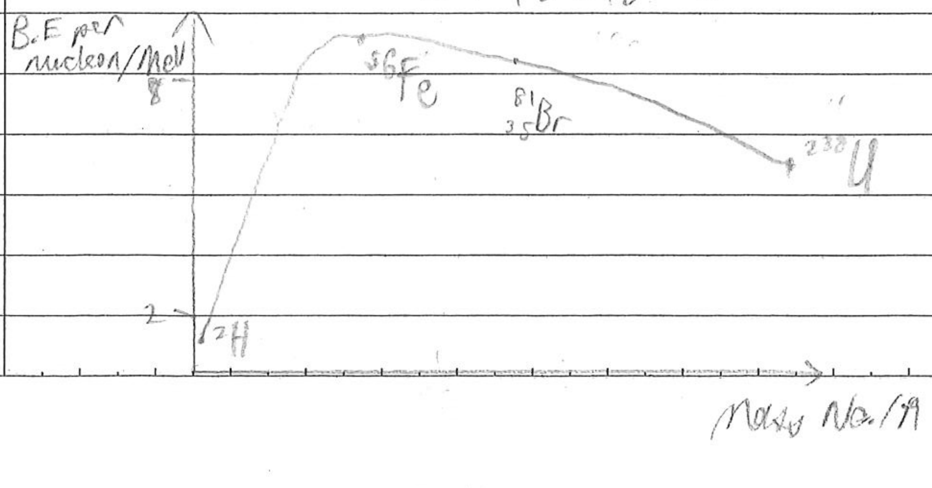
1c) It is very small compared to radius of atom.

2a)

$$35(1.0073u)c^2 + 46(1.0087u)c^2 = 80.8971uc^2 + B.E$$
$$BE = 35.2555uc^2 + 46.4002uc^2$$
$$-80.8971uc^2$$
$$= 0.7586uc^2$$

$$\text{B.E per nucleon} = \frac{0.7586(1.66\times10^{-27})(3.0\times10^{8})^2}{81}$$
$$= 1.40 \times 10^{-12}\ J$$

2b)



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2c) It is very unstable and into another nuclide (not energetically feasible).

2d) The two nuclides are more stable than the resulting nuclide and require energy to fuse, hence energy is absorbed, not released.

Nuclear Processes

3a) $^{238}U \longrightarrow {}^{234}Th + {}^{4}He$

$M_U c^2 = M_{Th} c^2 + M_{He} c^2 + E$

$E = (238.05079 - 234.04363 - 4.00260) u c^2$

$= 6.81 \times 10^{-13} J$

3b) $^{238}U \longrightarrow {}^{237}Pa + {}^{1}H$

Energy of reactant $= 238.05079 u c^2$

Energy of products $= (237.05121 + 1.00783) u c^2$

$= 238.05851 u c^2$

since energy of products > energy of reactant, it is not energetically feasible for ^{238}U to emit a proton.

4) $2(2.01419 u c^2) = 4.00277 u c^2 + E$

$E = (\cancel{4.02838} - 4.00277) u c^2$

$= 3.83 \times 10^{-12} J$ (3s.f)

4a) Power released $= \frac{100}{52} \times 5 \times 10^6$

$= 9.615 \times 10^6 W$

Moles of D $= \frac{2000}{2}$

$= 1000$

2 molecules of D release $3.82 \times 10^{-12} J$

E released by 1000 moles of D $= 6.023 \times 10^{23} \times 1000 \div 2 \times 3.82 \times 10^{-12}$

$= 1.15 \times 10^{15} J$

$E = mc^2$

Pinput

$E = \frac{2}{2 \times 1.66 \times 10^{-27}} \times 3.82 \times 10^{-12}$

$= 1.14 \times 10^{5}$

$t =$

Tan Zhi Yong 03S6H Nuclear physics

Subject: Date:

1a) Mass of constituents of $^2_1H = 1.0073u + 1.0087u$

$= 2.016\,u$

Mass defect $= 2.016u - 2.008032u$

$= 7.968 \times 10^{-3}\ u$

$= 1.32 \times 10^{-29}\ kg$

1b) $2.008032uc^2 + \text{Binding Energy} = 2.016uc^2$

Binding energy $= 2.016uc^2 - 2.00832uc^2$

$=$

$=$

2) $50(1.007825u)c^2 + 70(1.008665u)c^2 = 119.902199uc^2 + B.E$

$B.E = [(50)(1.007825) + (70)(1.008665) - 119.902199]uc^2$

$= 1020\ MeV$ (3s f)

B.E per nucleon $= \frac{1023}{120}$

$= 8.53\ MeV$

3) Neutron.

