

Module 2: Introduction to Quantitative Chemistry

Topic 2.2: The Mole Concept

Solutions

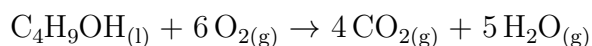
Foundation

1. Consider the following reaction:



How many moles of B is required to completely react with 2.50 moles of A?

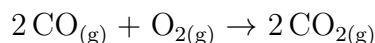
- (a) 2.50 mol
 - (b) 3.00 mol
 - (c) **3.75 mol**
 - (d) 7.50 mol
2. For the same reaction in Question 1, if 5.00 moles of A is mixed with 6.00 moles of B, how many moles of C is produced?
- (a) **4.00 mol**
 - (b) 5.00 mol
 - (c) 6.00 mol
 - (d) 12.0 mol
3. Butanol burns in oxygen according to the following equation:



How many moles of carbon dioxide would form if exactly 12 moles of oxygen was consumed in this reaction?

- (a) 2 mol
- (b) 4 mol
- (c) **8 mol**
- (d) 10 mol

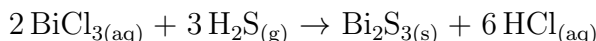
4. Carbon monoxide can be oxidised according to the following equation:



How many moles of oxygen is required to combust 28 g of carbon monoxide?

- (a) 0.40 mol
- (b) 0.50 mol
- (c) 0.60 mol
- (d) 0.70 mol

5. Consider the following reaction:



What volume of hydrogen sulfide gas at 25°C and 100 kPa is required to convert 0.600 moles of bismuth chloride into bismuth sulfide?

- (a) 7.40 L
- (b) 14.7 L
- (c) 20.2 L
- (d) 22.3 L

6. Aluminum can be extracted from aluminum oxide through the following electrolytic process:



What mass of aluminum oxide needs to be electrolysed to produce 500.0 L of oxygen at 0°C and 100 kPa?

- (a) 1020 g
- (b) 1327 g
- (c) 1497 g
- (d) 2275 g

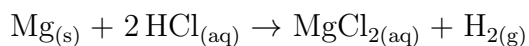
7. What volume of carbon dioxide gas is produced at 25°C and 100 kPa when 200.0 g of calcium carbonate is thermally decomposed?

- (a) 22.20 L
- (b) 24.50 L
- (c) 44.42 L
- (d) 49.54 L

8. What is the mass of calcium oxide produced when 25 g of calcium carbonate is thermally decomposed?

- (a) 10 g
- (b) 14 g
- (c) 16 g
- (d) 25 g

9. (a) Write a chemical equation for the reaction between magnesium and hydrochloric acid. 1



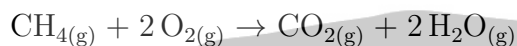
1 mark – Writes the correct chemical equation with states of matter

- (b) Calculate the mass of hydrochloric acid that is required to completely dissolve 6.00 g of magnesium. 2

$$\begin{aligned}n(\text{Mg}) &= \frac{6.00 \text{ g}}{24.31 \text{ g mol}^{-1}} \\&= 0.247 \text{ mol} \\n(\text{HCl}) &= 2 \times 0.247 \text{ mol} \\&= 0.494 \text{ mol} \\m(\text{HCl}) &= 0.494 \text{ mol} \times (1.008 + 35.45) \text{ g mol}^{-1} \\&= 18.0 \text{ g}\end{aligned}$$

2 marks – Calculates the correct moles of Mg and mass of HCl (1 mark each)

10. (a) Write a chemical equation for the complete combustion of methane (CH_4) gas. 1



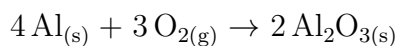
1 mark – Writes the correct chemical equation with states of matter (liquid water is also an acceptable product)

- (b) Calculate the mass AND volume of oxygen gas at 0°C and 100 kPa required to completely combust 10.0 g of methane. 3

$$\begin{aligned}n(\text{CH}_4) &= \frac{10.0 \text{ g}}{(12.01 + 4(1.008)) \text{ g mol}^{-1}} \\&= 0.623 \text{ mol} \\n(\text{O}_2) &= 2 \times 0.623 \text{ mol} \\&= 1.25 \text{ mol} \\m(\text{O}_2) &= 1.25 \text{ mol} \times 2(16.00) \text{ g mol}^{-1} \\&= 39.9 \text{ g} \\V(\text{O}_2) &= 1.25 \text{ mol} \times 22.71 \text{ L mol}^{-1} \\&= 28.3 \text{ L}\end{aligned}$$

