Problem set - 1

01/11/06

CEM 988
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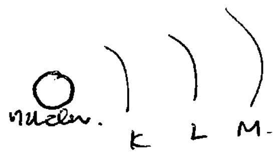
1.2).



Binding energy of L-shell is greater than that of M-shell, because L-shell is closer to the nucleus than M-shell. So, it is difficult to remone an electron from L-shell than M-shell.

If energy of nuclear excitatatn $= E_{ex}$ and kinetic energy of conversion electron $= KE_e$

$$KE_e = E_{ex} - BE_e$$

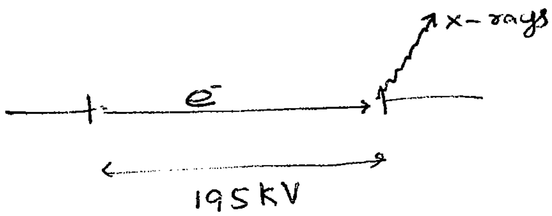
Therefore, energy of electron from M-shell is greater than that from L-shell. ✓

1.3). Energy of the α particle $= \dfrac{Q(A-4)}{A}$

$$= \frac{5.5\,MeV(210-4)}{210}$$

$$= \underline{\underline{5.3952\ MeV}}$$

1.4).



The total energy gained by the electron $= q \cdot V$

$= 1.602 \times 10^{-19}\, C \times 195 \times 10^{3}\, V$

$= 3.1239 \times 10^{-14}\, J$

If we assume that total energy of the electron is converted into X-rays.

So, energy of the x-ray photon $= 3.1239 \times 10^{-14}\, J$

$E = h\nu, \quad c = \nu\lambda$

$\therefore E = \frac{hc}{\lambda}$

$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\, Js \times 2.997 \times 10^{8}\, ms^{-1}}{3.1239 \times 10^{-14}\, J}$

$= 6.3568 \times 10^{-12}\, m$

$= 6.3568\, pm$ ✓

1.5).

$${}^{235}_{92}U_{143} \longrightarrow {}^{117}_{46}Pd_{71} + {}^{117}_{46}Pd_{71} + {}^{1}_{0}n_{1}$$

$m_n = 1.008664$ amu

$m_{Pd} = 116.917841$ amu

$m_U = 235.043929$ amu.

$$Q = \{m_u - (2m_{Pd} + m_n)\}_{amu} \times 1.66 \times 10^{-27}\ kg\,amu^{-1} \times c^2$$

$$= \{235.043929 - (2 \times 116.917841 + 1.008664)\}_{amu} \times 1.66 \times 10^{-27}\ kg\,amu^{-1} \times (2.997 \times 10^{8})^2\ m^2 s^{-2}$$

$$= 2.9758 \times 10^{-11}\ J$$

$$= \underline{\underline{185.7559\ MeV}}$$

1.6) $t_{1/2\,^3H} = 12.26\ yrs$ $\qquad \lambda = \frac{\ln 2}{t_{1/2}}$

$= ~~5.62917 \times 10^{8}\ s~~$ $\qquad m_T$

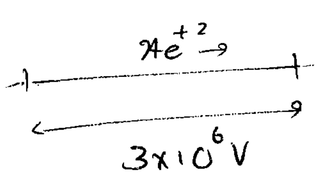
$= ~~3.9735 \times 10^{8}\ s~~ \rightarrow 3.869 \times 10^{8}\ s$

specific activity $= \frac{\text{Activity}}{\text{mass}} = \frac{N\lambda}{m} = \frac{N\lambda}{nM} = \frac{N\lambda}{N/N_A\,M} = \frac{N_A \lambda}{M}$

$$= \frac{6.022\ (~~1.602~~) \times 10^{23}\ mol^{-1} \times \ln 2}{3 \times 10^{-3}\ kg\,mol^{-1} \times ~~5.62917 \times 10^{8}\ s~~\ ~~3.9735 \times 10^{8}\ s~~\ 3.869 \times 10^{8}}$$

$$= \underline{\underline{3.59 \times 10^{17}\ (~~9.3152 \times 10^{16}~~)\ Bq\,kg^{-1}}} \quad \text{or } 9.72\ kCi/g$$

1.7).



$$E = qV$$

$$= 2 \times 1.602 \times 10^{-19}\ C \times 3 \times 10^{6}\ V$$

$$= 9.612 \times 10^{-13}\ J$$

$$= \underline{\underline{6\ MeV}}$$

1.8)

