

RADIOACTIVITY

Nuclear Size

Pages 296 – 297

$$1. \quad a) \quad r \approx (1.2 \times 10^{-15} \text{ m})(A)^{1/3} \\ \approx (1.2 \times 10^{-15} \text{ m})(1)^{1/3} \\ \approx 1.2 \times 10^{-15} \text{ m}$$

$$b) \quad r \approx (1.2 \times 10^{-15} \text{ m})(23)^{1/3} \\ \approx 3.4 \times 10^{-15} \text{ m}$$

$$c) \quad r \approx (1.2 \times 10^{-15} \text{ m})(32)^{1/3} \\ \approx 3.8 \times 10^{-15} \text{ m}$$

$$d) \quad r \approx (1.2 \times 10^{-15} \text{ m})(198)^{1/3} \\ \approx 7.0 \times 10^{-15} \text{ m}$$

$$e) \quad r \approx (1.2 \times 10^{-15} \text{ m})(212)^{1/3} \\ \approx 7.1 \times 10^{-15} \text{ m}$$

$$2. \quad r \approx (1.2 \times 10^{-15} \text{ m})(A)^{1/3}$$

$$A \approx \left(\frac{r}{1.2 \times 10^{-15} \text{ m}} \right)^3 \\ \approx \left(\frac{2.74 \times 10^{-15} \text{ m}}{1.2 \times 10^{-15} \text{ m}} \right)^3 \\ \approx 12$$

Isotopes

Pages 298 – 299

1. a) 8 protons, 16 – 8 = 8 neutrons
- b) 17 protons, 35 – 17 = 18 neutrons
- c) 92 protons, 234 – 92 = 142 neutrons
- d) 90 protons, 234 – 90 = 144 neutrons
- e) 6 protons, 14 – 6 = 8 neutrons
- f) 1 proton, 0 neutrons

2. a) #1 = hydrogen
- b) #27 = cobalt
- c) #26 = iron
- d) #79 = gold
- e) #38 = strontium

3. a) 6 protons, 14 – 6 = 8 neutrons
- b) 38 protons, 90 – 38 = 52 neutrons
- c) 92 protons, 238 – 92 = 146 neutrons

Mass Spectrometer

Pages 302 – 305

$$1. \quad F_e = F_m \\ q|E| = qvB_{\perp} \\ |E| = vB_{\perp} \\ = (3.50 \times 10^7 \text{ m/s})(0.500 \text{ T}) \\ = 1.75 \times 10^7 \text{ N/C}$$

$$2. \quad F_m = F_e \\ qvB_{\perp} = q|E| \\ |E| = vB_{\perp} \\ = (4.20 \times 10^6 \text{ m/s})(4.00 \times 10^{-2} \text{ T}) \\ = 1.68 \times 10^5 \text{ N/C}$$

$$|E| = \frac{V}{d} \\ V = |E|d \\ = (1.68 \times 10^5 \text{ N/C})(1.50 \times 10^{-2} \text{ m}) \\ = 2.52 \times 10^3 \text{ V}$$

$$3. \quad F_m = F_e \\ qvB_{\perp} = q|E| \\ v = \frac{|E|}{B_{\perp}} \\ = \frac{7.00 \times 10^3 \text{ V/m}}{2.50 \times 10^{-1} \text{ T}} \\ = 2.80 \times 10^4 \text{ m/s} \\ F_m = F_c \\ qvB_{\perp} = \frac{mv^2}{r} \\ m = \frac{qB_{\perp}r}{v} \\ = \frac{(1.60 \times 10^{-19} \text{ C})(2.50 \times 10^{-1} \text{ T})(8.12 \times 10^{-3} \text{ m})}{2.80 \times 10^4 \text{ m/s}} \\ = 1.16 \times 10^{-26} \text{ kg}$$

$$\begin{aligned}
 4. \quad \Delta E &= qV \\
 &= (1.60 \times 10^{-19} \text{ C})(4.00 \times 10^4 \text{ V}) \\
 &= 6.40 \times 10^{-15} \text{ J}
 \end{aligned}$$

