

Nuclear Chemistry

Section 135 – Nuclear Equations

135-1 Write a brief description or definition of each of the following:

- (a) nucleon
- (b) α particle
- (c) β particle
- (d) positron
- (e) γ ray
- (f) nuclide
- (g) mass number
- (h) atomic number

Solution

(a) A nucleon is any particle contained in the nucleus of the atom, so it can refer to protons and neutrons. (b) An α particle is one product of natural radioactivity and is the nucleus of a helium atom. (c) A β particle is a product of natural radioactivity and is a high-speed electron. (d) A positron is a particle with the same mass as an electron but with a positive charge. (e) Gamma rays compose electromagnetic radiation of high energy and short wavelength. (f) Nuclide is a term used when referring to a single type of nucleus. (g) The mass number is the sum of the number of protons and the number of neutrons in an element. (h) The atomic number is the number of protons in the nucleus of an element.

135-2 Which of the various particles (α particles, β particles, and so on) that may be produced in a nuclear reaction are actually nuclei?

Solution

α particles are He-4 nuclei; protons are H-1 nuclei.

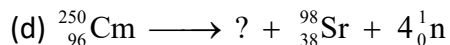
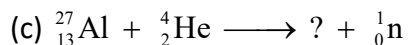
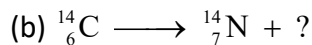
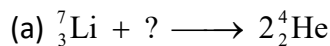
135-3 Complete each of the following equations by adding the missing species:

- (a) ${}_{13}^{27}\text{Al} + {}_2^4\text{He} \longrightarrow ? + {}_0^1\text{n}$
- (b) ${}_{94}^{239}\text{Pu} + ? \longrightarrow {}_{96}^{242}\text{Cm} + {}_0^1\text{n}$
- (c) ${}_{92}^{235}\text{U} \longrightarrow ? + {}_{55}^{135}\text{Cs} + 4{}_0^1\text{n}$
- (d) ${}_{92}^{235}\text{U} \longrightarrow ? + {}_{55}^{135}\text{Cs} + 4{}_0^1\text{n}$

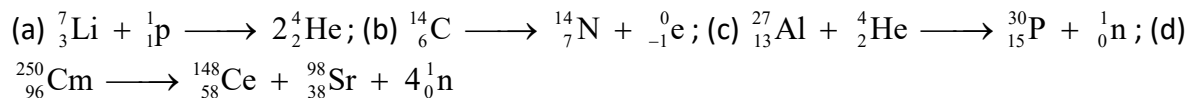
Solution

(a) ${}_{13}^{27}\text{Al} + {}_2^4\text{He} \longrightarrow {}_{15}^{30}\text{P} + {}_0^1\text{n}$; (b) ${}_{94}^{239}\text{Pu} + {}_2^4\text{He} \longrightarrow {}_{96}^{242}\text{Cm} + {}_0^1\text{n}$; (c) ${}_{7}^{14}\text{N} + {}_2^4\text{He} \longrightarrow {}_8^{17}\text{O} + {}_1^1\text{H}$; (d) ${}_{92}^{235}\text{U} \longrightarrow {}_{37}^{96}\text{Rb} + {}_{55}^{135}\text{Cs} + 4{}_0^1\text{n}$

135-4 Complete each of the following equations:



Solution



135-5 Write a balanced equation for each of the following nuclear reactions:

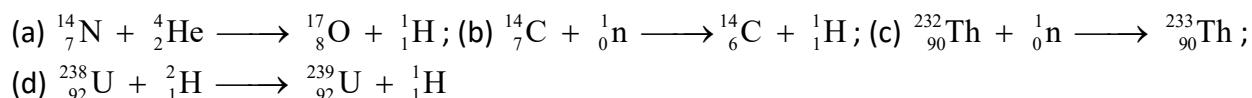
(a) the production of ${}^{17}_8\text{O}$ from ${}^{14}_7\text{N}$ by α particle bombardment

(b) the production of ${}^{14}_6\text{C}$ from ${}^{14}_7\text{N}$ by neutron bombardment

(c) the production of ${}^{233}_{90}\text{Th}$ from ${}^{232}_{90}\text{Th}$ by neutron bombardment

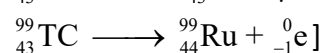
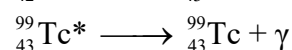
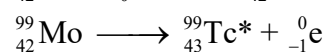
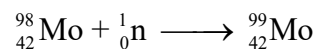
(d) the production of ${}^{239}_{92}\text{U}$ from ${}^{238}_{92}\text{U}$ by ${}^2_1\text{H}$ bombardment

Solution



135-6 Technetium-99 is prepared from ${}^{98}_{42}\text{Mo}$. Molybdenum-98 combines with a neutron to give molybdenum-99, an unstable isotope that emits a β particle to yield an excited form of technetium-99, represented as ${}^{99}_{43}\text{Tc}^*$. This excited nucleus relaxes to the ground state, represented as ${}^{99}_{43}\text{Tc}$, by emitting a γ ray. The ground state of ${}^{99}_{43}\text{Tc}$ then emits a β particle. Write the equations for each of these nuclear reactions.

Solution



135-7 The mass of the atom ${}^{19}_9\text{F}$ is 18.99840 amu.

(a) Calculate its binding energy per atom in millions of electron volts.

(b) Calculate its binding energy per nucleon.

Solution

(a) Determine the mass defect of the nuclide, which is the difference between the mass of 9 protons, 10 neutrons, and 9 electrons, and the observed mass of a ${}^{19}_9\text{F}$ atom:

mass defect = $[(9 \times 1.0073 \text{ amu}) + (10 \times 1.0087 \text{ amu}) + (9 \times 0.00055 \text{ amu})] - 18.99840 \text{ amu} = 19.15765 \text{ amu} - 18.99840 \text{ amu} = 0.15925 \text{ amu}$;

$$E = mc^2 = 0.15925 \text{ amu} \times \frac{1.6605 \times 10^{-27} \text{ kg}}{1 \text{ amu}} \times \left(2.998 \times 10^8 \frac{\text{m}}{\text{s}}\right)^2$$

$$= 2.377 \times 10^{-11} \text{ kg m/s}^2$$

$$= 2.377 \times 10^{-11} \text{ J}$$

$$2.377 \times 10^{-11} \text{ J} \times \frac{1 \text{ MeV}}{1.602 \times 10^{-13} \text{ J}} = 148.8 \text{ MeV per atom ;}$$

$$\text{(b) Binding energy per nucleon} = \frac{148.4 \text{ MeV}}{19} = 7.808 \text{ MeV/nucleon}$$

135-8 For the reaction ${}^{14}_6\text{C} \longrightarrow {}^{14}_7\text{N} + ?$, if 100.0 g of carbon reacts, what volume of nitrogen gas (N_2) is produced at 273K and 1 atm?

Solution

$$100.0 \text{ g } {}^{14}\text{C} \times \frac{1 \text{ mol } {}^{14}\text{C}}{14 \text{ g } {}^{14}\text{C}} \times \frac{1 \text{ mol } {}^{14}\text{N}}{1 \text{ mol } {}^{14}\text{C}} \times \frac{1 \text{ mol } {}^{14}\text{N}_2}{2 \text{ mol } {}^{14}\text{N}} = 3.57 \text{ mol } \text{N}_2$$

$$V = \frac{nRT}{P} = \frac{(3.57 \text{ mol } \text{N}_2)(0.0821 \text{ L atm/mol K})(273 \text{ K})}{1 \text{ atm}} = 80.0 \text{ L}$$