~~$^{9}_{4}Be + h\nu \rightarrow ^{8}_{4}Be + ^{1}_{0}n$~~

~~ma~~ $^{2}_{1}H + h\nu \longrightarrow ^{1}_{1}H + ^{1}_{0}n$

938.3 MeV   939.6 MeV

$m \rightarrow$ 1875.6128 MeV

$$Q = 1875.6128 - (938.3 + 939.6)\ \text{MeV}$$

$$= -2.2872\ \text{MeV} \qquad (2.225\ \text{MeV})$$

Q value should be positive to take place the reaction. So, energy of the photon should be greater than 2.2872 MeV. (or at least it shald be equal to 2.2872 MeV approximately)

1.9)

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

kinetic eng	K_D	$K_T = 0$	K_{He}	K_n.
velocity	V_D	$V_T = 0$	V_{He}	V_n.
masses	2.0141	3.0160	4.0026	1.008664 amu

From energy conservation

E_R = energy from the reaction

$$K_D + E_R = K_{He} + K_n.$$

See Below

$$150 \text{ keV} + 17600 \text{ keV} = \frac{1}{2} \times 1.66 \times 10^{-27} (4.0026 V_{He}^2 + 1.008664 V_n^2)$$

$$2.403 \times 10^{-14} J + 2.81952 \times 10^{-12} J = \frac{1}{2} \times 1.66 \times 10^{-27} (4.0026 V_{He}^2 + 1.008664 V_n^2)$$

$$3.42596 \times 10^{15} = 4.0026 V_{He}^2 + 1.008664 V_n^2 \quad \text{——— (1)}$$

From momentum conservation

$$m_D V_D = m_{He} V_{He} + m_n V_n$$

$$1.66 \times 10^{-27} (2.0141 \times 3.7914) \text{kgms}^{-1} = 1.66 \times 10^{-27} (4.0026 V_{He} + 1.008664 V_n)$$

$$K_D = \frac{1}{2} m V_D^2$$

$$V_D^2 = \frac{2 \times 2.403 \times 10^{-14}}{2.0141 \times 1.66 \times 10^{-27}}$$

$$V_D = 3.7914 \text{ ms}^{-1}$$

$$4.0026 V_{He} = 7.6363 - 1.008664 V_n$$

$$(V_{He})^2 = \left(\frac{7.6363 - 1.008664 V_n}{4.0026}\right)^2$$

from eq (1)

$$3.42596 \times 10^{15} = 4.0026 \left(\frac{7.6363 - 1.008664 V_n}{4.0026}\right)^2 + 1.008664 V_n^2$$

$$3.42596 \times 10^{15} = \frac{1}{4.0026} (7.6363 - 1.008664 V_n)^2 + 1.008664 V_n^2$$

$$1.371127 \times 10^{16} = 58.3130 - 15.4049 V_n + 1.0174 V_n^2 + 1.008664 V_n^2$$

$$1.371127 \times 10^{16} = -15.4049 V_n + 2.02606 V_n^2$$

$$2.02606 V_n^2 - 15.4049 V_n - 1.371127 \times 10^{16} = 0$$

$V_n = 8.2 \times 10^{7}$ ~~8.~~ ms^{-1}

Energy of the neutron $= \frac{1}{2} m_n V_n^2$

$= \frac{1}{2} \times 1.008664 \times 1.66 \times 10^{-27}\ kg \times (8.2 \times 10^{7})^2\ m^2 s^{-2}$

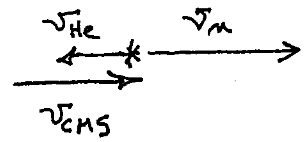
$= \underline{\underline{5.6652 \times 10^{-12}\ J}}$

$= \underline{\underline{35.3631}}\ MeV$ this would be much bigger than the Q value

$$^2d + {^3t} \rightarrow ({^5He^*}) \rightarrow {^1n} + {^4He} + Q$$

$Q = 13.135 + 14.950 - (8.071 + 2.425)\ MeV$ using mass defects (Δ)

$Q = 17.589\ MeV$



energy conservation: $E_d + E_t = E_n + E_{He} + Q$, $E_t = 0$ $E_d = 0.150\ MeV$

$$p^2/2m_d + 0 = p^2/2m_n + p^2/2m_{He} + Q$$

momentum cons. $p_d = p_n + p_{He}$ $p_d \cong \sqrt{2 m_d E_d} = 0.778\ MeV/c$

eliminate p_{He} ... solve for p_n ... $p_n = 5.497\ MeV/c$

... $E_n = p_n^2 / 2m_n = 14.99\ MeV$