$$E_k = \frac{1}{2}mv^2$$

$$\begin{aligned}
 v &= \sqrt{\frac{2E_k}{m}} \\
 &= \sqrt{\frac{2(6.40 \times 10^{-15} \text{ J})}{1.16 \times 10^{-26} \text{ kg}}} \\
 &= 1.05 \times 10^6 \text{ m/s}
 \end{aligned}$$

$$F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$\begin{aligned}
 r &= \frac{mv}{qB_{\perp}} \\
 &= \frac{(1.16 \times 10^{-26} \text{ kg})(1.05 \times 10^6 \text{ m/s})}{(1.60 \times 10^{-19} \text{ C})(0.700 \text{ T})} \\
 &= 1.09 \times 10^{-1} \text{ m}
 \end{aligned}$$

$$5. \quad F_e = F_m$$

$$q|E| = qvB_{\perp}$$

$$\begin{aligned}
 v &= \frac{|E|}{B_{\perp}} \\
 &= \frac{4.60 \times 10^5 \text{ V/m}}{0.850 \text{ T}} \\
 &= 5.41 \times 10^5 \text{ m/s}
 \end{aligned}$$

Mass:

$${}^{24}\text{Mg} = (24)(1.67 \times 10^{-27} \text{ kg}) = 4.01 \times 10^{-26} \text{ kg}$$

$${}^{25}\text{Mg} = (25)(1.67 \times 10^{-27} \text{ kg}) = 4.18 \times 10^{-26} \text{ kg}$$

$$F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB_{\perp}}$$

Radius:

$$\begin{aligned}
 {}^{24}\text{Mg} &= \frac{mv}{qB_{\perp}} \\
 &= \frac{(4.01 \times 10^{-26} \text{ kg})(5.41 \times 10^5 \text{ m/s})}{(1.60 \times 10^{-19} \text{ C})(0.250 \text{ T})} \\
 &= 0.542
 \end{aligned}$$

$$\begin{aligned}
 {}^{25}\text{Mg} &= \frac{(4.18 \times 10^{-26} \text{ kg})(5.41 \times 10^5 \text{ m/s})}{(1.60 \times 10^{-19} \text{ C})(0.250 \text{ T})} \\
 &= 0.565 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Diff} &= 2(0.565 - 0.542) \\
 &= 0.045 \text{ m}
 \end{aligned}$$

$$6. \quad F_e = F_m$$

$$q|E| = qvB_{\perp}$$

$$\begin{aligned}
 v &= \frac{|E|}{B_{\perp}} \\
 &= \frac{7.50 \times 10^4 \text{ N/C}}{0.300 \text{ T}} \\
 &= 2.50 \times 10^5 \text{ m/s}
 \end{aligned}$$

$$F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$\begin{aligned}
 m &= \frac{qB_{\perp}r}{v} \\
 &= \frac{(1.60 \times 10^{-19} \text{ C})(0.300 \text{ T})(11.3 \times 10^{-2} \text{ m})}{2.50 \times 10^5 \text{ m/s}} \\
 &= 2.17 \times 10^{-26} \text{ kg}
 \end{aligned}$$

$$\begin{aligned}
 \text{mass \#} &= \frac{2.17 \times 10^{-26} \text{ kg}}{1.67 \times 10^{-27} \text{ kg}} \\
 &= 13
 \end{aligned}$$

$$7. \quad F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$\begin{aligned}
 r &= \frac{mv}{qB_{\perp}} \\
 &= \frac{(14)(1.67 \times 10^{-27} \text{ kg})(1.00 \times 10^6 \text{ m/s})}{(1.60 \times 10^{-19} \text{ C})(0.900 \text{ T})} \\
 &= 0.162 \text{ m}
 \end{aligned}$$

$$8. \quad F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB_{\perp}}$$

$$R \propto m$$

mass:

$$\begin{aligned}
 \frac{{}^{16}\text{O}}{{}^{20}\text{Ne}} &= \frac{(16)(1.67 \times 10^{-27} \text{ kg})}{(20)(1.67 \times 10^{-27} \text{ kg})} \\
 &= \frac{16}{20} \\
 &= 0.800
 \end{aligned}$$

$$\begin{aligned}
 \therefore r &= (0.800)(15.1 \text{ cm}) \\
 &= 12.1 \text{ cm}
 \end{aligned}$$