3 marks – Calculates the correct moles of CH_4 , mass of O_2 and volume of O_2 (1 mark each)

11. (a) Write a chemical equation for the reaction between aluminum and oxygen gas. 1



1 mark – Writes the correct chemical equation with states of matter

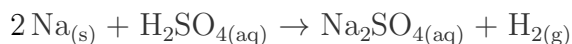
- (b) Calculate the mass of the salt produced when 0.89 g of aluminum is reacted with excess oxygen gas. 2

$$\begin{aligned}n(\text{Al}) &= \frac{0.89 \text{ g}}{26.98 \text{ g mol}^{-1}} \\&= 0.032 \text{ mol} \\n(\text{Al}_2\text{O}_3) &= \frac{2}{4} \times 0.032 \text{ mol} \\&= 0.016 \text{ mol} \\m(\text{Al}_2\text{O}_3) &= 0.016 \text{ mol} \times (2(26.98) + 3(16.00)) \text{ g mol}^{-1} \\&= 1.7 \text{ g}\end{aligned}$$

2 marks – Calculates the correct moles of Al and mass of Al_2O_3 (1 mark each)

12. During a class demonstration, Mr Geerling mixed 1.50 g of sodium with excess sulfuric acid.

- (a) Write a chemical equation for the reaction between sodium and sulfuric acid. 1



1 mark – Writes the correct chemical equation with states of matter

- (b) Calculate the mass of the salt produced from this reaction. 2

$$\begin{aligned}n(\text{Na}) &= \frac{1.50 \text{ g}}{22.99 \text{ g mol}^{-1}} \\&= 0.0652 \text{ mol} \\n(\text{Na}_2\text{SO}_4) &= \frac{1}{2} \times 0.0652 \text{ mol} \\&= 0.0326 \text{ mol} \\m(\text{Na}_2\text{SO}_4) &= 0.0326 \text{ mol} \times (2(22.99) + 32.07 + 4(16.00)) \text{ g mol}^{-1} \\&= 4.63 \text{ g}\end{aligned}$$

2 marks – Calculates the correct moles of Na and mass of Na_2SO_4 (1 mark each)

(c) Calculate the volume of the gas produced from this reaction at 25°C and 100 kPa.

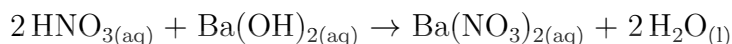
1

$$\begin{aligned}n(\text{H}_2) &= \frac{1}{2} \times 0.0652 \text{ mol} \\ &= 0.0326 \text{ mol} \\ V(\text{H}_2) &= 0.0326 \text{ mol} \times 24.79 \text{ L mol}^{-1} \\ &= 0.809 \text{ L}\end{aligned}$$

1 mark – Calculates the correct volume of H₂

13. (a) Write a chemical equation for the reaction between nitric acid and barium hydroxide.

1



1 mark – Writes the correct chemical equation with states of matter

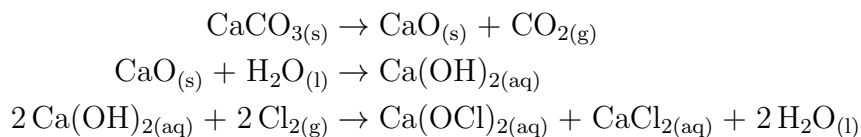
(b) Calculate the mass of the salt produced when 1.60 g of nitric acid is mixed with excess barium hydroxide.

