10. Review Questions

Set 21 – Calculations from equations – mole/mole

1. Methane (CH_4) combines with oxygen gas to form carbon dioxide gas and water vapour. Using a balanced equation for the reaction determine how many moles of carbon dioxide gas would be produced from one mole of methane gas.

2. When magnesium burns in air it forms magnesium oxide as shown in the following equation.

   $2Mg_{(s)} + O_{2\,(g)} \rightarrow 2MgO_{(s)}$

   Determine the number of moles of oxygen gas consumed in producing 5.0 mol of magnesium oxide.

3. Determine the number of moles of hydrochloric acid needed to consume 0.15 mol of zinc in the following reaction.

   $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

4. Calculate the number of moles of sodium nitrate produced when 0.05 mol of sodium carbonate is reacted with excess nitric acid as shown below.

   $Na_2CO_{3\,(s)} + 2HNO_{3\,(aq)} \rightarrow 2NaNO_{3\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

5. Determine the number of moles of potassium chlorate required to produce 4.50 mol of oxygen gas using the following reaction.

   $2KClO_{3\,(s)} \rightarrow 2KCl_{(s)} + 3O_{2\,(g)}$

For the experts

6. Carbon dioxide gas can be produced from calcium carbonate according to the following reaction.

   $CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

   If 5.0 mol of hydrochloric acid is added to 5.0 mol of calcium carbonate what is the maximum number of moles of carbon dioxide that can be produced?

   (Hint: consider the reactant which is in limited supply.)

Set 22 - Calculations from equations - mole/mass

1. Determine the mass of water that would be produced by the complete combustion of 1.0 mol of hydrogen gas.

2. Determine the mass of mercury that would be produced by heating 0.55 mol of mercury (II) oxide. The reaction is as follows.

$$2HgO_{(s)} \xrightarrow{heat} 2Hg_{(l)} + O_{2\,(g)}$$

3. Determine the mass of sodium chloride required to react with 12.0 mol of silver nitrate according to the following equation.

$$AgNO_{3\,(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3\,(aq)} + AgCl_{(s)}$$

4. When copper (II) carbonate is heated it breaks down to copper (II) oxide and carbon dioxide gas as shown below.

$$CuCO_{3\,(s)} \xrightarrow{heat} CuO_{(s)} + CO_{2\,(g)}$$

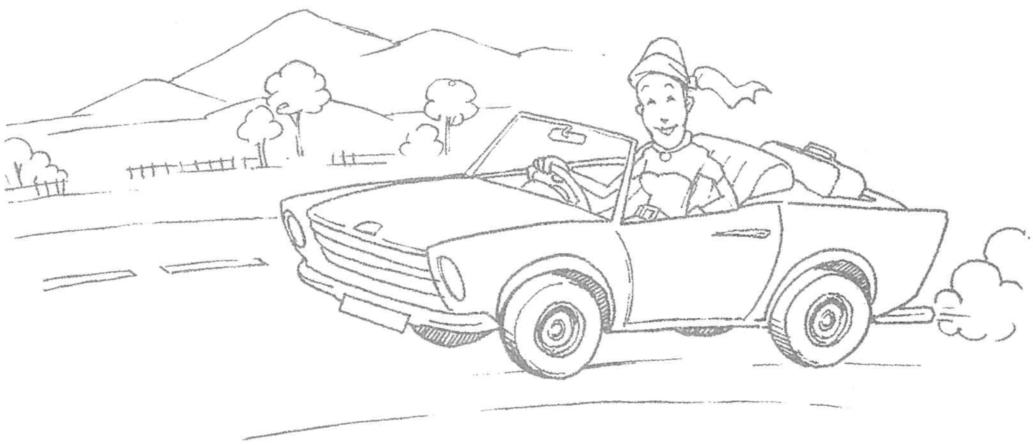
Determine the mass of copper (II) oxide and carbon dioxide gas produced by the decomposition of 0.40 mol of copper (II) carbonate.

5. Calculate the mass of carbon dioxide gas produced when 1.5 mol of propane gas (C_3H_8) are burnt in a plentiful supply of oxygen.

For the experts

6. Calculate the total mass of gases released in the atmosphere by the burning of 10.0 mol of octane (petrol) according to the following reaction.

$$2C_8H_{18\,(g)} + 25O_{2\,(g)} \rightarrow 16CO_{2\,(g)} + 18H_2O_{(g)}$$



Set 23 – Calculations from equations – mass/mole

1. Determine the number of moles of water produced by the complete combustion of 1.0 g of hydrogen gas.

2. Calculate the number of moles of hydrochloric acid necessary to completely consume 4.86 g of magnesium metal. The equation for the reaction is as follows.