9. $F_m = F_c$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$B_{\perp} = \frac{mv}{qr}$$

$$= \frac{(3.44 \times 10^{-25} \text{ kg})(5.00 \times 10^4 \text{ m/g})}{(3.20 \times 10^{-19} \text{ C})(19.6 \times 10^{-2} \text{ m})}$$

$$= 0.274 \text{ T}$$

$$m = \frac{qB_{\perp}^2 r^2}{2V}$$

$$= \frac{(1.60 \times 10^{-19} \text{ C})(7.20 \text{ T})^2 (0.140 \text{ m})^2}{2(2.86 \times 10^6 \text{ V})}$$

$$= 2.84 \times 10^{-26} \text{ kg}$$

10. $F_m = F_c$

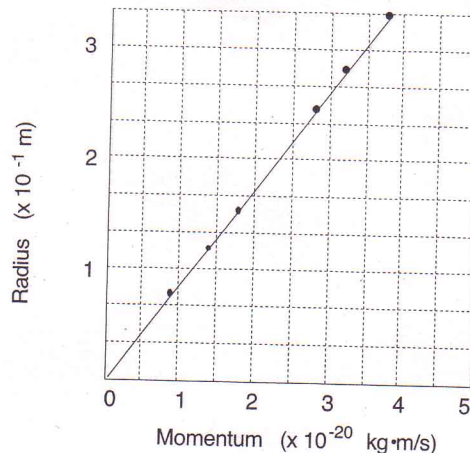
$$qvB_{\perp} = \frac{mv^2}{r}$$

$$v = \frac{qB_{\perp} r}{m}$$

$$E_k = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E_k}{m}}$$

12. a)



$$\Delta E = qV$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$\therefore \sqrt{\frac{2qV}{m}} = \frac{qB_{\perp} r}{m}$$

or $2V = \frac{qB_{\perp}^2 r^2}{m}$

$$m = \frac{qB_{\perp}^2 r^2}{2V}$$

$$= \frac{(3.20 \times 10^{-19} \text{ C})(0.200 \text{ T})^2 (10.2 \times 10^{-2} \text{ m})^2}{2(2.00 \times 10^3 \text{ V})}$$

$$= 3.33 \times 10^{-26} \text{ kg}$$

b) slope = $\frac{\text{rise}}{\text{run}}$

$$= \frac{2.7 \times 10^{-1} \text{ m}}{3.0 \times 10^{-20} \text{ kg}\cdot\text{m/s}}$$

$$= 9.0 \times 10^{18} \text{ s/kg}$$

$$F_m = F_c$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$B_{\perp} = \frac{mv}{qr}$$

$$= \frac{1}{\text{slope}}$$

$$= \frac{1}{(9.0 \times 10^{18} \text{ s/kg})q}$$

$$= (0.69 \pm 0.01) \text{ T}$$

11. ion accelerator ion deflection (separation)

$$\Delta E = qV$$

$$F_m = qvB_{\perp}$$

$$\Delta E = \frac{1}{2}mv^2$$

$$F_c = \frac{mv^2}{r}$$

$$qV = \frac{1}{2}mv^2$$

$$F_m = F_c$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$qvB_{\perp} = \frac{mv^2}{r}$$