4) $t_{\frac{1}{2}} = 1.42 \times 10^9 \times 365 \times 24 \times 3600\ s$

$= 4.478 \times 10^{16}\ s$

$A = \lambda N$

$= \frac{\ln 2}{t_{\frac{1}{2}}} N$

$N = \frac{4.478 \times 10^{16} \times 1}{\ln 2}$

$= 6.461 \times 10^{16}$

Mass $= \frac{6.461 \times 10^{16}}{6.023 \times 10^{23}} \times 238$

$= 2.55 \times 10^{-5}\ g$

5a) $I = I_0 e^{-\lambda t}$

5b) $\ln I$

Subject: Date:

6~~✱~~) Spontaneous means that it is not triggered by external factors.
Random means that it is impossible to state exactly which nucleus or exactly when a particular nucleus will disintegrate.
Half-life of the material refers to the time taken
~~6✱)~~ for ~~haff~~ half the number of radioactive nuclei in any given sample of a given isotope to decay.

6i) The decay constant is the probability per unit time for the particle to decay.

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ ~~$A = \lambda N$~~ ~~$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$~~

~~6ii)~~ $= \frac{\ln 2}{30 \times 24 \times 3600}$ ~~$\lambda = \frac{A}{N}$~~

$= 2.67 \times 10^{-7} s^{-1}$ (3s.f)

6ii)

$A = \lambda N$

$= 2.674 \times 10^{-7} \times 10^{12}$

$= 2.67 \times 10^{5}$ Bq (3s.f)

6iii)

~~$A = A_0 e^{-\lambda t}$~~ $N = N_0 e^{-\lambda t}$

~~$2.674 \times 10^{5} = 10$~~ $10^{4} = 10^{12} e^{-2.674 \times 10^{-7} t}$

~~$\ln 10^{4}$~~ $10^{-8} = e^{-2.674 \times 10^{-7} t}$

$\ln 10^{-8} = -2.674 \times 10^{-7} t$

$t = 6.89 \times 10^{7}$ s (3s.f)

6iv)

$A = \lambda N$

$= 2.674 \times 10^{-7} \times 10^{4}$

$= 2.67 \times 10^{-3}$ Bq (3s.f)

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Time fuel will last $= \frac{1.15 \times 10^{15}}{9.615 \times 10^{6}}$

$= 1.18 \times 10^{8}\,s$ (3s-f)

4b) For nuclear fusion to take place, hydrogen atoms must be brought close enough in order for them to fuse. Energy is required to overcome the very high Coulombic repulsion. Moreover, more energy is released in the form of heat as a result of fusion. No material is capable of withstanding such heat, hence fusion cannot be used to generate electricity.

can only take place at high T

4c) In nuclear fusion, lighter nuclides combine to form heavier, more stable nuclides, increasing binding energy and releasing energy in the process

5a) Nuclear fission.

1.6×10^{-13}

5b) $1.6 \times 10^{-13}(8.6 \times 87 + 8.4 \times 146) = (7.4 \times 235) + E$

$E = 3.7696 \times 10^{-11}\,J$

No. of fissions $= 2000 \times 10^{6} \times \frac{100}{25} \div (3.7696 \times 10^{-11})$

$= 2.12 \times 10^{20}$

6) $C = C_0 e^{-\lambda t}$

$\ln C = \ln C_0 - \lambda t$

Plot $\ln C$ vs t. Find gradient

$\frac{\ln 2}{t_{\frac{1}{2}}} = g$

$t_{\frac{1}{2}} =$

average of random count of radioactive sample deduct background count

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7) Vol. of Po $= \frac{10^{-6}}{0.01}$