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$$

3. Calculate the number of moles of sulfuric acid needed to produce 80.0 g of ammonium sulfate when it reacts with ammonia gas as follows.

$$2NH_{3\,(g)} + H_2SO_{4\,(aq)} \rightarrow (NH_4)_2SO_{4\,(aq)}$$

4. Calculate the number of moles of carbon dioxide gas produced when 2.4 g of copper carbonate are reacted with excess hydrochloric acid as shown below.

$$CuCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CuCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

5. Calculate the number of moles of magnesium metal required to form 1.56 g of magnesium nitride by the following reaction.

$$3Mg_{(s)} + N_{2\,(g)} \rightarrow Mg_3N_{2\,(s)}$$

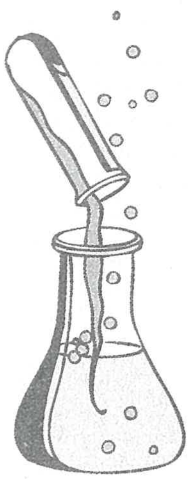
For the experts

6. When butane gas (commonly used as cigarette lighter fuel) burns in air, the gases produced are carbon dioxide and water vapour as follows.

$$2C_4H_{10\,(g)} + 13O_{2\,(g)} \rightarrow 8CO_{2\,(g)} + 10H_2O_{(g)}$$

Calculate the total number of moles of gaseous products from the combustion of 0.50 g of butane gas.

Set 24 – Calculations from equations – mass/mass



1. Calculate the mass of water produced by the complete combustion of 1.0 g of hydrogen gas.

2. Calculate the mass of silver metal produced when 6.35 g of copper are dissolved in silver nitrate according to the following reaction.

$Cu_{(s)} + 2AgNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + 2Ag_{(s)}$

3. Sodium peroxide reacts with water according to the following equation.

$2Na_2O_{2\,(s)} + 2H_2O_{(l)} \rightarrow 4NaOH_{(aq)} + O_{2\,(g)}$

If 25.0 g of Na_2O_2 are reacted calculate

a) the mass of sodium hydroxide produced

b) the mass of oxygen gas evolved.

4. Determine the mass of lead (II) iodide precipitated by adding excess potassium iodide to 7.50 g of lead (II) nitrate. The reaction is as follows.

$Pb(NO_3)_{2\,(aq)} + 2KI_{(aq)} \rightarrow PbI_{2\,(s)} + 2KNO_{3\,(aq)}$

5. Nitric acid reacts with calcium hydroxide as follows.

$2HNO_{3\,(aq)} + Ca(OH)_{2\,(aq)} \rightarrow Ca(NO_3)_{2\,(aq)} + 2H_2O_{(l)}$

Determine the mass of nitric acid required to completely neutralise 50.0 g of calcium hydroxide.

For the experts

6. Calcium metal reacts with hydrochloric acid to produce calcium chloride ($CaCl_2$) and hydrogen gas (H_2).

a) Write a balanced equation for the reaction.

b) If 4.0 g of hydrochloric acid are added to 4.0 g of calcium metal

(i) which reactant will be completely used up?

(ii) what mass of hydrogen gas will be produced?

Sets **Answers**

4. a) n (HCl) = m / M = 17.6 / 36.5 = 0.482 mol
∴ n (Cl) = 0.482 mol
∴ N (Cl) = (0.482)(6.02 x 10^{23})
= 2.90 x 10^{23} atoms

b) n ($PbSO_4$) = m / M
= 155.0 / (207.2 + 32.1 + 64.0)
= 0.511 mol
∴ n (Pb) = 0.511 mol
∴ N (Pb) = (0.511)(6.02 x 10^{23})
= 3.08 x 10^{23} atoms

c) n ($MgCO_3$) = m / M
= 22.2 / (24.3 + 12.0 + 48.0)
= 0.263 mol
∴ n (O) = (3)(0.263) = 0.790 mol
∴ N (O) = (0.790)(6.02 x 10^{23})
= 4.77 x 10^{23} atoms

d) n ($Cu(NO_3)_2$) = m / M
= 6.8 / (63.5 + 28.0 + 96.0)
= 0.0363 mol
∴ n (O) = (6)(0.0363) = 0.218 mol
∴ N (O) = (0.218)(6.02 x 10^{23})
= 1.31 x 10^{23} atoms