$$v = \frac{qB_{\perp} r}{m}$$

$$\sqrt{\frac{2qV}{m}} = \frac{qB_{\perp} r}{m}$$

$$\frac{2qV}{m} = \frac{q^2 B_{\perp}^2 r^2}{m^2}$$

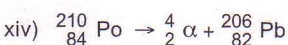
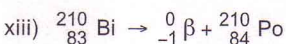
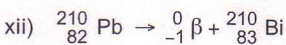
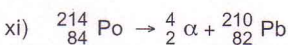
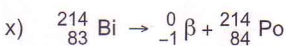
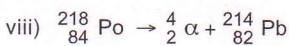
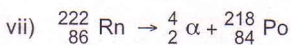
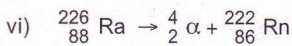
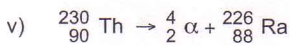
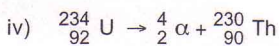
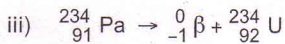
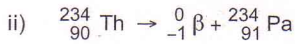
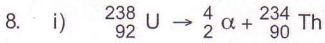
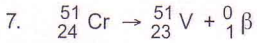
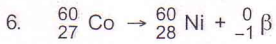
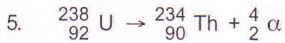
Alpha and Beta Decay

Pages 310 – 311

1. a) ${}_{88}^{226}\text{Ra}$ b) ${}_{2}^4\text{He}$
- c) ${}_{83}^{212}\text{Bi}$ d) ${}_{-1}^0\beta$
- e) ${}_{1}^0\beta$ f) ${}_{23}^{46}\text{V}$
2. e and f

3. c and d

4. Energy drops to a lower state



b) $E = mc^2$
 $= (6.31 \times 10^{-29} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$
 $= 5.68 \times 10^{-12} \text{ J}$

c) $\frac{5.68 \times 10^{-12} \text{ J}}{7} = 8.11 \times 10^{-13} \text{ J}$

2. a) 6 protons = $6(1.6726 \times 10^{-27} \text{ kg}) = 1.0036 \times 10^{-26} \text{ kg}$
8 neutrons = $8(1.6749 \times 10^{-27} \text{ kg}) = 1.3399 \times 10^{-26} \text{ kg}$
 $2.3435 \times 10^{-26} \text{ kg}$

mass defect = $(2.3435 \times 10^{-26} - 2.3252 \times 10^{-26}) \text{ kg}$
 $= 1.828 \times 10^{-28} \text{ kg}$

b) $E = mc^2$
 $= (1.828 \times 10^{-28} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$
 $= 1.65 \times 10^{-11} \text{ J}$

c) $\frac{1.65 \times 10^{-11} \text{ J}}{14} = 1.18 \times 10^{-12} \text{ J}$

3. 5 protons = $5(1.6726 \times 10^{-27} \text{ kg}) = 8.3630 \times 10^{-27} \text{ kg}$
6 neutrons = $6(1.6749 \times 10^{-27} \text{ kg}) = 1.0049 \times 10^{-26} \text{ kg}$
 $1.8412 \times 10^{-26} \text{ kg}$

mass nucleus = $(1.8412 \times 10^{-26} - 1.3184 \times 10^{-28}) \text{ kg}$
 $= 1.828 \times 10^{-26} \text{ kg}$

4. 3 protons = $3(1.6726 \times 10^{-27} \text{ kg}) = 5.0178 \times 10^{-27} \text{ kg}$
3 neutrons = $3(1.6749 \times 10^{-27} \text{ kg}) = 5.0247 \times 10^{-27} \text{ kg}$
 $1.0043 \times 10^{-26} \text{ kg}$

$E = mc^2$

$m = \frac{E}{c^2}$
 $= \frac{4.9118 \times 10^{-12} \text{ J}}{(3.00 \times 10^8 \text{ m/s})^2}$
 $= 5.46 \times 10^{-29} \text{ kg}$

mass nucleus = $(1.0043 \times 10^{-26} - 5.46 \times 10^{-29}) \text{ kg}$
 $= 9.9879 \times 10^{-27} \text{ kg}$

Half-life

Pages 316 – 320

1. $n = \frac{\text{time}}{T_{1/2}}$
 $= \frac{1.00 \text{ y}}{28.5 \text{ y}}$
 $= 0.0351$

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Mass Defect and Binding Energy

Pages 312 – 314

1. a) 4 protons = $4(1.6726 \times 10^{-27} \text{ kg}) = 6.6904 \times 10^{-27} \text{ kg}$
3 neutrons = $3(1.6749 \times 10^{-27} \text{ kg}) = 5.0247 \times 10^{-27} \text{ kg}$
 $1.1715 \times 10^{-26} \text{ kg}$

mass defect = $(1.1715 \times 10^{-26} - 1.1652 \times 10^{-26}) \text{ kg}$
 $= 6.31 \times 10^{-29} \text{ kg}$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (2.00 \text{ g}) \left(\frac{1}{2}\right)^{0.0351} \\
 &= 1.95 \text{ g}
 \end{aligned}$$

2.

