

## **PART 01:**

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### **Group 1: Writing and Balancing Chemical Equations**

- Write the chemical equations for these reactions:
  - Hydrogen reacts with copper oxide to form copper and water.
  - Carbon reacts with carbon dioxide to produce carbon monoxide.
  - Carbon combines with oxygen to yield carbon dioxide.
  - Magnesium reacts with sulfuric acid to produce hydrogen and magnesium sulfate.
  - Copper reacts with chlorine to form copper(II) chloride.
- Write balanced chemical equations for the following reactions:
  - Calcium reacts with water to produce hydrogen and calcium hydroxide solution.
  - Copper combines with oxygen to form copper(II) oxide.
  - Sodium reacts with oxygen to produce sodium oxide.
  - Iron reacts with hydrochloric acid to form iron(II) chloride solution and hydrogen.
  - Iron reacts with chlorine to produce iron(III) chloride.
- Balance the following chemical equations:
  - $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{NaOH}(\text{aq})$
  - $\text{KClO}_3(\text{s}) \rightarrow \text{KCl}(\text{s}) + \text{O}_2(\text{g})$
  - $\text{H}_2\text{O}_2(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$
  - $\text{Fe}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{Fe}_3\text{O}_4(\text{s})$
  - $\text{Mg}(\text{s}) + \text{N}_2(\text{g}) \rightarrow \text{Mg}_3\text{N}_2(\text{s})$
  - $\text{NH}_3(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{N}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
  - $\text{Fe}(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{Fe}_3\text{O}_4(\text{s}) + \text{H}_2(\text{g})$
  - $\text{H}_2\text{S}(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) + \text{SO}_2(\text{g})$
  - $\text{H}_2\text{S}(\text{g}) + \text{SO}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{S}(\text{s})$

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### **Group 2: Relative Formula Mass Calculations**

- Determine the relative formula masses of these compounds:  
(a)  $\text{Mg}(\text{OH})_2$  (b)  $\text{NaOH}$  (c)  $\text{KNO}_3$  (d)  $\text{MgCO}_3$  (e)  $\text{PbCl}_2$  (f)  $\text{MgCl}_2$  (g)  $\text{Mg}(\text{NO}_3)_2$  (h)  $\text{Zn}(\text{OH})_2$  (i)  $\text{ZnSO}_4$  (j)  $\text{H}_2\text{SO}_4$  (k)  $\text{HNO}_3$  (l)  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  (m)  $\text{CaSO}_4$  (n)  $\text{Pb}_3\text{O}_4$  (o)  $\text{P}_2\text{O}_5$  (p)  $\text{Na}_2\text{CO}_3$  (r)  $\text{Ca}(\text{OH})_2$  (s)  $\text{CuCO}_3$  (t)  $\text{CuSO}_4$  (u)  $\text{Ca}(\text{HCO}_3)_2$  (v)  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  (w)  $\text{Al}_2(\text{SO}_4)_3$  (x)  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  (y)  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  (z)  $\text{KClO}_3$
- Find the relative formula masses of these compounds: carbon dioxide, sulfuric acid, hydrogen chloride, and sodium hydroxide. Then calculate:
  - The mass of 1 mole of carbon dioxide.
  - The mass of 1 mole of sulfuric acid.
  - The mass of 1 mole of hydrogen chloride.
  - The mass of 1 mole of sodium hydroxide.
- Calculate the relative formula masses of these compounds and determine:
  - The mass of 1 mole of sodium chloride.
  - The mass of 0.5 mole of potassium hydroxide.
  - The mass of 4 moles of iron(II) chloride.
  - The mass of 2.5 moles of sodium carbonate.
  - The mass of 0.1 mole of zinc chloride.
- For each compound below, calculate the relative formula mass, then find: (a) the mass of 1 mole and (b) the mass of 0.25 mole:  
calcium chloride, copper carbonate, barium hydroxide, sodium nitrate.

5. Calculate the relative molecular masses of the following gases based on the given data:
- (a) 2.2 g of gas A occupies 1.12 dm<sup>3</sup> at s.t.p.
  - (b) 8.0 g of gas B occupies 2.8 dm<sup>3</sup> at s.t.p.
  - (c) 4.0 g of gas C occupies 560 cm<sup>3</sup> at s.t.p.
  - (d) 1.0 g of gas D occupies 1.4 dm<sup>3</sup> at s.t.p.
  - (e) 4.0 g of gas E occupies 3.2 dm<sup>3</sup> at s.t.p.
  - (f) 1.7 g of gas F occupies 2.24 dm<sup>3</sup> at s.t.p.
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### Group 3: Percentage Composition by Mass

1. Calculate the percentage by mass of calcium, carbon, and oxygen in calcium carbonate.
  2. Determine the percentage by mass of potassium, hydrogen, carbon, and oxygen in potassium hydrogencarbonate (KHCO<sub>3</sub>).
  3. Find the percentage by mass of:
    - (a) Nitrogen and oxygen in nitrogen monoxide (NO).
    - (b) Carbon and hydrogen in ethane (C<sub>2</sub>H<sub>6</sub>).
    - (c) Sodium, oxygen, and hydrogen in sodium hydroxide (NaOH).
    - (d) Sulphur and oxygen in sulfur trioxide (SO<sub>3</sub>).
    - (e) Carbon and hydrogen in propyne (C<sub>3</sub>H<sub>4</sub>).
  4. Determine the percentage by mass of:
    - (a) Carbon and hydrogen in heptane (C<sub>7</sub>H<sub>16</sub>).
    - (b) Magnesium and nitrogen in magnesium nitride (Mg<sub>3</sub>N<sub>2</sub>).
    - (c) Calcium and bromine in calcium bromide (CaBr<sub>2</sub>).
  5. Calculate the percentage by mass of:
    - (a) Carbon and hydrogen in pentene (C<sub>5</sub>H<sub>10</sub>).
    - (b) Nitrogen, hydrogen, and oxygen in ammonium nitrate.
    - (c) Iron, oxygen, and hydrogen in iron(II) hydroxide.
    - (d) Carbon, hydrogen, and oxygen in ethanedioic acid (H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>).
  6. Find the percentage by mass of:
    - (a) Iron, sulfur, and oxygen in iron(III) sulphate.
    - (b) Carbon, hydrogen, and oxygen in propanol (C<sub>3</sub>H<sub>7</sub>OH).
    - (c) Carbon, hydrogen, and oxygen in ethanoic acid (CH<sub>3</sub>COOH).
  7. Determine the percentage of nitrogen in pure ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>).
  8. Identify which compound has the largest percentage by mass of nitrogen:
    - (a) Ammonium chloride (NH<sub>4</sub>Cl)
    - (b) Ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>)
    - (c) Ammonium sulphate ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>)
    - (d) Ammonia (NH<sub>3</sub>)
  9. If ammonium sulfate ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>) and sodium nitrate (NaNO<sub>3</sub>) cost the same per ton, determine which is the cheaper source of nitrogen.
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### Group 4: Mole and Mass Calculations for Elements