5. a) n (SO_2) = 6.02 x 10^{23} / 6.02 x 10^{23}
= 1.0 mol
∴ m (SO_2) = n . M = (1.0)(32.1 + 32.0)
= 64.1 g

b) n (Zn) = 3.01 x 10^{24} / 6.02 x 10^{23} = 5.0 mol
∴ m (Zn) = n . M = (5.0)(65.4) = 327 g

c) n (C_8H_{18}) = 2.60 x 10^{22} / 6.02 x 10^{23}
= 0.0432 mol
∴ m (C_8H_{18}) = n.M = (0.0432)(96.0 + 18.0)
= 4.92 g

d) n (Ca^{2+}) = 4.5 x 1024/6.02 x 10^{23} = 7.475 mol
n (OH^-) = 9.0 x 10^{24}/6.02 x 10^{23} = 14.95 mol
i.e. 7.475 mol of $Ca(OH)_2$
∴ m ($Ca(OH)_2$) = n . M
= (7.475)(40.1 + 32.0 + 2.0) = 554 g
OR m (Ca^{2+}) = (7.475)(40.1) = 299.8 g
m (OH^-) = (14.95)(17.0) = 254.2 g
total = 554 g

6. n (S) = 2.0 x 10^{24} / 6.02 x 10^{23} = 3.32 mol
since 1 mole of H_2SO_4 contains 1 mole of sulfur
n (H_2SO_4) = 3.32 mol
m (H_2SO_4) = (3.32)(98.1) = 325.9 g

Set 21: Equations – mole/mole

1. CH_4 (g) + $2O_2$ (g) -> CO_2 (g) + $2H_2O$ (g)
1 mol CH_4 (g) gives 1 mol CO_2 (g)

2. n(O_2) / n (MgO) = $^1/_2$
∴ n (O_2) = ($^1/_2$) (5.0)
= 2.5 mol

3. n (HCl) / n (Zn) = $^2/_1$
∴ n (HCl) = (2) (0.15)
= 0.30 mol

4. n ($NaNO_3$) / n (Na_2CO_3) = $^2/_1$
∴ n (Na_2CO_3) = (2) (0.05)
= 0.10 mol

5. n ($KClO_3$) / n (O_2) = $^2/_3$
∴ n ($KClO_3$) = ($^2/_3$) (4.5)
= 3.0 mol

6. From the equation we can see that for every mole of $CaCO_3$ we need two moles of HCl. Hence since we have equal amounts of these reactants it means that the HCl will be the limiting reagent (i.e. will run out first). Hence consider only HCl for calculating amount of CO_2 produced.

n (CO_2) / n (HCl) = $^1/_2$
∴ n (CO_2) = ($^1/_2$) (5.0)
= 2.5 mol

Set 22: Equations – mole/mass

1. $2H_2$ (g) + O_2 (g) -> $2H_2O$ (g)
n (H_2O) / n (H_2) = $^2/_2$ = 1
∴ n (H_2O) produced = (1) (1.0) = 1.0 mol
∴ m (H_2O) produced = (1.0) (18.0) = 18.0 g

2. n (Hg) / n (HgO) = $^2/_2$ = 1
∴ n (Hg) produced = (1) (0.55) = 0.55 mol
∴ m (Hg) produced = (0.55) (200.6) = 110.3 g

3. n (NaCl) / n ($AgNO_3$) = $^1/_1$ = 1
∴ n (NaCl) required = (1) (12.0) = 12.0 mol
∴ m (NaCl) required = (12.0) (58.5) = 702 g

Sets Answers

4. $n(CuO) / n(CuCO_3) = {}^1/_1 = 1$
$n(CO_2) / n(CuCO_3) = {}^1/_1 = 1$
∴ $n(CuO)$ produced = (1)(0.40) = 0.40 mol
∴ $m(CuO)$ produced = (0.40)(79.5) = 31.8 also
∴ $n(CO_2)$ produced = (1)(0.40) = 0.40 mol
∴ $m(CO_2)$ produced = (0.40)(44) = 17.6 g

5. $C_3H_8 + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
$n(CO_2) / n(C_3H_8) = {}^3/_1 = 3$
∴ $n(CO_2)$ produced = (3)(1.5) = 4.5 mol
∴ $m(CO_2)$ produced = (4.5)(44) = 198 g