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{2.5 \text{ d}}{3.0 \text{ d}} \\
 &= 0.833
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 \frac{N}{N_0} &= \left(\frac{1}{2}\right)^{0.833} \\
 &= 0.56 \text{ or } 56\%
 \end{aligned}$$

3.

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{9.5 \text{ y}}{2.7 \text{ y}} \\
 &= 3.52
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 \frac{N}{N_0} &= \left(\frac{1}{2}\right)^{3.52} \\
 &= 0.087 \text{ times}
 \end{aligned}$$

4.

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{5.0 \text{ h}}{0.75 \text{ h}} \\
 &= 6.67
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (2.0 \text{ g}) \left(\frac{1}{2}\right)^{6.67} \\
 &= 0.020 \text{ g}
 \end{aligned}$$

5. 16 days:

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{16 \text{ d}}{16 \text{ d}} \\
 &= 1
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (1.8 \times 10^3 \text{ Bq}) \left(\frac{1}{2}\right)^1 \\
 &= 9.0 \times 10^2 \text{ Bq}
 \end{aligned}$$

24 days:

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{24.0 \text{ d}}{16 \text{ d}} \\
 &= 1.5
 \end{aligned}$$

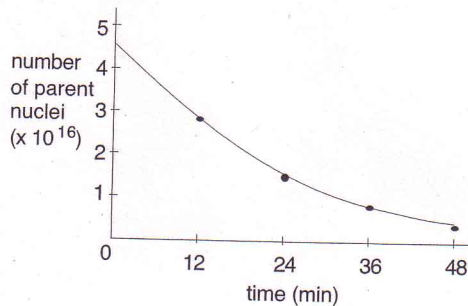
$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (1.8 \times 10^3 \text{ Bq}) \left(\frac{1}{2}\right)^{1.5} \\
 &= 6.4 \times 10^2 \text{ Bq}
 \end{aligned}$$

60 days:

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{60.0 \text{ d}}{16 \text{ d}} \\
 &= 3.75
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (1.8 \times 10^3 \text{ Bq}) \left(\frac{1}{2}\right)^{3.75} \\
 &= 1.3 \times 10^2 \text{ Bq}
 \end{aligned}$$

6.



7.

$$\begin{aligned}
 n &= \frac{\text{time}}{T_{1/2}} \\
 &= \frac{27.0 \text{ d}}{138 \text{ d}} \\
 &= 0.196
 \end{aligned}$$

$$\begin{aligned}
 N &= N_0 \left(\frac{1}{2}\right)^n \\
 &= (52.5 \text{ g}) \left(\frac{1}{2}\right)^{0.196} \\
 &= 45.8 \text{ g}
 \end{aligned}$$

$$8. \quad n = \frac{\text{time}}{T_{1/2}}$$

$$= \frac{14 \text{ h}}{24 \text{ h}}$$

$$= 0.58$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$= (3.0 \times 10^3 \text{ Bq}) \left(\frac{1}{2}\right)^{0.58}$$

$$= 2.0 \times 10^5 \text{ Bq}$$

$$9. \quad N = N_0 \left(\frac{1}{2}\right)^n$$

$$= (8.50 \times 10^{-3} \text{ g}) \left(\frac{1}{2}\right)^3$$

$$= 1.06 \times 10^{-3} \text{ g}$$

$$10. \quad n = \frac{\text{time}}{T_{1/2}}$$

$$= \frac{14.0 \text{ d}}{4.50 \text{ d}}$$

$$= 3.11$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$6.0 \times 10^6 \text{ Bq} = N_0 \left(\frac{1}{2}\right)^{3.11}$$