2

$$\begin{aligned}n(\text{HNO}_3) &= \frac{1.60 \text{ g}}{(1.008 + 14.01 + 3(16.00)) \text{ g mol}^{-1}} \\ &= 0.0254 \text{ mol} \\ n(\text{Ba}(\text{NO}_3)_2) &= \frac{1}{2} \times 0.0254 \text{ mol} \\ &= 0.0127 \text{ mol} \\ m(\text{Ba}(\text{NO}_3)_2) &= 0.0127 \text{ mol} \times (137.3 + 2(14.01 + 3(16.00))) \text{ g mol}^{-1} \\ &= 3.32 \text{ g}\end{aligned}$$

2 marks – Calculates the moles of HNO₃ and mass of Ba(NO₃)₂ (1 mark each)

14. Calcium hypochlorite ($\text{Ca}(\text{OCl})_2$) is often used to disinfect swimming pools. It can be prepared from calcium carbonate with the following series of reactions: 3



Calculate the mass of calcium hypochlorite that can be produced from 2.50 kg of calcium carbonate.

$$\begin{aligned}m(\text{CaCO}_3) &= 2.50 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} \\ &= 2500 \text{ g}\end{aligned}$$

$$\begin{aligned}n(\text{CaCO}_3) &= \frac{2500 \text{ g}}{(40.08 + 12.01 + 3(16.00)) \text{ g mol}^{-1}} \\ &= 25.0 \text{ mol}\end{aligned}$$

$$n(\text{CaO}) = 25.0 \text{ mol}$$

$$n(\text{Ca}(\text{OH})_2) = 25.0 \text{ mol}$$

$$\begin{aligned}n(\text{Ca}(\text{OCl})_2) &= \frac{1}{2} \times 25.0 \text{ mol} \\ &= 12.5 \text{ mol}\end{aligned}$$

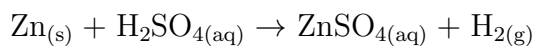
$$\begin{aligned}m(\text{Ca}(\text{OCl})_2) &= 12.5 \text{ mol} \times (40.08 + 2(16.00 + 35.45)) \text{ g mol}^{-1} \\ &= 1790 \text{ g}\end{aligned}$$

3 marks – Calculates the correct moles of CaCO_3 , moles of $\text{Ca}(\text{OCl})_2$ and mass of $\text{Ca}(\text{OCl})_2$ (1 mark each)



15. (a) Write a chemical equation for the reaction between zinc and sulfuric acid.

1



1 mark – Writes the correct chemical equation with states of matter

(b) Calculate the volume of the gas produced at 25°C and 100 kPa when 1.50 g of zinc is reacted with 1.70 g of sulfuric acid.

3

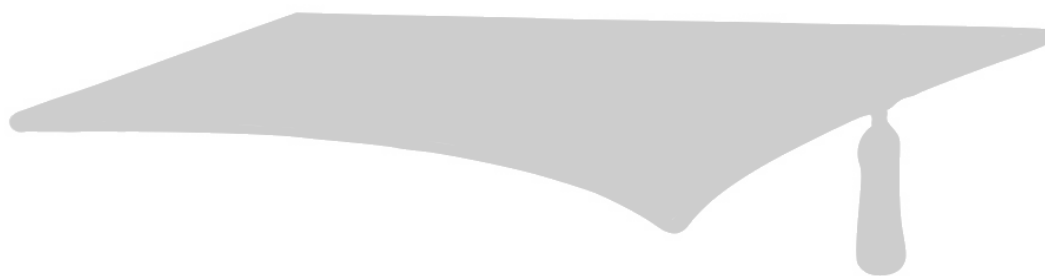
$$\begin{aligned} n(\text{Zn}) &= \frac{1.50 \text{ g}}{65.38 \text{ g mol}^{-1}} \\ &= 0.0229 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{H}_2\text{SO}_4) &= \frac{1.70 \text{ g}}{(2(1.008) + 32.07 + 4(16.00)) \text{ g mol}^{-1}} \\ &= 0.0173 \text{ mol} \end{aligned}$$

H_2SO_4 is the limiting reagent while Zn is in excess.

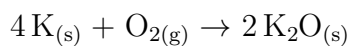
$$\begin{aligned} n(\text{H}_2) &= 0.0173 \text{ mol} \\ V(\text{H}_2) &= 0.0173 \text{ mol} \times 24.79 \text{ L mol}^{-1} \\ &= 0.430 \text{ L} \end{aligned}$$

3 marks – Calculates the correct moles of HNO_3 , moles of H_2SO_4 and volume of H_2 (1 mark each)



16. (a) Write a chemical equation for the reaction between potassium and oxygen.

