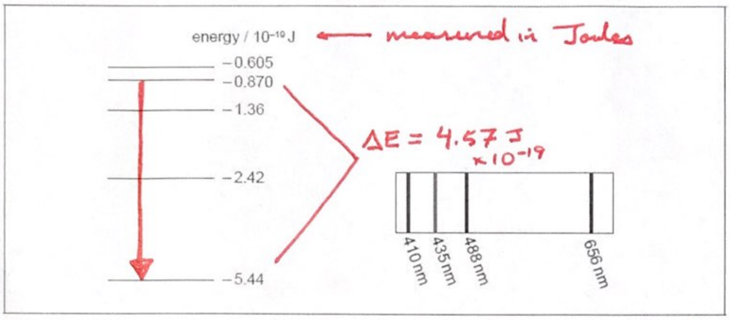
SPH4U1 Task – Nuclear Physics Name: Sol'n

1. The diagram shows the position of the principal lines in the visible spectrum of atomic hydrogen and some of the corresponding energy levels of the hydrogen atom. **(4 marks)**



$v = f \cdot \lambda \quad E = h \cdot f$

$\frac{c}{\lambda} = f$

$E = \frac{h \cdot c}{\lambda}$

λ — loss of energy

(a) Determine the energy of a photon of blue light (435nm) emitted in the hydrogen spectrum.

$$E = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(435 \times 10^{-9})}$$

$$E = 4.57 \times 10^{-19} \text{ J} \text{ or } \left(\frac{1 eV}{1.602 \times 10^{-19} J}\right) \ 2.88 eV$$

(b) Identify, with an arrow labelled B on the diagram, the transition in the hydrogen spectrum that gives rise to the photon with the energy in (a). $E = 2.88 eV$

4.57×10^{-19} J

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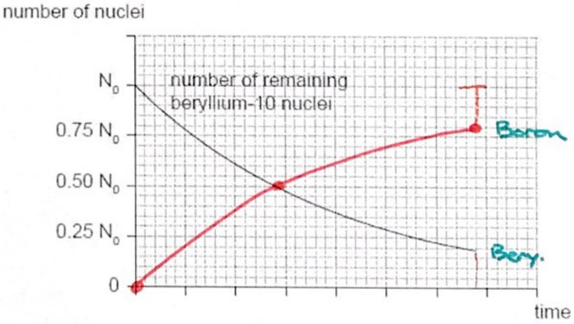
2. The radioactive nuclide beryllium-10 (Be-10) undergoes beta minus (β–) decay to form a stable boron (B) nuclide. **(8 marks)**

(a) Identify the missing information for this decay.

$${}^{10}_{\boxed{4}}\text{Be} \rightarrow {}^{\boxed{10}}_{5}\text{B} + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\upsilon}$$

The initial number of nuclei in a pure sample of beryllium-10 is N_0. The graph shows how the number of remaining **beryllium** nuclei in the sample varies with time.

(b) **On the graph**, sketch how the number of **boron** nuclei in the sample varies with time.



(c) After 4.3 × 10⁶ years, the following ratio exists. Determine the half-life of Beryllium-10.

$$\frac{\text{number of produced boron nuclei}}{\text{number of remaining beryllium nuclei}} = \frac{7}{1} = \frac{\frac{7}{8}}{\frac{1}{8}}$$

parts ↑

total = 8

$1 \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \frac{1}{8}$

3 half lives

$$\frac{4.3 \times 10^{6} \text{ yrs}}{3} = 1.43 \times 10^{6} \text{ years}$$

1 half life

(d) Beryllium-10 is used to investigate ice samples from Antarctica. A sample of ice initially contains 7.6 × 10¹¹ atoms of beryllium-10. State the number of remaining beryllium-10 nuclei in the sample after 2.8 × 10⁶ years.

$$A_f = A_i \left(\frac{1}{2}\right)^{\frac{t}{1.43 \times 10^{6}}}$$

$$A_f = 7.6 \times 10^{11} \left(\frac{1}{2}\right)^{\frac{2.8 \times 10^{6}}{1.43 \times 10^{6}}}$$

$$A_f = 1.96 \times 10^{11} \text{ atoms}$$

8.521 8.550 - more stable

3. Rhodium-106 ($^{106}_{45}\mathrm{Rh}$) decays into palladium-106 ($^{106}_{46}\mathrm{Pd}$) by beta minus (β^-) decay. **(8 marks)**

The binding energy per nucleon of rhodium is 8.521 MeV and that of palladium is 8.550 MeV.

(a) State what is meant by the binding energy of a nucleus.

Binding energy is the required energy to pull an atom apart into its protons & neutrons.
(per nucleon is the energy required to remove ONE nucleon)

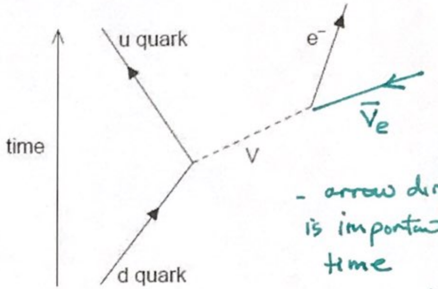
(b) Show that the energy released in the β^- decay of rhodium is about 3 MeV.

$$106 \times 8.521 + \text{Energy} = 106 \times 8.550$$
$$903.226 + \text{Energy} = 906.3$$
$$\text{Energy} \doteq 3\,\text{MeV} \longrightarrow$$

energy released from the neutron turning into a proton

(c) β^- decay is described by the following incomplete Feynman diagram.

(d) Draw a **labelled arrow** to *complete* the Feynman diagram.



- arrow direction is important to time

- anti = opposite arrow

Negative

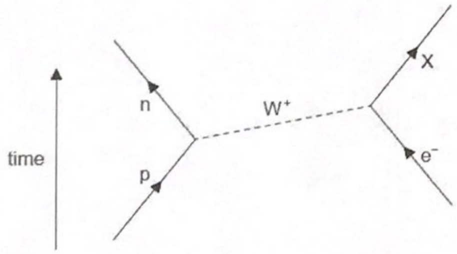
(e) Identify particle V. ⟶ W^- boson

(Conservation laws will help)

$$\begin{array}{lccccccc} & d & \rightarrow & u & + & e^- & + & \bar{\nu}_e \\ C & -\frac{1}{2} & \rightarrow & \frac{2}{3} & & -1 & + & 0 \\ B & \frac{1}{3} & \rightarrow & \frac{1}{3} & + & 0 & + & 0 \\ L & 0 & \rightarrow & 0 & + & 1 & - & 1 \end{array}$$

✓ ✓ ✓ } anti electron Neutrino

4. The Feynman diagram shows electron capture. **(4 marks)**



State and explain the nature of the particle labelled X. (Conversation laws will help.)

$$\begin{array}{lcccccccc} & p & + & e^- & \rightarrow & n & + & X \\ C & +1 & & -1 & \rightarrow & 0 & + & 0 \\ B & +1 & + & 0 & \rightarrow & +1 & + & 0 \\ L & 0 & + & 1 & \rightarrow & 0 & + & 1 \end{array}$$

X ⇒ No charge
Not a Baryon ∴ lepton

∴ Neutrino electron family