1. Find the relative atomic masses of sodium, magnesium, and lead, and calculate the mass of 1 mole of:
    - (a) Sodium
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- (b) Magnesium
  - (c) Lead
2. Determine the relative atomic masses of barium, chromium, and tin, and calculate the mass of:
    - (a) 0.1 mole of barium
    - (b) 0.1 mole of chromium
    - (c) 0.1 mole of tin
  3. Using relative atomic masses, calculate the mass of:
    - (a) 2 moles of iodine molecules
    - (b) 2 moles of silver
    - (c) 2 moles of aluminum
    - (d) 2 moles of mercury
  4. Calculate the mass of 0.25 mole of each element:
    - (a) Silver
    - (b) Sulfur
    - (c) Magnesium
    - (d) Calcium
    - (e) Neon
  5. Using relative atomic masses, determine the number of moles in:
    - (a) 54 g of aluminum
    - (b) 1.6 g of sulfur
    - (c) 42 g of iron
    - (d) 54 g of silver
    - (e) 13 g of zinc
  6. Calculate the mass of:
    - (a) 0.5 mole of chromium
    - (b) 1/7 mole of iron
    - (c) 1/3 mole of carbon
    - (d) 1/4 mole of magnesium
    - (e) 1/7 mole of nitrogen molecules
    - (f) 1/4 mole of oxygen molecules (Note: Nitrogen and oxygen exist as  $N_2$  and  $O_2$ .)
  7. Find the number of moles in:
    - (a) 46 g of sodium
    - (b) 130 g of zinc
    - (c) 10 g of calcium
    - (d) 2.4 g of magnesium
    - (e) 8 g of sulfur
  8. Calculate the mass of:
    - (a) 1 mole of sodium atoms
    - (b) 1/2 mole of nitrogen atoms
    - (c) 1/2 mole of nitrogen molecules
    - (d) 1/4 mole of sulfur atoms
    - (e) 0.2 mole of bromine atoms
    - (f) 0.2 mole of bromine molecules
  9. Determine the number of moles of atoms in:
    - (a) 23 g of sodium
    - (b) 64 g of sulfur
    - (c) 9 g of aluminum
    - (d) 120 g of calcium

- (e) 12 g of magnesium
  - (f) 7 g of iron
10. Calculate the mass of:
- (a) 10 moles of lead
  - (b) 1/6 mole of copper
  - (c) 0.1 mole of iodine molecules
  - (d) 10 moles of hydrogen molecules
  - (e) 0.25 mole of calcium
  - (f) 0.25 mole of bromine molecules
  - (g) 3/4 mole of iron
  - (h) 0.20 mole of zinc
  - (i) 1/2 mole of chlorine molecules
  - (j) 0.1 mole of neon
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#### Group 5: Mole and Mass Calculations for Compounds

1. Calculate the number of moles in:
- (a) 58.5 g of sodium chloride
  - (b) 26.5 g of anhydrous sodium carbonate
  - (c) 50.0 g of calcium carbonate
  - (d) 15.9 g of copper(II) oxide
  - (e) 8.0 g of sodium hydroxide
  - (f) 303 g of potassium nitrate
  - (g) 9.8 g of sulfuric acid
  - (h) 499 g of copper sulfate-5-water
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#### Group 6: Stoichiometry and Mass of Reactants/Products

1. Calculate the mass of magnesium oxide produced from the complete combustion of 24 g of magnesium. Write the equation and use relative atomic masses.
  2. Determine the mass of magnesium oxide formed from the complete combustion of 6 g of magnesium. Write the equation, use relative atomic masses, and apply a ratio calculation.
  3. Find the mass of carbon dioxide produced by the complete combustion of 12 g of carbon. Write the equation and use relative atomic masses.
  4. Calculate the mass of carbon dioxide formed from the complete combustion of 4 g of carbon. Write the equation, use relative atomic masses, and use a ratio calculation.
  5. Determine the mass of sulfur needed to produce 64 g of sulfur dioxide. Write the equation and use relative atomic masses.
  6. Calculate the mass of sulfur required to produce 8 g of sulfur dioxide.
  7. Find the mass of sulfur needed to produce 100 g of sulfur dioxide.
  8. For the reaction  $\text{CuO(s)} + \text{H}_2\text{(g)} \rightarrow \text{Cu(s)} + \text{H}_2\text{O(g)}$ , calculate the mass of copper obtained from:
    - (a) 79.5 g of copper(II) oxide
    - (b) 15.9 g of copper(II) oxideUse relative atomic masses in the equation.
  9. Calculate the mass of carbon dioxide produced by heating 10 g of calcium carbonate. Write the equation, use relative atomic masses, and apply a ratio calculation.
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10. Determine the mass of hydrogen produced by reacting 12 g of magnesium with excess dilute sulfuric acid. Write the equation, use relative atomic masses, and apply a ratio calculation.
11. Calculate the mass of carbon that can be completely burned in 32 g of oxygen. Follow the three-step process.
12. Find the mass of iron needed to produce 4.4 g of iron(II) sulfide when heated with excess sulfur. Use the three-step process.
13. Calculate the mass of carbon required to reduce 15.9 g of copper(II) oxide to copper in the reaction  $\text{CuO(s)} + \text{C(s)} \rightarrow \text{Cu(s)} + \text{CO(g)}$ .
14. For the reaction  $2\text{Fe(s)} + 3\text{Cl}_2\text{(g)} \rightarrow 2\text{FeCl}_3\text{(s)}$ , determine the mass of iron(III) chloride produced from 8 g of iron.
15. In a mixture of 8 g of iron and 4 g of sulfur heated to form iron(II) sulfide ( $\text{FeS}$ ), calculate how much iron remains unreacted.
16. Calculate the mass of lead(II) oxide produced by heating 33.1 g of lead(II) nitrate in the reaction  $2\text{Pb(NO}_3)_2\text{(s)} \rightarrow 2\text{PbO(s)} + 4\text{NO}_2\text{(g)} + \text{O}_2\text{(g)}$ .
17. Determine the mass of carbon dioxide produced from 15 g of calcium carbonate reacting with acid in the reaction  $\text{CaCO}_3\text{(s)} + 2\text{HCl(aq)} \rightarrow \text{CO}_2\text{(g)} + \text{CaCl}_2\text{(aq)} + \text{H}_2\text{O(l)}$ .
18. Calculate the mass of sodium hydroxide needed to neutralize a solution containing 7.3 g of hydrogen chloride in the reaction  $\text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$ .
19. Find the mass of sodium sulfate formed when 49 g of sulfuric acid is neutralized by sodium hydroxide in the reaction  $\text{H}_2\text{SO}_4\text{(aq)} + 2\text{NaOH(aq)} \rightarrow \text{Na}_2\text{SO}_4\text{(aq)} + 2\text{H}_2\text{O(l)}$ .
20. Calculate the mass of zinc chloride formed when 13 g of zinc is completely converted to chloride.
21. Determine the mass of potassium chloride produced when a solution containing 8 g of potassium hydroxide is neutralized with hydrochloric acid in the reaction  $\text{KOH(aq)} + \text{HCl(aq)} \rightarrow \text{KCl(aq)} + \text{H}_2\text{O(l)}$ .
22. Calculate the mass of sodium nitrate needed to produce 126 g of nitric acid in the reaction  $\text{NaNO}_3\text{(l)} + \text{H}_2\text{SO}_4\text{(l)} \rightarrow \text{HNO}_3\text{(l)} + \text{NaHSO}_4\text{(s)}$ .
23. Calculate the mass of copper(II) sulfate crystals ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) theoretically obtainable from 8.0 g of copper(II) oxide.
24. Determine the theoretical yield of hydrated zinc sulfate crystals ( $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ) from 4.05 g of zinc oxide. Describe the preparation process starting from zinc oxide.
25. Calculate the mass of copper(II) oxide required to theoretically produce 1000 g of copper(II) sulfate crystals ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ). ( $\text{Cu} = 64$ )
26. For the reaction  $4\text{NH}_3 + 6\text{NO} \rightarrow 5\text{N}_2 + 6\text{H}_2\text{O}$ , calculate the mass of ammonia needed to react with 1.8 g of NO emitted per mile by a car traveling 10,000 miles in one year.
27. For a power station burning 48,000 tons of fossil carbon ( $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ ), calculate the daily tonnage of carbon dioxide added to the atmosphere.
28. A motorist drives 20 miles daily for 250 days, with a car consuming 20 miles/gallon and petrol containing 2 g/gallon of lead. Calculate the total lead discharged into the environment.
29. When 25.0 g of a mixture of sodium carbonate and sodium hydrogencarbonate is heated ( $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$ ) and loses 6.2 g, calculate the mass of each salt in the original mixture.

