Chapter 14

Answers to Questions

1. $H_2SO_4(aq) + 2\ KOH(aq) \rightarrow K_2SO_4(aq) + 2\ H_2O(l)$

Strategy	Relationship
Vol/conc H_2SO_4 → mol H_2SO_4	n = c × V
Mol H_2SO_4 → mol KOH	1 mol H_2SO_4 ≡ 2 mol KOH
Mol/vol KOH→ conc KOH	c = n/V

$$\text{Mol } H_2SO_4 = 0.2000\ \text{mol} \cdot \text{L}^{-1} \times 1.473 \times 10^{-2}\ \text{L} = 2.946 \times 10^{-3}\ \text{mol } H_2SO_4$$

$$\text{Mol KOH} = 2.946 \times 10^{-3}\ \text{mol } H_2SO_4 \times \left(\frac{2\ \text{mol KOH}}{1\ \text{mol } H_2SO_4}\right) = 5.892 \times 10^{-3}\ \text{mol KOH}$$

$$\text{Concentration KOH} = \frac{5.892 \times 10^{-3}\ \text{mol}}{2.500 \times 10^{-2}\ \text{L}} = 0.2357\ \text{mol} \cdot \text{L}^{-1}$$

2. $2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$

Strategy	Relationship
Vol/conc $Ba(OH)_2$ → mol $Ba(OH)_2$	n = c × V
Mol $Ba(OH)_2$ → mol HCl	1 mol $Ba(OH)_2$ ≡ 2 mol HCl
Mol/vol HCl→ conc HCl	c = n/V

$$\text{Mol } Ba(OH)_2 = 0.1000\ \text{mol} \cdot \text{L}^{-1} \times 2.500 \times 10^{-2}\ \text{L} = 2.500 \times 10^{-3}\ \text{mol } Ba(OH)_2$$

$$\text{Mol HCl} = 2.500 \times 10^{-3}\ \text{mol } Ba(OH)_2 \times \left(\frac{2\ \text{mol HCl}}{1\ \text{mol } Ba(OH)_2}\right) = 5.000 \times 10^{-3}\ \text{mol HCl}$$

$$\text{Concentration HCl} = \frac{5.000 \times 10^{-3}\ \text{mol}}{3.216 \times 10^{-2}\ \text{L}} = 0.1555\ \text{mol} \cdot \text{L}^{-1}$$

3. $Fe(s) + CuSO_4(aq) \rightarrow Cu(s) + FeSO_4(aq)$

(a)

Strategy	Relationship
Mass Fe → mol Fe	1 mol Fe ≡ 55.8 g
Mol Fe → mol $CuSO_4$	1 mol Fe ≡ 1 mol $CuSO_4$
Mol/conc $CuSO_4$→ vol $CuSO_4$	V = n/c

$$\text{Mol Fe} = 0.279 \text{ g Fe} \times \left(\frac{1 \text{ mol}}{55.8 \text{ g}}\right) = 5.00 \times 10^{-3} \text{ mol Fe}$$

$$\text{Mol } CuSO_4 = 5.00 \times 10^{-3} \text{ mol Fe} \times \left(\frac{1 \text{ mol } CuSO_4}{1 \text{ mol Fe}}\right) = 5.00 \times 10^{-3} \text{ mol } CuSO_4$$

$$\text{Volume } CuSO_4 = \frac{5.00 \times 10^{-3} \text{ mol}}{0.200 \text{ mol} \cdot \text{L}^{-1}} = 2.50 \times 10^{-2} \text{ L} = 25.0 \text{ mL}$$

(b)

Strategy	Relationship
Mol Fe → mol Cu	1 mol Fe ≡ 1 mol Cu
Mol Cu → mass Cu	1 mol Cu ≡ 63.5 g

$$\text{Mol Cu} = 5.00 \times 10^{-3} \text{ mol Fe} \times \left(\frac{1 \text{ mol Cu}}{1 \text{ mol Fe}}\right) = 5.00 \times 10^{-3} \text{ mol Cu}$$

$$\text{Mass Cu} = 5.00 \times 10^{-3} \text{ mol Cu} \times \left(\frac{63.5 \text{ g}}{1 \text{ mol}}\right) = 0.318 \text{ g Cu}$$

