KTT 111 : Inorganic Chemistry 1 : Model Answers
Sem 2: 2005/2006 : Q1 : NUCLEAR REACTIONS

Sem 2 (2005/2006): Nuclear Reactions

Q1 (a) $^{27}_{13}Al \longrightarrow\ ^{23}_{11}Na +\ ^{4}_{2}He$

26.9815u → 22.9898u + 4.0026u = 26.9924u

Reason 1:

Generally, when a radioactive nuclide decays, it forms a nuclide of lower energy and the excess energy is carried off by the emitted radiation.
In this case, the total energy of the product (daughter nuclide) is less than the total energy of the reactant (parent nuclide).
So this decays cannot take place ie Al-27 cannot decay.

Reason 2:

Generally, when a heavier nucleus undergoing fission (split into lighter ones) the product nuclei must have greater binding energy per nucleon (more stable) than the reactant nucleus, and the difference in energy is released.

$^{27}_{13}Al$ (26.9815u): $13p^+ : (13 \times 1.007284u) = 13.094644u$
$14n : (14 \times 1.00866u) = 14.12124u$
Total = 27.21588u

$\Delta m = (27.21588 - 26.9815) = 0.23438u$

Binding energy per nucleon $= \frac{(0.23438 \times 931.5)\text{ MeV}}{27 \text{ nucleons}} = 8.086$ MeV/nucleon

$^{23}_{11}Na$ (22.9898u): $11p^+ : 11 \times 1.007284u = 11.080124u$
$12n : 12 \times 1.00866u = 12.10392u$
Total = 23.18404

$\Delta m = (23.18404 - 22.9898) = 0.19424u$

∴ Binding energy per nucleon $= \frac{(0.19424 \times 931.5)\text{ MeV}}{23 \text{ nucleons}} = 7.866$ MeV/nucleon ← less than 8.086 MeV/nucleon

In this case, the product nuclei has lesser binding energy per nucleon than the reactant nuclide.
Thus Al-27 cannot decay to Na-23.

1/3

Sem 2 (2005/2006): Nuclear Reactions

Q1(b)(i) $^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{17}_{8}O + ^{1}_{1}H$ (proton)

(ii) Total mass of the reactants $= m_N + m_{He}$

$= (2.32530 \times 10^{-26} kg) + (0.66466 \times 10^{-26} kg)$

$= 2.98996 \times 10^{-26} kg$

Total mass of the products $= m_O + m_H$

$= (2.82282 \times 10^{-26} kg) + (0.16735 \times 10^{-26} kg)$

$= 2.99017 \times 10^{-26} kg$

$\Delta m = (2.99017 \times 10^{-26} kg) - (2.98996 \times 10^{-26} kg)$

$= 2.1 \times 10^{-30} kg$

$\Delta E = \Delta m \cdot c^2$

$= (2.1 \times 10^{-30} kg)(3 \times 10^{8} ms^{-1})^2$

$= 1.89 \times 10^{-13} J$

∴ The minimum energy of the α-particle to enable this reaction to occur is $= 1.89 \times 10^{-13} J$ (Ans)

Q1(c)(i) $^{234}_{90}Th \longrightarrow ^{234}_{91}Pa + ^{0}_{-1}e$

Given: $t_{1/2} = 24$ days

For Th-234 (231.811u): $90p^+ : (90 \times 1.00728)u = 90.6552\,u$

$144n : (144 \times 1.00866)u = 145.24704\,u$

$235.90224\,u$

$\Delta m = (235.90224 - 231.811)u$

$= 4.09124\,u$

$\Delta m = \left(\frac{4.09124 \times 10^{-3}}{6.022 \times 10^{23}}\right) kg = 6.794 \times 10^{-27} kg$ $\quad \left(\because 1u = \frac{10^3}{N_A} kg\right)$

$\Delta E = \Delta m c^2$

$= (6.794 \times 10^{-27} kg)(3 \times 10^{8} ms^{-1})^2$

$= 6.11 \times 10^{-10} J\, atom^{-1}$

The binding energy for Th-234 $= 6.11 \times 10^{-10} J\, atom^{-1}$ (Ans)

Q_1 (c) cont.....

For Pa-234 (230.9234) :

$$91p^+ : (90 \times 1.00728)u = 90.6552\,u$$
$$143n : (143 \times 1.00866)u = 144.238384$$
$$\overline{\quad 234.8936\,u \quad}$$

$$\Delta m = (234.8936 - 230.923)u$$
$$= 3.9706\,u$$
$$= \left(\frac{3.9706 \times 10^{-3}}{6.022 \times 10^{23}}\right) kg = 6.593 \times 10^{-27} kg$$

$$\Delta E = \Delta m \cdot c^2$$
$$= (6.593 \times 10^{-27} kg)(3 \times 10^{8} m s^{-1})^2$$
$$= 5.93 \times 10^{-10}\ J\,atom^{-1}$$

The binding energy for Pa-234 $= 5.93 \times 10^{-10}\ J\,atom^{-1}$ (Ans)

Q_1(c)(ii)

$$\left.\begin{array}{l} t_{1/2} = 24\ days \\ N_o = 100\% \\ N_t = 10\% \end{array}\right\}$$

$$\ln \frac{N_o}{N_t} = kt \;\; ; \;\; t_{1/2} = \frac{\ln 2}{k}$$
$$\ln\left(\frac{100}{10}\right) = \left(\frac{\ln 2}{24\ days}\right)t$$
$$\ln 10 = \left(\frac{0.6931}{24}\right)t$$
$$\therefore t = \frac{(\ln 10)(24)}{(0.6931)}$$
$$= 79.7\ days.\ (Ans)$$

Prepared by
V.Manoharan
vmano@usm.my
manovv1955@yahoo.com
04-6533888 ext 3566