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#### Group 7: Gas Volume Calculations

- Calculate the volume of carbon dioxide (at s.t.p.) produced by combusting 12 g of carbon. Write the equation and determine:
  - Moles of  $\text{CO}_2$  from 1 mole of carbon.
  - Volume of  $\text{CO}_2$  from 1 mole of carbon.
  - Moles of carbon in 12 g.
  - Volume of  $\text{CO}_2$  produced.
- Determine the volume of hydrogen (at s.t.p.) produced when 12 g of magnesium reacts with excess acid. Write the equation and calculate:
  - Moles of  $\text{H}_2$  from 1 mole of Mg.
  - Volume of  $\text{H}_2$  from 1 mole.
  - Moles of Mg in 12 g.
  - Volume of  $\text{H}_2$  produced.
- Find the volume of hydrogen (at s.t.p.) produced when 6.5 g of zinc reacts with excess acid. Write the equation and calculate:
  - Moles of  $\text{H}_2$  from 1 mole of Zn.
  - Volume of  $\text{H}_2$  from 1 mole.
  - Moles of Zn in 6.5 g.
  - Volume of  $\text{H}_2$  produced.
- Calculate the volume of carbon dioxide (at s.t.p.) produced by heating 10 g of calcium carbonate. Write the equation and determine:
  - Moles of  $\text{CO}_2$  from 1 mole of  $\text{CaCO}_3$ .
  - Volume of  $\text{CO}_2$  from 1 mole.
  - Moles of  $\text{CaCO}_3$  in 10 g.
  - Volume of  $\text{CO}_2$  produced.
- Determine the volume of oxygen (at s.t.p.) needed for the complete combustion of 125  $\text{cm}^3$  of methane, and the volume of carbon dioxide produced. Write the equation and calculate:
  - Moles of  $\text{O}_2$  per mole of  $\text{CH}_4$ .
  - Volumes of  $\text{O}_2$  per volume of  $\text{CH}_4$ .
  - Volume of  $\text{O}_2$  for 125  $\text{cm}^3$  of  $\text{CH}_4$ .
  - Moles of  $\text{CO}_2$  per mole of  $\text{CH}_4$ .
  - Volumes of  $\text{CO}_2$  per volume of  $\text{CH}_4$ .
  - Volume of  $\text{CO}_2$  produced.
- Calculate the volume of oxygen (at s.t.p.) reacting with 10 g of carbon and the volume of carbon dioxide formed.
- For the reaction  $\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ , calculate the mass of marble needed to produce 10.00 g of  $\text{CO}_2$  and the volume of  $\text{CO}_2$  at s.t.p.
- For  $\text{Zn}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{ZnCl}_2(\text{aq})$ , determine the mass of zinc needed to produce 100 g of hydrogen and the volume of  $\text{H}_2$  at (a) s.t.p. and (b) room temperature and 1 atm.
- For  $\text{PbO}(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{Pb}(\text{s}) + \text{H}_2\text{O}(\text{g})$ , calculate the volume of hydrogen (at s.t.p.) needed to reduce 4.46 g of lead(II) oxide and the mass of lead formed.
- For  $2\text{Pb}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{PbO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$ , calculate the volume of oxygen (at s.t.p.) from decomposing 3.31 g of lead(II) nitrate.
- For  $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$ , calculate the volume of oxygen (at s.t.p.) from decomposing 1.7 g of hydrogen peroxide.
- For  $2\text{KClO}_3(\text{s}) \rightarrow 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$ , determine the mass of potassium chlorate(V) needed to produce 112  $\text{cm}^3$  of oxygen at s.t.p.
- Calculate the volume of oxygen needed to convert 123  $\text{cm}^3$  of hydrogen into water via explosion.

14. For  $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$ , calculate the volume of oxygen (at s.t.p.) needed to combust 44 g of propane and the volume of  $\text{CO}_2$  formed.
15. For  $2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$ , calculate the volume of  $\text{CO}_2$  (at s.t.p.) from heating 4.20 g of sodium hydrogencarbonate, and from reacting 4.2 g with excess HCl.
16. Calculate the volume of hydrogen (at s.t.p.) needed to reduce  $250 \text{ cm}^3$  of propene ( $\text{C}_3\text{H}_6$ ) to propane ( $\text{C}_3\text{H}_8$ ).
17. Calculate the volume of carbon dioxide (at s.t.p.) from combusting  $250 \text{ cm}^3$  of butane ( $\text{C}_4\text{H}_{10}$ ) at s.t.p.
18. Calculate the volume of oxygen (at s.t.p.) from  $50 \text{ cm}^3$  of hydrogen peroxide solution (68 g/L).
19. Determine (a) the volume of 17.0 g of ammonia at s.t.p., and (b) the volume of 17.0 g of a 1:3 nitrogen-hydrogen mixture at s.t.p.
20. For  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ :  
 (a) How many moles are in 64 g of methane?  
 (b) How many moles of oxygen are needed to burn 64 g of methane?
21. For  $2\text{C}_4\text{H}_{10} + 13\text{O}_2 \rightarrow 8\text{CO}_2 + 10\text{H}_2\text{O}$ :  
 (a) Calculate the volume of oxygen used and  $\text{CO}_2$  produced from burning  $100 \text{ cm}^3$  of butane at room temperature and pressure (adjusted to original conditions).  
 (b) Calculate (i) the number of molecules in  $5600 \text{ cm}^3$  of hydrogen at s.t.p., and (ii) the number of atoms in 20 g of calcium. (1 mole =  $22400 \text{ cm}^3$  at s.t.p.; Avogadro's constant =  $6.02 \times 10^{23}$ )
22. For  $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$ , calculate the volume of residual gases after exploding  $20 \text{ cm}^3$  of ethane with  $100 \text{ cm}^3$  of oxygen, adjusted to original room temperature and pressure.
23. For  $2\text{Ca}(\text{NO}_3)_2 \rightarrow 2\text{CaO} + 4\text{NO}_2 + \text{O}_2$ , calculate the volume at s.t.p. of (a) nitrogen dioxide and (b) oxygen from heating 16.4 g of calcium nitrate ( $M_r = 164$ ).
24. For  $(\text{NH}_4)_2\text{SO}_4 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaSO}_4 + 2\text{NH}_3 + 2\text{H}_2\text{O}$ , calculate the volume of ammonia at room temperature and pressure from 0.1 mol of ammonium sulfate.
25. For  $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$ , calculate (a) the mass and (b) the volume at s.t.p. of  $\text{CO}_2$  from decomposing 4.20 g of sodium hydrogencarbonate.
26. For  $2\text{Ag}_2\text{CO}_3 \rightarrow 4\text{Ag} + 2\text{CO}_2 + \text{O}_2$ , calculate (a) the volume of oxygen at room temperature and pressure and (b) the mass of silver from decomposing 0.01 mol of silver carbonate. ( $\text{Ag} = 108$ ; 1 mole =  $24 \text{ dm}^3$  at RTP)