6. $n(CO_2) / n(C_8H_{18}) = {}^{16}/_2 = 8$
∴ $n(CO_2)$ produced = (8)(10.0) = 80.0 mol
∴ $m(CO_2)$ produced = (80)(44) = 3520 g
$n(H_2O) / n(C_8H_{18}) = {}^{18}/_2 = 9$
∴ $n(H_2O)$ produced = (9)(10.0) = 90.0 mol
∴ $m(H_2O)$ produced = (90.0)(18.0) = 1620 g
∴ total mass of gases = 5140 g

Set 23: Equations – mass/mole

1. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
$n(H_2O) / n(H_2) = {}^2/_2 = 1$
$n(H_2)$ available = $m/M = {}^1/_2 = 0.5$ mol
∴ $n(H_2O)$ produced = (1)(0.5) = 0.5 mol

2. $n(HCl) / n(Mg) = {}^2/_1 = 2$
$n(Mg)$ available = $m/M = ({}^{4.86}/_{24.3})$
= 0.20 mol
∴ $n(HCl)$ produced = (2)(0.20) = 0.40 mol

3. $n(H_2SO_4) / n((NH_4)_2SO_4) = {}^1/_1 = 1$
$n((NH_4)_2SO_4)$ produced = $m/M = ({}^{80.0}/_{132.1})$
= 0.606 mol
∴ $n(H_2SO_4)$ required = (1)(0.606)
= 0.606 mol

4. $n(CO_2) / n(CuCO_3) = {}^1/_1 = 1$
$n(CuCO_3)$ reacted = $m/M = ({}^{2.4}/_{123.5})$
= 0.0194 mol
∴ $n(CO_2)$ produced = (1)(0.0194)
= 0.0194 mol

5. $n(Mg) / n(Mg_3N_2) = {}^1/_1 = 3$
$n(Mg_3N_2)$ required = $m/M = ({}^{1.56}/_{100.9})$
= 0.0155 mol
∴ $n(Mg)$ needed = (3)(0.0155)
= 0.0465 mol

6. $n(CO_2) / n(C_4H_{10}) = {}^8/_2 = 4$
$n(H_2O) / n(C_4H_{10}) = {}^{10}/_2 = 5$
$n(C_4H_{10})$ reacted = $m / M = ({}^{0.50}/_{58.0})$
= 8.62×10^{-3} mol
∴ $n(CO_2)$ produced = $(4)(8.62 \times 10^{-3})$
= 0.035 mol
$n(H_2O)$ produced = $(5)(8.62 \times 10^{-3})$ mol
= 0.043 mol
∴ total moles gaseous products = 0.078 mol

Set 24: Equations – mass/mass

1. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
$n(H_2O) / n(H_2) = {}^2/_2 = 1$
$n(H_2)$ reacted = $m / M = ({}^1/_2)$
= 0.5 mol
∴ $n(H_2O)$ produced = (1)(0.5) = 0.5 mol
∴ $m(H_2O)$ produced = (0.5)(18.0) = 9.0 g

2. $n(Ag) / n(Cu) = {}^2/_1 = 2$
$n(Cu)$ reacted = $m / M = ({}^{6.35}/_{63.5})$
= 0.10 mol
∴ $n(Ag)$ produced = (2)(0.10) = 0.20 mol
∴ $m(Ag)$ produced = (0.20)(107.9) = 21.6 g

3. $n(NaOH)/n(Na_2O_2) = {}^4/_2 = 2$
$n(O_2) / n(Na_2O_2) = {}^1/_2 = 0.5$
$n(Na_2O_2)$ reacted = $m / M = ({}^{25.0}/_{78.9})$
= 0.32 mol
∴ $n(NaOH)$ produced = (2)(0.32) = 0.64 mol
∴ $m(NaOH)$ produced = (0.64)(40) = 25.6 g
also $n(O_2)$ produced = (0.5)(0.32) = 0.16 mol
∴ $m(O_2)$ produced = (0.16)(32.0) = 5.12 g

4. $n(PbI_2) / n(Pb(NO_3)_2) = {}^1/_1 = 1$
$n(Pb(NO_3)_2)$ reacted = $m/M = ({}^{7.50}/_{331.2})$
= 0.0226 mol
∴ $m(PbI_2)$ produced = (0.0226)(461.0)
= 10.4 g