$$N_0 = 5.18 \times 10^7 \text{ Bq}$$

$$11. \quad n = \frac{\text{time}}{T_{1/2}}$$

$$= \frac{1.00 \text{ y}}{5.27 \text{ y}}$$

$$= 0.190$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$= (2.00 \times 10^{18}) \left(\frac{1}{2}\right)^{0.190}$$

$$= 1.75 \times 10^{18}$$

$$12. \quad n = \frac{\text{time}}{T_{1/2}}$$

$$= \frac{1.00 \times 10^3 \text{ y}}{5.73 \times 10^3 \text{ y}}$$

$$= 0.174$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$= (0.23 \text{ Bq/g}) \left(\frac{1}{2}\right)^{0.174}$$

$$= 0.20 \text{ Bq/g}$$

$$13. \quad N = N_0 \left(\frac{1}{2}\right)^n$$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{0.037 \text{ Bq}}{0.29 \text{ Bq}} = 0.161$$

$$\log 0.161 = \log \left(\frac{1}{2}\right)^n$$

$$n = \frac{\log 0.161}{\log \frac{1}{2}}$$

$$= 2.64$$

i.e. 2.64 half-lives

$$\text{time} = (2.64)(5.73 \times 10^3 \text{ years})$$

$$= 1.5 \times 10^4 \text{ years}$$

$$14. \quad n = \frac{\text{time}}{T_{1/2}}$$

$$= \frac{180 \text{ minutes}}{45 \text{ minutes}}$$

$$= 4$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$= (2.8 \times 10^4 \text{ decays/s}) \left(\frac{1}{2}\right)^4$$

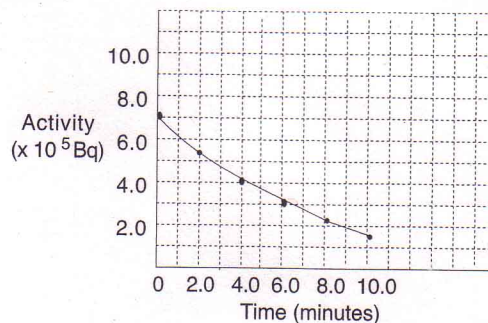
$$= 1.75 \times 10^3 \text{ decays/s}$$

$$\frac{\text{activity (volume used)}}{\text{activity (full volume)}} = \frac{\text{volume used}}{\text{full volume}}$$

$$\frac{3.0 \text{ decays/s}}{1.75 \times 10^3 \text{ decays/s}} = \frac{10.0 \text{ cm}^3}{V}$$

$$V = 5.8 \times 10^3 \text{ cm}^3$$

15.



Half-life = 5.0 minutes

16.
$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$1.0 \text{ g} = (1.2 \text{ g}) \left(\frac{1}{2}\right)^n$$

$$0.833 = \left(\frac{1}{2}\right)^n$$

$$\log 0.833 = n \log \left(\frac{1}{2}\right)$$

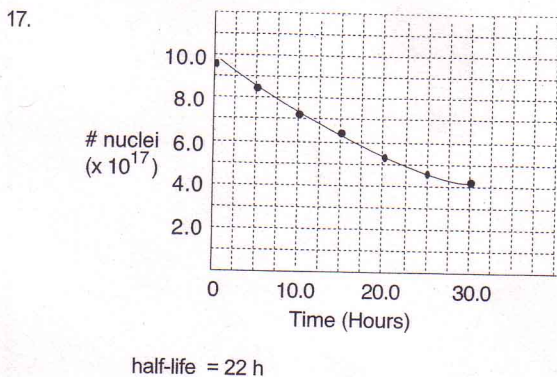
$$n = 0.263$$

$$n = \frac{\text{time}}{T_{1/2}}$$

$$T_{1/2} = \frac{\text{time}}{n}$$

$$= \frac{7.0 \text{ d}}{0.263}$$

$$= 27 \text{ days}$$



Fission and Fusion

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1. a) ${}_{54}^{143}\text{Xe}$
 b) ${}_{49}^{124}\text{In}$
2. a) ${}_{1}^2\text{H}$
 b) ${}_{7}^{14}\text{N}$