#### Group 8: Empirical and Molecular Formula Calculations

1. Determine the empirical formulas of compounds with these compositions:  
 (a) 50% sulfur, 50% oxygen  
 (b) 40% sulfur, 60% oxygen  
 (c) 47% nitrogen, 53% oxygen  
 (d) 30.5% nitrogen, 69.5% oxygen  
 (e) 75% carbon, 25% hydrogen  
 (f) 85.7% carbon, 14.3% hydrogen
2. Calculate the empirical formulas for compounds formed from:  
 (a) 0.62 g phosphorus and 0.48 g oxygen  
 (b) 1.4 g nitrogen and 0.30 g hydrogen  
 (c) 0.62 g lead and 0.064 g oxygen  
 (d) 3.5 g silicon and 4.0 g oxygen  
 (e) 1.10 g manganese and 0.64 g oxygen

- (f) 4.2 g nitrogen and 12.0 g oxygen  
(g) 2.6 g chromium and 5.3 g chlorine
- Find the empirical formulas of compounds formed when:
    - 0.69 g sodium forms 0.93 g of sodium oxide
    - 10.35 g lead forms 11.41 g of lead oxide
    - 0.035 g nitrogen forms 0.115 g of nitrogen oxide
    - 2.54 g copper forms 2.86 g of copper oxide
    - 11.2 g iron forms 25.4 g of iron chloride
    - 14.0 g iron combines with 26.6 g chlorine
  - Determine the empirical formulas of compounds formed when:
    - 0.24 g carbon combines with 0.64 g oxygen
    - 20.7 g lead forms 23.9 g of lead oxide
    - 15.9 g copper combines with 17.7 g chlorine
    - 6 g magnesium combines with 4 g oxygen
    - 1.8 g magnesium forms 2.5 g of magnesium nitride
    - 9 g aluminum forms 89 g of aluminum bromide
  - Calculate the empirical formulas of these hydrates:
    - Magnesium sulfate crystals: 48.8%  $\text{MgSO}_4$ , 51.2% water
    - Copper sulfate crystals: 63.9%  $\text{CuSO}_4$ , 36.1% water
    - Chromium(III) nitrate crystals: 59.5%  $\text{Cr}(\text{NO}_3)_3$ , 40.5% water
  - Determine the empirical formulas of compounds with these compositions:
    - 20% magnesium, 26.6% sulfur, 53.3% oxygen
    - 35% nitrogen, 5% hydrogen, 60% oxygen
    - 60% carbon, 13.3% hydrogen, 26.7% oxygen
    - 40% carbon, 6.7% hydrogen, 53.3% oxygen
  - A hydrocarbon with 80% carbon and a relative molecular mass of 30: Calculate its empirical formula, and write (a) its molecular formula and (b) a structural formula.
  - For 1.23 g of hydrated magnesium sulfate losing 0.63 g on heating, calculate the empirical formula of the crystals.
  - Butane has an empirical formula of  $\text{C}_2\text{H}_5$  and a relative molecular mass of 58. Find its molecular formula and one possible structural formula. For benzene (empirical formula  $\text{CH}$ ,  $M_r = 78$ ), determine its molecular formula and a possible structural formula.
  - A hydrocarbon with 85.7% carbon and a relative molecular mass of 28: Calculate its empirical formula, (a) molecular formula, and (b) structural formula.
  - Two oxides of metal M ( $A_r = 207$ ) contain 7.18% and 13.4% oxygen. Calculate their empirical formulas.
  - For 0.61 g of  $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$  losing water to leave 0.52 g of anhydrous  $\text{BaCl}_2$ , calculate the empirical formula of the crystals.
  - A hydrocarbon with 7.7% hydrogen: Calculate its empirical formula and suggest a structural formula.
  - For 4.17 g of a phosphorus chloride containing 3.55 g chlorine ( $A_r(\text{P}) = 31$ ,  $A_r(\text{Cl}) = 35.5$ ), find its empirical formula.
  - For an oxide (A) of chromium: (a) 5 g yields 2.6 g Cr on reduction ( $A_r(\text{Cr}) = 52$ ,  $A_r(\text{O}) = 16$ ); find its empirical formula. (b) Oxide (A) forms oxide (B) with 24 g oxygen per molar mass of Cr; find oxide (B)'s empirical formula. (c) Write the equation for oxide (B) formation from oxide (A).
  - A compound ( $M_r = 28$ ) with 85.7% carbon and 14.3% hydrogen: Determine (a) empirical formula, (b) molecular formula, (c) structural formula, (d) name, and (e) series.
  - A polymer with 85.7% carbon and 14.3% hydrogen: Calculate its empirical formula.

18. For 2.7 g aluminum producing 13.35 g aluminum chloride, find the empirical formula.
  19. Two saturated hydrocarbons ( $M_r = 58$ , 82.8% carbon): For each, determine (a) molecular formula and (b) structural formula.
  20. A compound with 29.4% calcium, 23.5% sulfur, 47.1% oxygen: Calculate its empirical formula.
  21. For 3.22 g of  $M_2SO_4 \cdot 10H_2O$  losing mass to 1.42 g, calculate the relative atomic mass of M.
  22. For 7 g of hydrocarbon X producing 22 g  $CO_2$  and 9 g  $H_2O$ , with 21 g occupying 11.2 dm<sup>3</sup> at s.t.p.: Find (a) grams of H and C in 7 g, (b) empirical formula, (c)  $M_r$ , and (d) molecular formula.
  23. For compound A (empirical formula  $C_2H_6O$ ), 4.6 g vaporizes to 2.24 dm<sup>3</sup> at s.t.p.: Find its molecular formula.
  24. For liquid B (empirical formula  $C_2H_4O$ ), 4.4 g vaporizes to 1.12 dm<sup>3</sup>: Determine its molecular formula.
- 