Sets Answers

5. $n(HNO_3) / n(Ca(OH)_2) = 2/1 = 2$
$n(Ca(OH)_2)$ reacted $= m/M = (50.0/74.1)$
$= 0.675$ mol
$\therefore n(HNO_3)$ required $= (2)(0.675)$
$= 1.35$ mol
$\therefore m(HNO_3)$ required $= (1.35)(63.0) = 85.0$ g

6. a) $Ca_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_{2\,(g)}$

b) $n(Ca)$ available $= m / M = (4.0/40.1)$
$= 0.10$ mol
$n(HCl)$ available $= m / M = (4.0/36.5)$
$= 0.11$ mol

i) From the equation we can see that for every mole of calcium that reacts two moles of hydrochloric acid are required. Hence there is insufficient hydrochloric acid to consume all the calcium. (i.e. HCl will be completely used up)

ii) $n(H_2) / n(HCl) = 1/2 = 0.5$ mol
$\therefore n(H_2)$ produced $= (0.5)(0.11)$
$= 0.055$ mol
$\therefore m(H_2)$ produced $= (0.055)(2.0)$
$= 0.11$ g

Set 25: Molar volume

1. a) $n(He) = V/22.4 = 11.2/22.4 = 0.50$ mol

b) $n(Cl_2) = V/22.4 = 0.560/22.4 = 0.025$ mol

c) $n(CO_2) = V/22.4 = 0.200/22.4 = 0.0089$ mol

d) $n(CH_4) = V/22.4 = 384/22.4 = 17.1$ mol

2. a) $V(SO_2) = (2.0)(22.4) = 44.8$ L

b) $V(NH_3) = (0.15)(22.4) = 3.36$ L

c) $V(O_2) = (125)(22.4) = 2800$ L

d) $V(C_4H_{10}) = (0.042)(22.4) = 0.941$ L

3. a) $n(H_2) = m/M = 24.0/2.0 = 12.0$ mol

$V(H_2) = (12.0)(22.4) = 268.8$ L

b) $n(O_2) = m/M = 200/32 = 6.25$ mol

$V(O_2) = (6.25)(22.4) = 140$ L

c) $n(SO_2) = m/M = 1.25/64.1 = 0.0195$ mol

$V(SO_2) = (0.0195)(22.4) = 0.437$ L

d) $n(CO) = m/M = 60.0/28.0 = 1.75$ mol

$V(CO) = (0.0195)(22.4) = 0.437$ L

4. a) $n(O_2) = m/M = 20/22.4 = 0.893$ mol

$\therefore m(O_2) = (0.893)(32.0) = 28.6$ g

b) $n(Cl_2) = V/22.4 = 20.0/22.4 = 0.893$ mol

$\therefore m(Cl_2) = (0.893)(71.0) = 63.4$ g

c) $n(CO_2) = V/22.4 = 0.560/22.4 = 0.025$ mol

$\therefore m(CO_2) = (0.025)(44.0) = 1.10$ g

d) $n(NH_3) = V/22.4 = 3500/22.4 = 156.25$ mol

$\therefore m(NH_3) = (156.25)(17.0) = 2656$ g

5. a) Gas jar B contains the greatest number of molecules (Avogadro's hypothesis: equal volumes of gases contain equal number of particles).

b) Gas jar A contains greatest mass of gas.

6. $n(N_2) = V/22.4 = 0.780/22.4 = 0.0348$ mol

$\therefore m(N_2) = (0.0348)(28.0) = 0.975$ g, similarly

$n(O_2) = 0.210/22.4 = 9.37 \times 10^{-3}$ mol

$\therefore m(O_2) = (9.37 \times 10\text{-}3)(32.0) = 0.300$ g

$n(Ar) = 0.010/22.4 = 4.46 \times 10^{-4}$ mol

$\therefore m(Ar) = (4.46 \times 10^{-4})(40.0) = 0.018$ g

$\therefore$ mass of 1 L of dry air $\approx$ 1.293 g

Set 26: Equations - volume / volume

1. $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$
1 vol 1 vol

vol (CO_2) / vol $(O_2) = 1/1 = 1$

vol (O_2) consumed = 50 L

$\therefore$ vol (CO_2) produced = (1)(50) = 50 L

2. a) vol (CO) / vol $(CO_2) = 2/2 = 1$

$\therefore$ vol (CO) consumed = (1)(0.060) = 0.060 L

= 60 mL