NUCLEAR CHEMISTRY

NUCLEAR STABILITY AND RADIOACTIVE DECAY

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PRACTICE PROBLEM 1

Calculate the nuclear binding energy of ^{6}Li given that the mass of a proton is 1.0073 amu, the mass of a neutron is 1.0087 amu, and the mass of the ^{6}Li nucleus is 6.0154 amu. Note that $1\ \text{amu} = 1.66 \times 10^{-27}\ \text{kg}$ and $1\ \text{J} = 1\ \text{kg} \cdot {}^{\text{m}^2}/_{\text{s}^2}$.

— answer —

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First, we need to determine that ^{6}Li has 3 protons and 3 neutrons.

Second, we need to calculate the mass defect (Δm):

$$\begin{aligned}\Delta m &= \left[\sum m_{\text{neutrons}} + \sum m_{\text{protons}}\right] - m_{\text{nucleus}} \\ &= [3\times(1.0087\ \text{amu}) + 6\times(1.0073\ \text{amu})] - 6.0154\ \text{amu} \\ \Delta m &= 0.0326\ \text{amu}\end{aligned}$$

Finally, calculate the nuclear binding energy (BE):

$$\begin{aligned}\text{BE}(^{6}\text{Li}) &= (\Delta m)c^2 \\ &= \left(0.0326\ \text{amu} \times \frac{1.66 \times 10^{-27}\ \text{kg}}{1\ \text{amu}}\right)\left(3.00 \times 10^{8}\ \frac{\text{m}}{\text{s}}\right)^2 \\ \text{BE}(^{6}\text{Li}) &= 4.87 \times 10^{-12}\ \text{J}\end{aligned}$$

PRACTICE PROBLEM 2

Predict the type(s) of radioactive decay that ^{19}Ne might undergo.

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First, determine the ratio of neutrons:protons in ^{19}Ne.

$$^{19}_{10}\text{Ne} \rightarrow \frac{9\ \text{n}}{10\ \text{p}}$$

This indicates that ^{19}Ne is neutron-poor (it would be below the belt of stability). Thus it is most likely to undergo either:

(i) Electron capture $^{19}_{10}\text{Ne} + {}^{0}_{-1}\beta \rightarrow {}^{19}_{9}\text{F}$

(ii) Positron emission $^{19}_{10}\text{Ne} \rightarrow {}^{19}_{9}\text{F} + {}+{}^{0}_{+1}\beta$

PRACTICE PROBLEM 3

Predict the type(s) of radioactive decay that ^{210}Po might undergo.

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— answer —

First, determine the ratio of neutrons:protons in ^{210}Po.

$$^{210}_{84}\mathrm{Po} \rightarrow \frac{126\ \mathrm{n}}{84\ \mathrm{p}}$$

This indicates that ^{210}Po is very neutron-rich, and it is very heavy (Z > 83). Therefore, it is most likely to undergo alpha decay:

$$^{210}_{84}\mathrm{Po} \rightarrow {}^{206}_{82}\mathrm{Pb} + {}^{4}_{2}\alpha$$

PRACTICE PROBLEM 4

Predict the type(s) of radioactive decay that ^{131}I might undergo.

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— answer —

First, determine the ratio of neutrons:protons in ^{131}I.

$$^{131}_{53}\mathrm{I} \rightarrow \frac{78\ \mathrm{n}}{53\ \mathrm{p}}$$

This indicates that ^{131}i is neutron-rich. Therefore, it is most likely to undergo beta decay:

$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\beta$$