Chapter 29

Problems: 5, 6, 10, 14, 16, 21, 22, 24, 36, 39, 53, 57

5.Strategy The nucleon number A is the sum of the total number of protons Z and neutrons N. Use the Periodic Table of the elements to find the number of protons.

Solution Find the number of protons.
Potassium has atomic number 19, so Z = 19.
N = # of neutrons = 21
Find the nucleon number.
$A = Z + N = 19 + 21 = 40$
So, the symbol is $\boxed{{}^{40}_{19}\text{K}}$.

6. Strategy The nucleon number A is the sum of the total number of protons Z and neutrons N. Use the Periodic Table of the elements to find the number of protons.

Solution Find the number of protons.
Cl has atomic number 17, so Z = 17. The nucleon number is 35.
Find the number of neutrons.
$N = A - Z = 35 - 17 = \boxed{18}$ neutrons.

10.Strategy The ${}^{4}\text{He}$ nucleus has 2 protons and 2 neutrons. Use Eqs. (29-7) and (29-8) to find the mass defect and binding energy.

Solution Find the mass defect.

$$\begin{aligned}\Delta m &= (\text{mass of 2 protons and 2 neutrons}) - (\text{mass of nucleus})\\ &= 2\times 1.007\,276\,5\text{ u} + 2\times 1.008\,664\,9\text{ u} - 4.001\,51\text{ u} = 0.030\,37\text{ u}\end{aligned}$$

The binding energy is $E_\text{B} = (\Delta m)c^2 = 0.030\,37\text{ u}\times 931.494\text{ MeV/u} = \boxed{28.29\text{ MeV}}$.

14. Strategy The nucleon number A is the sum of the total number of protons Z and neutrons N. Use Eqs. (29-7) and (29-8) to find the mass defect and binding energy. The binding energy per nucleon is the binding energy divided by the total number of nucleons in the nucleus.

Solution

(a) The ${}^{16}\text{O}$ atom has 8 protons, 8 neutrons, and 8 electrons. Its mass is 15.994 914 6 u. Find the mass defect.

$$\begin{aligned}\Delta m &= (\text{mass of 8 }{}^{1}\text{H atoms and 8 neutrons}) - (\text{mass of }{}^{16}\text{O atom})\\ &= 8\times 1.007\,825\,0\text{ u} + 8\times 1.008\,664\,9\text{ u} - 15.994\,914\,6\text{ u} = 0.137\,004\,6\text{ u}\end{aligned}$$

The binding energy is $E_\text{B} = (\Delta m)c^2 = 0.137\,004\,6\text{ u}\times 931.494\text{ MeV/u} = \boxed{127.619\text{ MeV}}$.

(b) Calculate the average binding energy per nucleon.

$$\frac{E_\text{B}}{A} = \frac{127.619\text{ MeV}}{16\text{ nucleons}} = \boxed{7.976\,19\text{ MeV/nucleon}}$$

This result matches the value given in Figure 29.2.

16.Strategy Use the conversion factor to SI units for MeV and u.

Solution Convert to SI units.

$$\frac{1\text{ MeV}}{1\text{ u}} = \frac{10^6 \times 1.602\,176\,531\,4\times10^{-19}\text{ J}}{1.660\,539\times10^{-27}\text{ kg}} = 9.648\,533\times10^{13}\text{ m}^2/\text{s}^2$$

Divide c^2 by the result.

$$\frac{c^2}{1\text{ MeV}/1\text{ u}} = \frac{(2.997\,924\,58\times10^8\text{ m/s})^2}{9.648\,533\times10^{13}\text{ m}^2/\text{s}^2} = 931.494 \text{ to six significant figures.}$$

So, $c^2 = 931.494$ MeV/u.

21. Strategy In beta-minus decay, the atomic number Z increases by 1 while the mass number A remains constant. Use Eq. (29-11).

Solution

For the parent $\left({}^{40}_{19}\text{K}\right)$ Z = 19, so the daughter nuclide will have Z = 19 + 1 = 20, which is the element Ca. The symbol for the daughter is $\boxed{{}^{40}_{20}\text{Ca}}$.

22. Strategy In alpha decay, the atomic number Z and the mass number A are decreased by 2 and 4, respectively. Use (Eq. 29-10).

Solution In this case, the parent nuclide has Z = 90 and A = 232, so the daughter nuclide will have Z = 88 and
A = 228, which is the element radium. Write out the reaction.

${}^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + {}^{4}_{2}\alpha$, so $\boxed{{}^{232}_{90}\text{Th} \rightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\alpha}$. The daughter nuclide is $\boxed{{}^{228}_{88}\text{Ra}}$.

24. Strategy In beta-plus decay a positron is emitted, the atomic number Z is decreased by 1 while the mass number A stays the same. Use Eq. (29-12).