4. $Sn(s) + 2\ AgNO_3(aq) \rightarrow 2\ Ag(s) + Sn(NO_3)_2(aq)$

(a)

Strategy	Relationship
Mass Sn → mol Sn	1 mol Sn ≡ 118.7 g
Mol Sn → mol $AgNO_3$	1 mol Sn ≡ 2 mol $AgNO_3$
Mol/conc $AgNO_3$→ vol $AgNO_3$	V = n/c

$$\text{Mol Sn} = 0.7845 \text{ g Sn} \times \left(\frac{1 \text{ mol}}{118.7 \text{ g}}\right) = 6.609 \times 10^{-3} \text{ mol Sn}$$

$$\text{Mol } AgNO_3 = 6.609 \times 10^{-3} \text{ mol Sn} \times \left(\frac{2 \text{ mol } AgNO_3}{1 \text{ mol Sn}}\right) = 1.322 \times 10^{-2} \text{ mol } AgNO_3$$

$$\text{Volume } AgNO_3 = \frac{1.322 \times 10^{-2} \text{ mol}}{0.1250 \text{ mol} \cdot \text{L}^{-1}} = 0.1057 \text{ L} = 105.7 \text{ mL}$$

(b)

Strategy	Relationship
Mol Sn → mol Ag	1 mol Fe ≡ 2 mol Ag
Mol Ag → mass Ag	1 mol Ag ≡ 107.9 g

$$\text{Mol Sn} = 6.609 \times 10^{-3} \text{ mol Ag} \times \left(\frac{2 \text{ mol Ag}}{1 \text{ mol Sn}}\right) = 1.322 \times 10^{-2} \text{ mol Ag}$$

$$\text{Mass Ag} = 1.322 \times 10^{-2} \text{ mol Ag} \times \left(\frac{107.9 \text{ g}}{1 \text{ mol}}\right) = 1.426 \text{ g Ag}$$

5. $Na_2CO_3(s) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + CO_2(g) + H_2O(l)$

(a)

Strategy	Relationship
Mass Na_2CO_3 → mol Na_2CO_3	1 mol Na_2CO_3 ≡ 106.0 g
Mol Na_2CO_3 → mol HCl	1 mol Na_2CO_3 ≡ 2 mol HCl
Mol/conc $AgNO_3$→ vol $AgNO_3$	V = n/c

$$\text{Mol } Na_2CO_3 = 5.83 \text{ g } Na_2CO_3 \times \left(\frac{1 \text{ mol}}{106.0 \text{ g}}\right) = 5.50 \times 10^{-2} \text{ mol } Na_2CO_3$$

$$\text{Mol HCl} = 5.50 \times 10^{-2} \text{ mol } Na_2CO_3 \times \left(\frac{2 \text{ mol HCl}}{1 \text{ mol } Na_2CO_3}\right) = 0.110 \text{ mol HCl}$$

$$\text{Volume HCl} = \frac{0.110 \text{ mol}}{0.200 \text{ mol} \cdot \text{L}^{-1}} = 0.550 \text{ L or } 550 \text{ mL}$$

(b)

Strategy	Relationship
Mol Na_2CO_3 → mol CO_2	1 mol Na_2CO_3 ≡ 1 mol CO_2
Mol/press/temp CO_2 → vol CO_2	V = nRT/P

$$\text{Mol } CO_2 = 5.50 \times 10^{-2} \text{ mol } Na_2CO_3 \times \left(\frac{1 \text{ mol } CO_2}{1 \text{ mol } Na_2CO_3}\right) = 5.50 \times 10^{-2} \text{ mol } CO_2$$

$$V = \frac{nRT}{P} = \frac{(5.50 \times 10^{-2} \text{ mol})(8.31 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(292 \text{ K})}{(98.7 \text{ kPa})} = 1.35 \text{ L}$$