1



1 mark – Writes the correct chemical equation with states of matter

(b) Calculate the mass of the salt produced when 5.00 g of potassium is reacted with 0.70 L of oxygen gas at 0°C and 100 kPa.

3

$$n(\text{K}) = \frac{5.00 \text{ g}}{39.10 \text{ g mol}^{-1}}$$

$$= 0.128 \text{ mol}$$

$$n(\text{O}_2) = \frac{0.70 \text{ L}}{22.71 \text{ L mol}^{-1}}$$

$$= 0.031 \text{ mol}$$

O₂ is the limiting reagent while K is in excess.

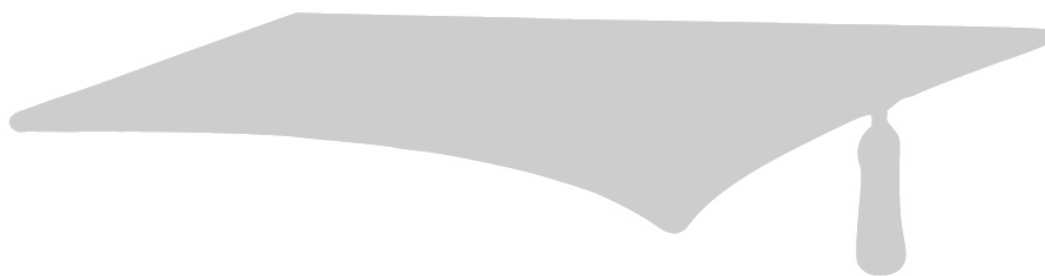
$$n(\text{K}_2\text{O}) = 2 \times 0.031 \text{ mol}$$

$$= 0.062 \text{ mol}$$

$$m(\text{K}_2\text{O}) = 0.062 \text{ mol} \times (2(39.10) + 16.00) \text{ g mol}^{-1}$$

$$= 5.8 \text{ g}$$

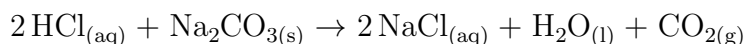
3 marks – Calculates the correct moles of K, moles of O₂ and mass of K₂O (1 mark each)



17. Sodium carbonate can be used to neutralise acid spills. In a particular incident, a university student added 9.00 g of solid sodium carbonate to a spill containing 8.50 g of hydrochloric acid.

(a) Write a chemical equation for the reaction that occurs.

1



1 mark – Writes the correct chemical equation with states of matter

(b) Calculate the mass of the salt produced from this reaction.

3

$$n(\text{HCl}) = \frac{8.50 \text{ g}}{(1.008 + 35.45) \text{ g mol}^{-1}} \\ = 0.233 \text{ mol}$$

$$n(\text{Na}_2\text{CO}_3) = \frac{9.00 \text{ g}}{(2(22.99) + 12.01 + 3(16.00)) \text{ g mol}^{-1}} \\ = 0.0849 \text{ mol}$$

Na_2CO_3 is the limiting reagent while HCl is in excess.

$$n(\text{NaCl}) = 2 \times 0.0849 \text{ mol} \\ = 0.170 \text{ mol}$$

$$m(\text{NaCl}) = 0.170 \text{ mol} \times (22.99 + 35.45) \text{ g mol}^{-1} \\ = 9.92 \text{ g}$$

3 marks – Calculates the correct moles of HCl, moles of Na_2CO_3 and mass of NaCl (1 mark each)

(c) Calculate the volume of the gas produced from this reaction at 25°C and 100 kPa.

1

$$n(\text{CO}_2) = 0.0849 \text{ mol} \\ V(\text{CO}_2) = 0.0849 \text{ mol} \times 24.79 \text{ L mol}^{-1} \\ = 2.11 \text{ L}$$

1 mark – Calculates the correct volume of H_2

(d) Calculate the mass of the leftover reactant at the end of the reaction.

1

$$n(\text{HCl})_{\text{leftover}} = 0.233 \text{ mol} - 2 \times 0.0849 \text{ mol} \\ = 0.0633 \text{ mol} \\ m(\text{HCl})_{\text{leftover}} = 0.0633 \text{ mol} \times (1.008 + 35.45) \text{ g mol}^{-1} \\ = 2.31 \text{ g}$$

1 mark – Calculates the correct mass of HCl leftover