### Group 9: Avogadro's Constant and Number of Particles

1. Using Avogadro's constant ( $6 \times 10^{23} \text{ mol}^{-1}$ ), calculate the number of atoms in:
  - (a) 35.5 g chlorine
  - (b) 27 g aluminum
  - (c) 3.1 g phosphorus
  - (d) 336 g iron
  - (e) 48 g magnesium
  - (f) 1.6 g oxygen
  - (g) 0.4 g oxygen
  - (h) 216 g silver
2. Calculate the mass of zinc containing:
  - (a)  $6 \times 10^{23}$  atoms
  - (b)  $6 \times 10^{20}$  atoms
3. Determine the mass of aluminum containing:
  - (a)  $2 \times 10^{23}$  atoms
  - (b)  $6 \times 10^{20}$  atoms
4. Find the mass of carbon containing:
  - (a)  $6 \times 10^{23}$  atoms
  - (b)  $2 \times 10^{21}$  atoms
5. Calculate:
  - (a) The mass of calcium with the same number of atoms as 12 g magnesium
  - (b) The mass of silver with the same number of atoms as 3 g aluminum
  - (c) The mass of zinc with the same number of atoms as 1 g helium
  - (d) The mass of sodium with 5 times the number of atoms in 39 g potassium
6. Identify which contains the same number of atoms as 7 g iron:
  - (a) 4 g aluminum (b) 4 g magnesium (c) 4 g sulfur (d) 3 g carbon (e) 4 g calcium
7. Identify which contains the same number of atoms as 10 g calcium:
  - (a) 6 g sodium (b) 13 g chromium (c) 8 g magnesium (d) 26 g silver (e) 7 g aluminum
8. For 7 g nitrogen and 11 g hydrocarbon X occupying the same volume at s.t.p.:
  - (a) How many moles of  $N_2$  are in 7 g nitrogen?
  - (b) What is the relative molecular mass of X?

9. Given 1 mole =  $6 \times 10^{23}$  particles, calculate:
- The number of molecules in 3.4 g ammonia
  - The mass of copper deposited from  $\text{CuSO}_4$  by  $2 \times 10^{23}$  electrons
- 

#### Group 10: Preparation of Compounds and Related Calculations

- Describe how to prepare dry hydrated copper(II) sulfate crystals ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) from copper(II) oxide and dilute sulfuric acid. Calculate the mass of crystals from 0.01 mole of  $\text{CuO}$ .
    - Describe what happens when the crystals are heated until no mass change occurs, and calculate the percentage change in mass.
  - Describe how to prepare dry hydrated sodium sulfate crystals ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ) from dilute sodium hydroxide and sulfuric acid.
    - Calculate the mass of crystals from 0.05 mole of  $\text{NaOH}$ .
  - Describe how to prepare dry hydrated zinc sulfate crystals ( $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ) from zinc oxide and dilute sulfuric acid.
    - Calculate the mass of crystals from 0.05 mole of  $\text{ZnO}$ .
    - For 0.01 mole of  $\text{ZnSO}_4$  crystals dissolved and treated with excess  $\text{BaCl}_2$ , describe observations, write the ionic equation, and calculate the mass of the dry solid product.
  - Describe how to prepare reasonably dry hydrated zinc sulfate crystals ( $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ) from zinc oxide, and calculate the theoretical yield from 4.05 g of  $\text{ZnO}$ .
  - Draw a labeled diagram of an apparatus to determine the formula of water by reducing dry copper(II) oxide with dry hydrogen.
    - Using results ( $\text{CuO}$  before = 15.80 g,  $\text{Cu}$  after = 12.60 g, water collector before = 65.06 g, after = 68.66 g), determine the formula of water.
    - Suggest why early work deduced H and O relative atomic masses as 1 and 8.
- 

#### Group 11: Electrolysis and Charge Calculations

- Which requires the largest quantity of electricity for discharge at an electrode?
    - 1 mole of  $\text{Zn}^{2+}$
    - 2 moles of  $\text{Fe}^{3+}$
    - 3 moles of  $\text{OH}^-$
    - 4 moles of  $\text{Cl}^-$
    - 5 moles of  $\text{Ag}^+$
  - Calculate the number of coulombs required to liberate:
    - 54 g aluminum
    - 54 g silver(Faraday constant = 96500 coulombs/mole)
- 

#### Group 12: Concentration and Titration Calculations

- A sodium hydroxide solution contains  $8.0 \text{ g dm}^{-3}$ .  $25.0 \text{ cm}^3$  of this neutralizes  $35.0 \text{ cm}^3$  of nitric acid. Calculate:
    - Concentration of  $\text{NaOH}$  in  $\text{mol dm}^{-3}$
    - Concentration of  $\text{HNO}_3$  in  $\text{mol dm}^{-3}$
    - Concentration of  $\text{HNO}_3$  in  $\text{g dm}^{-3}$
  - Calculate the volume of  $1.5 \text{ mol dm}^{-3}$  sulfuric acid needed to react with 7.95 g of copper(II) oxide.
-

3. For  $2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$ , find the volume of  $0.25 \text{ mol dm}^{-3}$  HCl needed to neutralize the NaOH from 0.23 g of sodium.
  4. In a titration,  $25.0 \text{ cm}^3$  of HCl neutralizes  $20.0 \text{ cm}^3$  of  $0.25 \text{ mol dm}^{-3}$   $\text{Na}_2\text{CO}_3$ . Calculate:
    - (a) Moles of  $\text{Na}_2\text{CO}_3$  used
    - (b) Moles of HCl used
    - (c) Concentration of HCl in  $\text{mol dm}^{-3}$
  5. For 2.1 g of  $\text{NaHCO}_3$  reacting with HCl, calculate the volume of  $0.50 \text{ mol dm}^{-3}$  HCl needed to liberate maximum  $\text{CO}_2$ , and the volume of  $\text{CO}_2$  at s.t.p.
  6. A solution of  $\text{Na}_2\text{CO}_3$  contains 53.0 g in  $250 \text{ cm}^3$ . Calculate:
    - (a) Concentration in  $\text{mol dm}^{-3}$
    - (b) Volume of  $0.25 \text{ mol dm}^{-3}$  HCl needed to neutralize  $25.0 \text{ cm}^3$  of the solution
- 
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## PART 02

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### Exercise 1:

Calculation of the Molar Mass of Compounds

Calculate the molar mass of the following compounds

1.  $\text{H}_2\text{O}$
2.  $\text{CO}_2$
3.  $\text{NH}_3$
4.  $\text{C}_2\text{H}_5\text{OH}$
5.  $\text{C}_2\text{H}_4$
6.  $\text{SO}_2$
7.  $\text{SO}_3$
8.  $\text{HBr}$
9.  $\text{H}_2\text{SO}_4$
10.  $\text{HNO}_3$
11.  $\text{NaCl}$
12.  $\text{NaNO}_3$
13.  $\text{Na}_2\text{CO}_3$
14.  $\text{NaOH}$
15.  $\text{Na}_2\text{SO}_4$
16.  $\text{KMnO}_4$
17.  $\text{K}_2\text{CrO}_4$
18.  $\text{KHCO}_3$