6. $2\ Ca_3(PO_4)_2(s) + 6\ SiO_2(s) + 5\ C(s) \rightarrow P_4(s) + 6\ CaSiO_3(s) + 5\ CO_2(g)$

(a)

Strategy	Relationship
Mass P_4 → mol P_4	1 mol P_4 ≡ 124.0 g
Mol P_4 → mol $Ca_3(PO_4)_2$	1 mol P_4 ≡ 2 mol $Ca_3(PO_4)_2$
Mol $Ca_3(PO_4)_2$ → mass $Ca_3(PO_4)_2$	1 mol $Ca_3(PO_4)_2$ ≡ 310.3 g

$$\text{Mol } P_4 = 1.00 \times 10^3 \text{ g } P_4 \times \left(\frac{1 \text{ mol}}{124.0 \text{ g}}\right) = 8.06 \text{ mol } P_4$$

$$\text{Mol } Ca_3(PO_4)_2 = 8.06 \text{ mol } P_4 \times \left(\frac{2 \text{ mol } Ca_3(PO_4)_2}{1 \text{ mol } P_4}\right) = 16.1 \text{ mol } Ca_3(PO_4)_2$$

$$\text{Mass } Ca_3(PO_4)_2 = 16.1 \text{ mol } Ca_3(PO_4)_2 \times \left(\frac{310.3 \text{ g}}{1 \text{ mol}}\right)$$
$$= 5.00 \times 10^3 \text{ g } Ca_3(PO_4)_2 = 5.00 \text{ kg } Ca_3(PO_4)_2$$

(b)

Strategy	Relationship
Mol P_4 → mol CO_2	1 mol P_4 ≡ 5 mol CO_2
Mol/press/temp CO_2 → vol CO_2	V = nRT/P

$$\text{Mol } CO_2 = 8.06 \text{ mol } P_4 \times \left(\frac{5 \text{ mol } CO_2}{1 \text{ mol } P_4}\right) = 40.3 \text{ mol } CO_2$$

$$V = \frac{nRT}{P} = \frac{(40.3\ \text{mol})(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(673\ \text{K})}{(104.2\ \text{kPa})} = 2.16 \times 10^3\ \text{L}$$

7. (a) $M_2CO_3(aq) + CaCl_2(aq) \rightarrow CaCO_3(s) + 2\ MCl(aq)$

(b)

Strategy	Relationship
Mass $CaCO_3$ → mol $CaCO_3$	1 mol $CaCO_3 \equiv 100.1$ g
Mol $CaCO_3$ → mol M_2CO_3	1 mol $CaCO_3 \equiv 1$ mol M_2CO_3
Mol, mass M_2CO_3 → molar mass M_2CO_3	m.m. = m/n

$$\text{Mol } CaCO_3 = 0.1001\ \text{g } CaCO_3 \times \left(\frac{1\ \text{mol}}{100.1\ \text{g}}\right) = 1.000 \times 10^{-3}\ \text{mol } CaCO_3$$

$$\text{Mol } M_2CO_3 = 1.000 \times 10^{-3}\ \text{mol } CaCO_3 \times \left(\frac{1\ \text{mol } M_2CO_3}{1\ \text{mol } CaCO_3}\right)$$
$$= 1.000 \times 10^{-3}\ \text{mol } M_2CO_3$$

$$\text{Molar mass } M_2CO_3 = \left(\frac{0.1382\ \text{g}}{1.000 \times 10^{-3}\ \text{mol}}\right) = 138.2\ \text{g} \cdot \text{mol}^{-1}\ M_2CO_3$$

(c) Molar mass, 2 M = (138.2 – 60.0) g·mol^{-1} = 78.2 g·mol^{-1}
M = 39.1 g·mol^{-1}

(d) As M has to be a metal which forms an ion with a +1 charge, it is potassium

8. (a) $M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2\ MCl(aq)$

(b)