$= 10^{-4}\ cm^3$

No. of emissions over 140 days $= 12 \times 10^{12} \times 140$

$= 1.68 \times 10^{15}$

No. of Po atoms in 10^{-6} g $= 1.68 \times 10^{15} \times 2$

$= 3.36 \times 10^{15}$

Mass of 1 cm³ of Po = 0.001 kg

No. of Po atoms $= 0.001 \times \frac{3.36 \times 10^{15}}{10^{-9}}$

$= 3.36 \times 10^{22}$

8) $A = A_0 e^{-\lambda t}$

$0.19 = 0.26 e^{-\frac{\ln 2}{5730} t}$

$\frac{0.19}{0.26} = e^{-\frac{t \ln 2}{5730}}$

$\ln \frac{0.19}{0.26} = -t \frac{\ln 2}{5730}$

$t = -\frac{5730}{\ln 2} \left(\frac{0.19}{0.26}\right)$

$= 2590$ years (3s.f)

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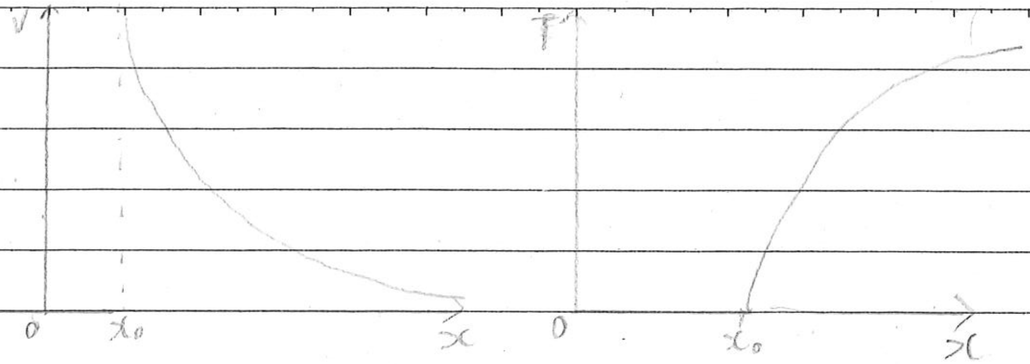

1b i) Electrostatic potential energy.

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$\frac{Qq}{4\pi\varepsilon_0 d} = 4.8 \times 1.6 \times 10^{-13}$ ~~$= -\frac{6.67 \times (6.63\times10^{-27})(3.297\times10^{-25})(6.64\times10^{-27})}{4.8\times1.6\times10^{-19}\times10^{6}}$~~

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2a) $35(1.0073u)c^2 + 46(1.0087u)c^2 = 80.8971uc^2 + B.E$

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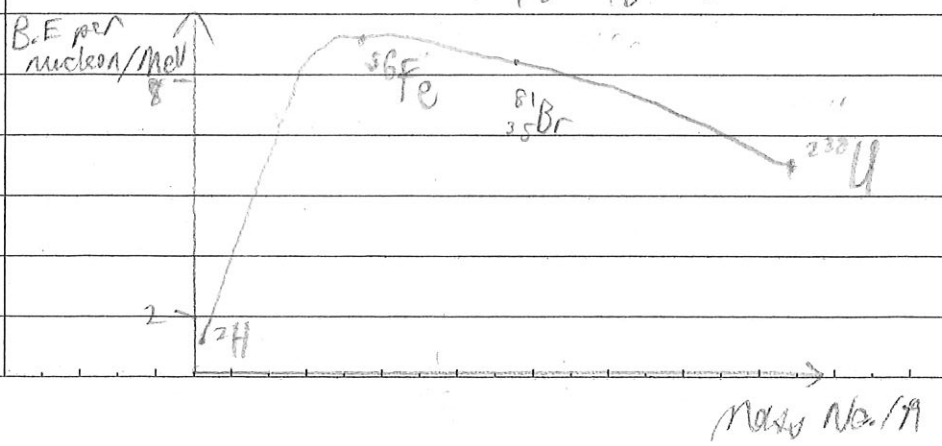

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