19. KI
20. CsNO<sub>3</sub>
21. CaCl<sub>2</sub>
22. Ca(NO<sub>3</sub>)<sub>2</sub>
23. Ca(OH)<sub>2</sub>
24. CaSO<sub>4</sub>
25. BaCl<sub>2</sub>
26. AlCl<sub>3</sub>
27. Al(NO<sub>3</sub>)<sub>3</sub>
28. Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>
29. FeSO<sub>4</sub>
30. FeCl<sub>2</sub>
31. FeCl<sub>3</sub>
32. Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>
33. PbO
34. PbO<sub>2</sub>
35. Pb<sub>3</sub>O<sub>4</sub>
36. Pb(NO<sub>3</sub>)<sub>2</sub>
37. PbCl<sub>2</sub>
38. PbSO<sub>4</sub>
39. CuCl
40. CuCl<sub>2</sub>
41. CuSO<sub>4</sub>
42. ZnCl<sub>2</sub>
43. AgNO<sub>3</sub>
44. NH<sub>4</sub>Cl
45. (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>
46. NH<sub>4</sub>VO<sub>3</sub>
47. KClO<sub>3</sub>
48. KIO<sub>3</sub>
49. NaClO
50. NaNO<sub>2</sub>

51.  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
52.  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
53.  $(\text{NH}_4)_2\text{SO}_4 \cdot \text{Fe}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$
54.  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$
55.  $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$
56.  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
57.  $\text{Cu}(\text{NH}_3)_4\text{SO}_4 \cdot 2\text{H}_2\text{O}$
58.  $\text{CH}_3\text{CO}_2\text{H}$
59.  $\text{CH}_3\text{COCH}_3$
60.  $\text{C}_6\text{H}_5\text{CO}_2\text{H}$

**Exercise 2: Writing Formulae from Names**

1. Sodium chloride
2. Sodium hydroxide
3. Sodium carbonate
4. Sodium sulphate
5. Sodium phosphate
6. Potassium chloride
7. Potassium bromide
8. Potassium iodide
9. Potassium hydrogencarbonate
10. Potassium nitrite
11. Magnesium chloride
12. Magnesium nitrate
13. Magnesium hydroxide
14. Magnesium oxide
15. Magnesium carbonate
16. Calcium oxide
17. Calcium chloride
18. Calcium sulphate
19. Calcium carbonate
20. Barium chloride
21. Barium sulphate

22. Aluminium chloride
23. Aluminium oxide
24. Aluminium hydroxide
25. Aluminium sulphate
26. Copper(II) sulphate
27. Copper(II) oxide
28. Copper(II) chloride
29. Copper(II) nitrate
30. Copper(I) oxide
31. Copper(I) chloride
32. Zinc nitrate
33. Zinc carbonate
34. Zinc oxide
35. Silver chloride
36. Silver bromide
37. Silver iodide
38. Silver nitrate
39. Silver oxide
40. Lead(II) nitrate
41. Lead(II) carbonate
42. Lead(II) oxide
43. Lead(IV) oxide
44. Lead(II) chloride
45. Lead(IV) chloride
46. Lead(II) sulphide
47. Tin(II) chloride
48. Tin(IV) chloride
49. Iron(II) sulphate
50. Iron(II) chloride
51. Iron(III) sulphate
52. Iron(III) chloride
53. Iron(III) hydroxide

54. Iron(II) hydroxide
55. Ammonium chloride
56. Ammonium carbonate
57. Ammonium hydroxide
58. Ammonium nitrate
59. Ammonium sulphate
60. Ammonium phosphate
61. Phosphorus trichloride
62. Phosphorus pentachloride
63. Phosphorus trioxide
64. Phosphorus pentoxide
65. Hydrogen phosphate (Phosphoric acid)
66. Hydrogen sulphate (Sulphuric acid)
67. Hydrogen nitrate (Nitric acid)
68. Hydrogen chloride (Hydrochloric acid)
69. Carbon tetrachloride
70. Silicon tetrachloride
71. Silicon dioxide
72. Sulphur dioxide
73. Sulphur trioxide
74. Hydrogen sulphide
75. Chlorine(I) oxide
76. Nitrogen dioxide
77. Nitrogen monoxide
78. Carbon dioxide
79. Carbon monoxide
80. Hydrogen hydroxide

**Exercise 3: Names from Formulae**

Provide the names for the following compounds based on their formulae.

1.  $\text{H}_2\text{O}$
2.  $\text{CO}_2$
3.  $\text{NH}_3$

4.  $O_2$
5.  $H_2$
6.  $SO_2$
7.  $SO_3$
8.  $HCl$
9.  $HI$
10.  $HF$
11.  $CH_4$
12.  $H_2S$
13.  $HBr$
14.  $H_2SO_4$
15.  $HNO_3$
16.  $NaCl$
17.  $NaNO_3$
18.  $Na_2CO_3$
19.  $NaOH$
20.  $Na_2SO_4$
21.  $CaCl_2$
22.  $Ca(NO_3)_2$
23.  $Ca(OH)_2$
24.  $CaSO_4$
25.  $BaCl_2$
26.  $AlCl_3$
27.  $Al(NO_3)_3$
28.  $Al_2(SO_4)_3$
29.  $FeSO_4$
30.  $FeCl_2$
31.  $FeCl_3$
32.  $Fe_2(SO_4)_3$
33.  $PbO$
34.  $PbO_2$
35.  $Pb(NO_3)_2$

36.  $\text{PbCl}_2$
37.  $\text{PbSO}_4$
38.  $\text{Cu}(\text{NO}_3)_2$
39.  $\text{CuCl}$
40.  $\text{CuCl}_2$
41.  $\text{CuSO}_4$
42.  $\text{ZnCl}_2$
43.  $\text{AgNO}_3$
44.  $\text{NH}_4\text{Cl}$
45.  $(\text{NH}_4)_2\text{SO}_4$
46.  $\text{NH}_4\text{VO}_3$
47.  $\text{KClO}_3$
48.  $\text{KIO}_3$
49.  $\text{NaClO}$
50.  $\text{NaNO}_2$
51.  $\text{C}_2\text{H}_6$
52.  $\text{C}_4\text{H}_{10}$
53.  $\text{C}_8\text{H}_{18}$
54.  $(\text{NH}_4)_2\text{CO}_3$
55.  $\text{KMnO}_4$
56.  $\text{K}_2\text{CrO}_4$
57.  $\text{KHCO}_3$
58.  $\text{KI}$
59.  $\text{Co}(\text{NO}_3)_2$
60.  $\text{KAt}$

**Exercise 4a: Calculation of the Number of Moles of Material in a Given Mass**

Calculate the number of moles in the given mass of each substance.