Solution In this case, the parent nuclide has Z = 11 and A = 22, so the daughter nuclide will have Z = 10 and
A = 22, which is the element neon. Write out the reaction.

${}^{A}_{Z}P \rightarrow {}_{Z-1}^{A}D + {}^{0}_{+1}\text{e} + {}^{0}_{0}\nu$, so $\boxed{{}^{22}_{11}\text{Na} \rightarrow {}^{22}_{10}\text{Ne} + {}^{0}_{+1}\text{e} + {}^{0}_{0}\nu}$. The daughter nuclide is $\boxed{{}^{22}_{10}\text{Ne}}$.

36. Strategy The activity as a function of time is given by $R = R_0 e^{-t/\tau}$. Use Eq. (29-22) to find the time constant.

Solution Find the number of days for the activity to decrease to 2.5×10^6 Bq.

$$e^{-t/\tau} = \frac{R}{R_0},\ \text{so}\ -\frac{t}{\tau} = \ln\frac{R}{R_0}\ \text{or}\ t = -\tau\ln\frac{R}{R_0} = -\frac{8.0\text{ d}}{\ln 2}\times\ln\frac{2.5\times10^6\text{ Bq}}{6.4\times10^8\text{ Bq}} = \boxed{64\text{ d}}.$$

39. Strategy The ratio of C-14 to C-12 in the bone is 1/4 as much as in a living sample. The ratio is reduced by a factor of 1/2 for each half-life.

Solution Since $2^{-2} = 1/4$, we conclude that the age of the bone is 2 half-lives, or

$2\times5730\text{ yr} = \boxed{11{,}500\text{ yr}}$.

53. (a) Strategy The mass numbers on the two sides of the reaction must be equal. Let x be the number of neutrons.

Solution Find the number of neutrons.

$235+1=141+93+x,\ \text{so } x=\boxed{2}.$

(b) **Strategy** From Figure 29.2, the binding energies per nucleon of ^{235}U, ^{141}Cs, and ^{93}Rb are approximately 7.6 MeV, 8.35 MeV, and 8.7 MeV, respectively. The energy released is equal to the increase in the binding energy.

Solution The binding energies of the three nuclides are as follows:

^{235}U: $235\times 7.6\text{ MeV}=1786\text{ MeV}$, ^{141}Cs: $141\times 8.35\text{ MeV}=1177\text{ MeV}$,

^{93}Rb: $93\times 8.7\text{ MeV}=809\text{ MeV}$.

Find the binding energy.

$1177\text{ MeV}+809\text{ MeV}-1786\text{ MeV}=200\text{ MeV}$

The energy released is approximately $\boxed{200\text{ MeV}}$.

(c) **Strategy** The atomic masses of $^{235}_{92}\text{U}$, $^{141}_{55}\text{Cs}$, and $^{93}_{37}\text{Rb}$ are 235.043 923 1 u, 140.920 044 0 u, and

92.922 032 8 u, respectively. Atomic masses can be used, since both sides include the same number of electrons (92).

Solution Find the change in mass.

$\Delta m=140.920\,044\,0\text{ u}+92.922\,032\,8\text{ u}+2\times 1.008\,664\,9\text{ u}-235.043\,923\,1\text{ u}-1.008\,664\,9\text{ u}=-0.193\,181\,4\text{ u}$

The energy released is $E=|\Delta m|c^2=0.193\,181\,4\text{ u}\times 931.494\ \text{MeV/u}=\boxed{179.947\text{ MeV}}$.

(d) **Strategy** Divide the energy released by the rest energy.

Solution

$$\frac{|\Delta E|}{E_0}=\frac{|\Delta m|}{m}=\frac{0.193\,181\,4\text{ u}}{235.043\,923\,1\text{ u}}\boxed{\approx 0.000\,822}$$

57.Strategy The total charge and total number of nucleons must remain the same. The energy released is equal to the difference between the binding energy of the reaction product and that of the deuteron. Compare the thermal energy to the coulomb repulsion.

Solution

(a) The atomic number of X must be 1 + 1 = 2, so X is helium. The mass number of X must be 1 + 2 = 3. The reaction product is $\boxed{^{3}_{2}\text{He}}$.

(b) The binding energies are as follows:

$^{1}_{1}\text{H}$: 0, $^{2}_{1}\text{H}$: $2\times 1.1\text{ MeV}=2.2\text{ MeV}$, $^{3}_{2}\text{He}$: $3\times 2.6\text{ MeV}=7.8\text{ MeV}$.

Find the energy released.

$7.8\text{ MeV}-2.2\text{ MeV}=\boxed{5.6\text{ MeV}}$

(c)

At room temperature, the kinetic energies of the proton and the deuteron are much too small to overcome their Coulomb repulsion.