

THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF PHYSICS

PHYS3050 NUCLEAR PHYSICS

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Question 1 [15 marks]

A Σ^0 particle, at rest, decays into a Λ^0 and a gamma-ray $\Sigma^0 \rightarrow \Lambda^0 + \gamma$. The rest-masses of the Σ^0 and the Λ^0 are $1193 \text{ MeV}/c^2$ and $1116 \text{ MeV}/c^2$, respectively. Determine the energy of the gamma-ray produced. [Hint: it's not a simple case of $E = 1193 - 1116 = 77 \text{ MeV}$].

Question 2 [10 marks]

Beryllium has only one stable isotope ${}^9_4\text{Be}$. When a 50 MeV proton strikes a beryllium target it is found that a high energy neutron is emitted from the target.

- (i) Use the conservation laws appropriate to nuclear reactions to determine the residual nucleus in the reaction which produces the neutrons. Write down the full nuclear reaction.
- (ii) Determine the Q of the reaction and so estimate the energy of the neutrons emitted in the forward direction i.e. the same direction of propagation as the incident protons.

Question 3 [5 marks]

Estimate the ratio of the surface energy term per nucleon for ${}^{40}\text{Ca}$ to that of ${}^{208}\text{Pb}$.

Question 4 [10 marks]

Recent news articles about 'table-top cold fusion' claim that neutrons are produced via the reaction $d + d \rightarrow n + X$ where X is a nucleus in its ground state.

- (i) Identify X.
- (ii) How much energy is released in this reaction ?

①



Conserve momentum

$$P_{\Lambda^0} = P_{\gamma} = \frac{E_{\gamma}}{c}$$

$$\therefore K_{\Lambda^0} = \frac{P_{\Lambda^0}^2}{2M_{\Lambda^0}} = \frac{E_{\gamma}^2}{2M_{\Lambda^0}c^2} \quad \text{non-relativistic}$$

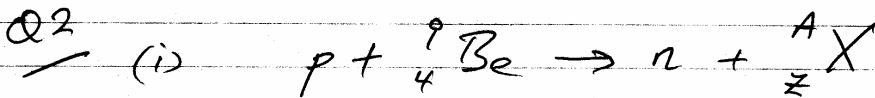
conserve energy

$$M_{\Sigma^0}c^2 = M_{\Lambda^0}c^2 + K_{\Lambda^0} + E_{\gamma}$$

$$1193 = 1116 + \frac{E_{\gamma}^2}{(2 \times 1116)} + E_{\gamma} \quad \text{in MeV}$$

$$\rightarrow E_{\gamma}^2 + 2232 E_{\gamma} - 171864 = 0$$

$$\rightarrow E_{\gamma} = 74.51 \text{ MeV}$$



conserve charge

$$1+4 \rightarrow Z=5 \therefore \text{Boron}$$

" mass

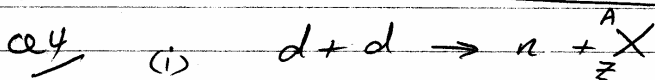
$$1+9 \rightarrow 1+A \therefore A=9$$

$$\Rightarrow {}_5^9\text{B}$$

$$\begin{aligned}
 \text{Q3} \quad \text{Surface energy term} &= -a_s A^{2/3} = \text{nucleus} \\
 &= -a_s A^{2/3} / A \text{ per nucleon} \\
 &= -a_s / A^{1/3}
 \end{aligned}$$

$$\Rightarrow \text{ratio } 40\text{Ca} / 208\text{Pb}$$

$$= \left(\frac{208}{40} \right)^{1/3} = 1.73$$



$$\text{charge} \quad 1 + 1 \rightarrow 0 + Z : Z = 2 \therefore \text{Helium}$$

$$\text{mass} \quad 2 + 2 \rightarrow 1 + A : A = 3$$

$$\therefore \overset{3}{2}\text{He}$$

$$(ii) \quad M_d = 2.01355321 \text{ u}$$

$$M_n = 1.00866501 \text{ u}$$

$$\text{At. Mass } \left(\overset{3}{2}\text{He} \right) = 3.016029 \text{ u}$$

$$M_e = 5.485803 \times 10^{-4} \text{ u}$$

$$Q = (2 \times M_d) - [M_n + \text{At. M} \left(\overset{3}{2}\text{He} \right) - 2M_e] \cdot c^2$$

$$= +0.003510 \text{ u}$$

$$\times 931.502 \text{ MeV}/c^2 \rightarrow 3.27 \text{ MeV}$$