Strategy	Relationship
Mass $BaSO_4$ → mol $BaSO_4$	1 mol $BaSO_4 \equiv 233.40$ g
Mol $BaSO_4$ → mol M_2SO_4	1 mol $BaSO_4 \equiv 1$ mol M_2SO_4
Mol, mass M_2SO_4 → molar mass M_2SO_4	m.m. = m/n

$$\text{Mol } BaSO_4 = 1.1670 \text{ g } BaSO_4 \times \left(\frac{1 \text{ mol}}{233.40 \text{ g}}\right) = 5.0000 \times 10^{-3} \text{ mol } BaSO_4$$

$$\text{Mol } M_2SO_4 = 5.0000 \times 10^{-3} \text{ mol } BaSO_4 \times \left(\frac{1 \text{ mol } M_2SO_4}{1 \text{ mol } BaSO_4}\right)$$
$$= 5.0000 \times 10^{-3} \text{ mol } M_2SO_4$$

$$\text{Molar mass } M_2SO_4 = \left(\frac{0.8715 \text{ g}}{5.0000 \times 10^{-3} \text{ mol}}\right) = 174.3 \text{ g} \cdot \text{mol}^{-1} \ M_2SO_4$$

(c) Molar mass, 2 M = (174.3 – 96.1) g·mol^{-1} = = 78.2 g·mol^{-1}
M = 39.1 g·mol^{-1}

(d) As M has to be a metal which forms an ion with a +1 charge, it is potassium

9. $MH_2(s) + 2\ H_2O(l) \rightarrow M(OH)_2(aq) + 2\ H_2(g)$

(a)

Strategy	Relationship
Press/vol/temp → mol H_2	n = PV/RT
Mol H_2 → mol MH_2	2 mol H_2 ≡ 1 mol MH_2
Mol, mass MH_2 → molar mass MH_2	m.m. = m/n

$$n_{H_2} = \frac{PV}{RT} = \frac{(98.7 \text{ kPa})(0.125 \text{ L})}{(8.314 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298 \text{ K})} = 4.98 \times 10^{-3} \text{ mol } H_2$$

$$\text{Mol } MH_2 = 4.98 \times 10^{-3} \text{ mol } H_2 \times \left(\frac{1 \text{ mol } MH_2}{2 \text{ mol } H_2}\right) = 2.49 \times 10^{-3} \text{ mol } MH_2$$

$$\text{molar mass } MH_2 = \left(\frac{0.347 \text{ g}}{2.49 \times 10^{-3} \text{ mol}}\right) = 139 \text{ g} \cdot \text{mol}^{-1}$$

(b) Molar mass, M = (139 – 2.02) g·mol^{-1} = 137 g·mol^{-1}

(c) M has to be barium (barium has about the same molar mass as M and it forms a +2 ion).

10. $M_2CO_3(s) + 2\ HCl(aq) \rightarrow 2\ MCl(aq) + CO_2(g) + H_2O(l)$

(a)

Strategy	Relationship
Press/vol/temp → mol CO_2	n = PV/RT
Mol CO_2 → mol M_2CO_3	1 mol CO_2 ≡ 1 mol M_2CO_3
Mol, mass M_2CO_3 → molar mass M_2CO_3	m.m. = m/n

$$n_{CO_2} = \frac{PV}{RT} = \frac{(94.4\ \text{kPa})(0.225\ \text{L})}{(8.314\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298\ \text{K})} = 8.58 \times 10^{-3}\ \text{mol}\ CO_2$$

$$\text{Mol}\ M_2CO_3 = 8.58 \times 10^{-3}\ \text{mol}\ CO_2 \times \left(\frac{1\ \text{mol}\ M_2CO_3}{1\ \text{mol}\ CO_2}\right)$$
$$= 8.58 \times 10^{-3}\ \text{mol}\ M_2CO_3$$

$$\text{molar mass}\ M_2CO_3 = \left(\frac{1.185\ \text{g}}{8.58 \times 10^{-3}\ \text{mol}}\right) = 138\ \text{g} \cdot \text{mol}^{-1}$$

(b) Molar mass, 2 M = (138 – 60.0) g·mol^{-1} = 78 g·mol^{-1}
M = 39 g·mol^{-1}

(c) As M has to be a metal which forms an ion with a +1 charge, it is potassium.