1. 9 g of  $\text{H}_2\text{O}$
2. 88 g of  $\text{CO}_2$
3. 1.7 g of  $\text{NH}_3$
4. 230 g of  $\text{C}_2\text{H}_5\text{OH}$
5. 560 g of  $\text{C}_2\text{H}_4$

6. 0.64 g of  $\text{SO}_2$
7. 80 g of  $\text{SO}_3$
8. 17.82 g of  $\text{HBr}$
9. 0.098 g of  $\text{H}_2\text{SO}_4$
10. 3.15 g of  $\text{HNO}_3$
11. 19.305 g of  $\text{NaCl}$
12. 21.25 g of  $\text{NaNO}_3$
13. 2.226 g of  $\text{Na}_2\text{CO}_3$
14. 0.8 g of  $\text{NaOH}$
15. 17.75 g of  $\text{Na}_2\text{SO}_4$
16. 3.16 g of  $\text{KMnO}_4$
17. 32.478 g of  $\text{K}_2\text{CrO}_4$
18. 2.0 g of  $\text{KHCO}_3$
19. 3.32 g of  $\text{KI}$
20. 3.9 g of  $\text{CsNO}_3$
21. 0.111 g of  $\text{CaCl}_2$
22. 41 g of  $\text{Ca}(\text{NO}_3)_2$
23. 1.48 g of  $\text{Ca}(\text{OH})_2$
24. 0.34 g of  $\text{CaSO}_4$
25. 41.6 g of  $\text{BaCl}_2$
26. 20.8 g of  $\text{BaCl}_2$
27. 13.35 g of  $\text{AlCl}_3$
28. 1.811 g of  $\text{Al}_2(\text{SO}_4)_3$
29. 39.52 g of  $\text{FeSO}_4$
30. 13.208 g of  $\text{FeCl}_2$
31. 32.5 g of  $\text{FeCl}_3$
32. 32.8 g of  $\text{Fe}_2(\text{SO}_4)_3$
33. 11.15 g of  $\text{PbO}$
34. 319.46 g of  $\text{PbO}_2$
35. 17.12 g of  $\text{Pb}_3\text{O}_4$
36. 67.524 g of  $\text{Pb}(\text{NO}_3)_2$
37. 19.726 g of  $\text{PbCl}_2$

38. 3.03 g of  $\text{PbSO}_4$
39. 4.95 g of  $\text{CuCl}$
40. 34.18 g of  $\text{CuCl}_2$
41. 1.995 g of  $\text{CuSO}_4$
42. 20.73 g of  $\text{ZnCl}_2$
43. 17 g of  $\text{AgNO}_3$
44. 2.83 g of  $\text{NH}_4\text{Cl}$
45. 0.5676 g of  $(\text{NH}_4)_2\text{SO}_4$
46. 4.212 g of  $\text{NH}_4\text{VO}_3$
47. 32.585 g of  $\text{KClO}_3$
48. 5.136 g of  $\text{KIO}_3$
49. 1.8625 g of  $\text{NaClO}$
50. 108.786 g of  $\text{NaNO}_2$

**Exercise 4b: Calculation of the Mass of Material in a Given Number of Moles**

**Calculate the mass of the following substances given the number of moles.**

1. 2 moles of  $\text{H}_2\text{O}$
2. 3 moles of  $\text{CO}_2$
3. 2.8 moles of  $\text{NH}_3$
4. 0.5 moles of  $\text{C}_2\text{H}_5\text{OH}$
5. 1.2 moles of  $\text{C}_2\text{H}_4$
6. 0.64 moles of  $\text{SO}_2$
7. 3 moles of  $\text{SO}_3$
8. 1 mole of  $\text{HBr}$
9. 0.016 moles of  $\text{H}_2\text{SO}_4$
10. 0.15 moles of  $\text{HNO}_3$
11. 0.45 moles of  $\text{NaCl}$
12. 0.25 moles of  $\text{NaNO}_3$
13. 0.14 moles of  $\text{Na}_2\text{CO}_3$
14. 2 moles of  $\text{NaOH}$
15. 0.9 moles of  $\text{Na}_2\text{SO}_4$
16. 0.05 moles of  $\text{KMnO}_4$
17. 0.18 moles of  $\text{K}_2\text{CrO}_4$

18. 1 mole of  $\text{KHCO}_3$
19. 1.5 moles of  $\text{KI}$
20. 0.12 moles of  $\text{CsNO}_3$
21. 0.1 moles of  $\text{CaCl}_2$
22. 0.25 moles of  $\text{Ca}(\text{NO}_3)_2$
23. 0.004 moles of  $\text{Ca}(\text{OH})_2$
24. 0.1 moles of  $\text{CaSO}_4$
25. 0.21 moles of  $\text{BaCl}_2$
26. 0.072 moles of  $\text{AlCl}_3$
27. 0.357 moles of  $\text{Al}(\text{NO}_3)_3$
28. 0.0293 moles of  $\text{Al}_2(\text{SO}_4)_3$
29. 0.117 moles of  $\text{FeSO}_4$
30. 0.6 moles of  $\text{FeCl}_2$
31. 0.018 moles of  $\text{FeCl}_3$
32. 0.1 moles of  $\text{Fe}_2(\text{SO}_4)_3$
33. 0.09 moles of  $\text{PbO}$
34. 3.1 moles of  $\text{PbO}_2$
35. 0.00029 moles of  $\text{Pb}_3\text{O}_4$
36. 0.15 moles of  $\text{Pb}(\text{NO}_3)_2$
37. 0.1 moles of  $\text{PbCl}_2$
38. 0.0159 moles of  $\text{PbSO}_4$
39. 0.04 moles of  $\text{CuCl}$
40. 0.9 moles of  $\text{CuCl}_2$
41. 3 moles of  $\text{CuSO}_4$
42. 0.165 moles of  $\text{ZnCl}_2$
43. 0.06 moles of  $\text{AgNO}_3$
44. 0.08 moles of  $\text{NH}_4\text{Cl}$
45. 0.0739 moles of  $(\text{NH}_4)_2\text{SO}_4$
46. 0.037 moles of  $\text{NH}_4\text{VO}_3$
47. 0.078 moles of  $\text{KClO}_3$
48. 0.07 moles of  $\text{KIO}_3$
49. 1 mole of  $\text{NaClO}$

50. 5 moles of  $\text{NaNO}_2$

**Exercise 4c: Calculation of the Volume of a Given Number of Moles of a Gas**

**Calculate the volume (in  $\text{cm}^3$ ) of the following gases given the number of moles (assume standard conditions where 1 mole occupies 24,000  $\text{cm}^3$ ).**

1. 1 mole of  $\text{CH}_4$
2. 0.1 moles of  $\text{O}_2$
3. 0.5 moles of  $\text{N}_2$
4. 2 moles of  $\text{H}_2$
5. 0.12 moles of  $\text{CO}_2$
6. 3.4 moles of  $\text{SO}_2$
7. 0.11 moles of  $\text{SO}_3$
8. 0.004 moles of  $\text{HBr}$
9. 10 moles of  $\text{NH}_3$
10. 0.45 moles of  $\text{NO}$
11. 0.0056 moles of  $\text{NO}_2$
12. 0.009 moles of  $\text{N}_2\text{O}$
13. 0.04 moles of  $\text{Cl}_2$
14. 0.123 moles of  $\text{HCl}$
15. 0.0023 moles of  $\text{H}_2\text{S}$
16. 8 moles of  $\text{CH}_4$
17. 0.00001 moles of  $\text{O}_2$
18. 6 moles of  $\text{N}_2$
19. 0.0076 moles of  $\text{CO}$
20. 3 moles of  $\text{H}_2\text{O}(\text{g})$

**Exercise 4d: Calculation of the Number of Moles of Gas in a Given Volume**

**Calculate the number of moles of the following gases given their volumes (in  $\text{cm}^3$ ) at standard conditions (1 mole = 24,000  $\text{cm}^3$ ).**

