Nuclear Chemistry

1. Write, using proper symbolism, the symbols for

   Nitrogen-13 $^{13}_{7}N$

   Tritium $^{3}_{1}H$

   Boron-10 $^{10}_{5}B$

   The isotope of lead containing 125 neutrons $^{207}_{82}Pb$

2. What is an alpha particle? A helium nucleus: $^{4}_{2}He$

   … β–particle? A nuclear electron: $^{0}_{-1}e$

   … neutrino? An infinitesimally small particle that can travel enormous distances without encountering or colliding with other matter.

3. Write the equation for the spontaneous disintegration of $^{238}_{92}U$ during which an α-particle is produced.

   $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$

4. Write the equation for the slow neutron initiated fission reaction of $^{235}_{92}U$ to produce barium-141 and krypton-92.

   $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

5. Write the equation for the fusion boron-10 with an α-particle. The by-product of this reaction is a single neutron.

   $^{10}_{5}B + {}^{4}_{2}He \rightarrow {}^{17}_{7}N + {}^{1}_{0}n$

6. a. When two protons combine in a fusion reaction, a deuteron, positron, and neutrino are formed. The mass of the proton is 1.0078 u, the mass of the deuteron is 2.0141 u, and the mass of the positron is 4.49 x 10^{-4} u. Assuming the mass of the neutrino is negligible, how much energy (in J) is produced this nuclear fusion reaction? (1 u = 1.6606 x 10^{-27} kg)

$${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + {}^{0}_{1}\beta + \nu$$

total mass of protium = $2\times(1.0078\text{ u}) = 2.0156$ u

total mass of products = 2.0141 u + 4.49×10^{-4} u = 2.01455 u

mass defect = 2.0156 u - 2.01455 u = 0.001051 u

mass defect (kg) = $0.001051\text{ u} \times 1.6606\times10^{-27}\ {}^{\text{kg}}\!/_{\text{u}} = 1.7453\times10^{-30}\text{ kg}$

Energy produced = $E=mc^2$

$$E = 1.7453\times10^{-30}\text{ kg}\times(3.00\times10^{8}\ {}^{\text{m}}\!/_{\text{s}})^2 = 1.571\times10^{-13}\text{ J}$$

b. How much energy is produced when 3 x 10^{23} atom pairs (1.0 g) combine?

$$E = 1.571\times10^{-13}\text{ J}\times(3\times10^{23}\text{atom pairs}) = 4.7\times10^{10}\text{J(!)}$$

7. What is the name of the primary nuclear reaction thought to be powering the Sun? Write the reaction.

PROTON-PROTON CHAIN REACTION (Branch I)

$${}^{1}_{1}\text{H} \xrightarrow[{}^{0}_{+1}\beta,\nu]{{}^{1}_{1}\text{H}} {}^{2}_{1}\text{H} \xrightarrow[\gamma]{{}^{1}_{1}\text{H}} {}^{3}_{2}\text{He}$$

$$\longrightarrow {}^{4}_{2}\text{He} + 2\ {}^{1}_{1}\text{H}$$

$${}^{1}_{1}\text{H} \xrightarrow[{}^{0}_{+1}\beta,\nu]{{}^{1}_{1}\text{H}} {}^{2}_{1}\text{H} \xrightarrow[\gamma]{{}^{1}_{1}\text{H}} {}^{3}_{2}\text{He}$$

$${}^{0}_{+1}\beta + {}^{0}_{-1}\beta \longrightarrow 2\ \gamma$$

8. What is another nuclear reaction thought to be going on in the Sun? Write the reaction.

PROTON-PROTON CHAIN REACTION (Branch II)

$${}^{3}_{2}\text{He} + {}^{4}_{2}\text{He} \xrightarrow[\gamma]{} {}^{7}_{4}\text{Be} \xrightarrow[\nu]{{}^{0}_{-1}\beta} {}^{7}_{3}\text{Li}$$

9. When the hydrogen in a solar mass star is depleted to the point that core hydrogen fusion can no longer be sustained, the triple-alpha process starts. Write the equation for the triple-alpha reaction.

$$3\,{}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C}$$

10. In larger stars, the CNO cycle may be the primary "power-plant" reaction. Write the complete equation for the CNO cycle.

$${}^{12}_{6}\mathrm{C} \xrightarrow[\gamma]{{}^{1}_{1}\mathrm{H}} {}^{13}_{7}\mathrm{N} \xrightarrow[{}^{0}_{+1}\beta,\nu]{} {}^{13}_{6}\mathrm{C} \xrightarrow[\gamma]{{}^{1}_{1}\mathrm{H}} {}^{14}_{7}\mathrm{N} \xrightarrow[\gamma]{{}^{1}_{1}\mathrm{H}} {}^{15}_{8}\mathrm{O} \xrightarrow[{}^{0}_{+1}\beta,\nu]{} {}^{15}_{7}\mathrm{N} \xrightarrow[{}^{4}_{2}\mathrm{He}]{{}^{1}_{1}\mathrm{H}} {}^{12}_{6}\mathrm{C}$$