3. mass of reactants mass of products

$$\begin{array}{r} {}^{235}\text{U} = 3.9029 \times 10^{-25} \text{ kg} \\ n = 1.6749 \times 10^{-27} \text{ kg} \\ \hline 3.9196 \times 10^{-25} \text{ kg} \end{array} \quad \begin{array}{r} {}^{140}\text{Xe} = 2.3234 \times 10^{-25} \text{ kg} \\ {}^{94}\text{Sr} = 1.5595 \times 10^{-25} \text{ kg} \\ 2n = 3.3498 \times 10^{-27} \text{ kg} \\ \hline 3.9164 \times 10^{-25} \text{ kg} \end{array}$$

$$\text{mass defect} = (3.9196 \times 10^{-25} - 3.9164 \times 10^{-25}) \text{ kg}$$

$$= 3.202 \times 10^{-28} \text{ kg}$$

$$E = mc^2$$

$$= (3.202 \times 10^{-28} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$$

$$= 2.93 \times 10^{-11} \text{ J}$$

4. mass of reactants mass of products

$$\begin{array}{r} {}^2\text{H} = 3.3444 \times 10^{-25} \text{ kg} \\ {}^3\text{H} = 5.0082 \times 10^{-27} \text{ kg} \\ \hline 8.3526 \times 10^{-25} \text{ kg} \end{array} \quad \begin{array}{r} {}^4\text{He} = 6.6463 \times 10^{-27} \text{ kg} \\ n = 1.6749 \times 10^{-27} \text{ kg} \\ \hline 8.3212 \times 10^{-27} \text{ kg} \end{array}$$

$$\text{mass defect} = (8.3526 \times 10^{-27} - 8.3212 \times 10^{-27}) \text{ kg}$$

$$= 3.14 \times 10^{-29} \text{ kg}$$

$$E = mc^2$$

$$= (3.14 \times 10^{-27} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$$

$$= 2.83 \times 10^{-12} \text{ J}$$

5. mass of reactants mass of products

$$\begin{array}{r} {}^{235}\text{U} = 3.9029 \times 10^{-25} \text{ kg} \\ n = 1.6749 \times 10^{-27} \text{ kg} \\ \hline 3.9196 \times 10^{-25} \text{ kg} \end{array} \quad \begin{array}{r} {}^{142}\text{La} = 2.3563 \times 10^{-25} \text{ kg} \\ {}^{91}\text{Br} = 1.5097 \times 10^{-25} \text{ kg} \\ 3n = 5.0247 \times 10^{-27} \text{ kg} \\ \hline 3.9162 \times 10^{-25} \text{ kg} \end{array}$$

$$\text{mass defect} = (3.9196 \times 10^{-25} - 3.9162 \times 10^{-25}) \text{ kg}$$

$$= 3.449 \times 10^{-28} \text{ kg}$$

$$E = mc^2$$

$$= (3.449 \times 10^{-28} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$$

$$= 3.10 \times 10^{-11} \text{ J}$$

6. mass of reactants mass of products

$$\begin{array}{r} {}^{16}\text{O} = 2.6560 \times 10^{-26} \text{ kg} \\ {}^2\text{H} = 3.3444 \times 10^{-27} \text{ kg} \\ \hline 2.9904 \times 10^{-26} \text{ kg} \end{array} \quad \begin{array}{r} {}^{14}\text{N} = 2.3252 \times 10^{-26} \text{ kg} \\ {}^4\text{He} = 6.6463 \times 10^{-27} \text{ kg} \\ \hline 2.9898 \times 10^{-26} \text{ kg} \end{array}$$

$$\text{mass defect} = (2.9904 \times 10^{-26} - 2.9898 \times 10^{-26}) \text{ kg}$$

$$= 5.70 \times 10^{-30} \text{ kg}$$

$$E = mc^2$$

$$= (5.70 \times 10^{-30} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2$$

$$= 5.13 \times 10^{-13} \text{ J}$$

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