1. 200  $\text{cm}^3$  of  $\text{CH}_4$
2. 500  $\text{cm}^3$  of  $\text{O}_2$
3. 1,000  $\text{cm}^3$  of  $\text{N}_2$
4. 1,280  $\text{cm}^3$  of  $\text{H}_2$
5. 235  $\text{cm}^3$  of  $\text{CO}_2$

6. 225 cm<sup>3</sup> of SO<sub>2</sub>
7. 255 cm<sup>3</sup> of SO<sub>3</sub>
8. 80 cm<sup>3</sup> of HBr
9. 2,000 cm<sup>3</sup> of NH<sub>3</sub>
10. 2,400 cm<sup>3</sup> of NO
11. 700 cm<sup>3</sup> of NO<sub>2</sub>
12. 5,600 cm<sup>3</sup> of N<sub>2</sub>O
13. 2,200 cm<sup>3</sup> of Cl<sub>2</sub>
14. 210 cm<sup>3</sup> of HCl
15. 800 cm<sup>3</sup> of H<sub>2</sub>S
16. 80 cm<sup>3</sup> of CH<sub>4</sub>
17. 1.92 cm<sup>3</sup> of O<sub>2</sub>
18. 20,000 cm<sup>3</sup> of N<sub>2</sub>
19. 420 cm<sup>3</sup> of CO
20. 900 cm<sup>3</sup> of H<sub>2</sub>O(g)

**Exercise 4e: Calculation of the Mass of a Given Volume of Gas**

**Calculate the mass of the following gases given their volumes (in cm<sup>3</sup>) at standard conditions (1 mole = 24,000 cm<sup>3</sup>).**

1. 200 cm<sup>3</sup> of CH<sub>4</sub>
2. 500 cm<sup>3</sup> of O<sub>2</sub>
3. 1,000 cm<sup>3</sup> of N<sub>2</sub>
4. 1,280 cm<sup>3</sup> of H<sub>2</sub>
5. 235 cm<sup>3</sup> of CO<sub>2</sub>
6. 225 cm<sup>3</sup> of SO<sub>2</sub>
7. 255 cm<sup>3</sup> of SO<sub>3</sub>
8. 80 cm<sup>3</sup> of HBr
9. 2,000 cm<sup>3</sup> of NH<sub>3</sub>
10. 2,400 cm<sup>3</sup> of NO
11. 700 cm<sup>3</sup> of NO<sub>2</sub>
12. 5,600 cm<sup>3</sup> of N<sub>2</sub>O
13. 2,200 cm<sup>3</sup> of Cl<sub>2</sub>
14. 210 cm<sup>3</sup> of HCl
15. 800 cm<sup>3</sup> of H<sub>2</sub>S

16. 80 cm<sup>3</sup> of CH<sub>4</sub>
17. 1.92 cm<sup>3</sup> of O<sub>2</sub>
18. 20,000 cm<sup>3</sup> of N<sub>2</sub>
19. 420 cm<sup>3</sup> of CO
20. 900 cm<sup>3</sup> of H<sub>2</sub>O(g)

**Exercise 4f: Calculation of the Volume of a Given Mass of Gas**

**Calculate the volume (in cm<sup>3</sup>) of the following gases given their masses at standard conditions (1 mole = 24,000 cm<sup>3</sup>).**

1. 5.76 g of CH<sub>4</sub>
2. 13.2 g of O<sub>2</sub>
3. 10 g of N<sub>2</sub>
4. 0.5 g of H<sub>2</sub>
5. 0.352 g of CO<sub>2</sub>
6. 0.448 g of SO<sub>2</sub>
7. 2.25 g of SO<sub>3</sub>
8. 16.2 g of HBr
9. 680 g of NH<sub>3</sub>
10. 135 g of NO
11. 136 g of NO<sub>2</sub>
12. 700 g of N<sub>2</sub>O
13. 159.5 g of Cl<sub>2</sub>
14. 7.3 g of HCl
15. 5.95 g of H<sub>2</sub>S
16. 1.6 g of CH<sub>4</sub>
17. 0.5 g of O<sub>2</sub>
18. 2 g of N<sub>2</sub>
19. 18.55 g of CO
20. 80 g of H<sub>2</sub>O(g)

**Exercise 4g: Calculation of the Relative Molecular Mass of a Gas from Mass and Volume Data**

**Calculate the relative molecular mass (M<sub>r</sub>) of the following gases given their mass and volume at standard conditions (1 mole = 24,000 cm<sup>3</sup>).**

1. 0.8 g occupies 120 cm<sup>3</sup>
2. 1.6 g occupies 600 cm<sup>3</sup>
3. 0.5 g occupies 150 cm<sup>3</sup>

4. 0.71 g occupies 240 cm<sup>3</sup>
5. 0.02 g occupies 2,400 cm<sup>3</sup>
6. 0.14 g occupies 120 cm<sup>3</sup>
7. 0.075 g occupies 60 cm<sup>3</sup>
8. 0.29 g occupies 120 cm<sup>3</sup>
9. 0.08 g occupies 60 cm<sup>3</sup>
10. 0.56 g occupies 480 cm<sup>3</sup>
11. 0.17 g occupies 120 cm<sup>3</sup>
12. 0.085 g occupies 120 cm<sup>3</sup>
13. 0.19 g occupies 120 cm<sup>3</sup>
14. 0.07 g occupies 60 cm<sup>3</sup>
15. 0.22 g occupies 120 cm<sup>3</sup>
16. 0.16 g occupies 120 cm<sup>3</sup>
17. 0.844 g occupies 96 cm<sup>3</sup>
18. 0.365 g occupies 240 cm<sup>3</sup>
19. 0.405 g occupies 120 cm<sup>3</sup>
20. 0.32 g occupies 60 cm<sup>3</sup>

#### Exercise 6a: Balancing Equations

Balance the following chemical equations.

1.  $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$
2.  $\text{BaCl}_2 + \text{NaOH} \rightarrow \text{Ba}(\text{OH})_2 + \text{NaCl}$
3.  $\text{H}_2\text{SO}_4 + \text{KOH} \rightarrow \text{K}_2\text{SO}_4 + \text{H}_2\text{O}$
4.  $\text{K}_2\text{CO}_3 + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2$
5.  $\text{CaCO}_3 + \text{HNO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$
6.  $\text{Ca} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{H}_2$
7.  $\text{Pb}(\text{NO}_3)_2 + \text{NaI} \rightarrow \text{PbI}_2 + \text{NaNO}_3$
8.  $\text{Al}_2(\text{SO}_4)_3 + \text{NaOH} \rightarrow \text{Al}(\text{OH})_3 + \text{Na}_2\text{SO}_4$
9.  $\text{Al}(\text{OH})_3 + \text{NaOH} \rightarrow \text{NaAlO}_2 + \text{H}_2\text{O}$
10.  $\text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbO} + \text{NO}_2 + \text{O}_2$
11.  $\text{FeSO}_4 \rightarrow \text{Fe}_2\text{O}_3 + \text{SO}_2 + \text{SO}_3$
12.  $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$
13.  $\text{NaNO}_3 \rightarrow \text{NaNO}_2 + \text{O}_2$

14.  $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
15.  $\text{C}_4\text{H}_{10} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
16.  $\text{PCl}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + \text{HCl}$
17.  $\text{HNO}_3 + \text{Cu} \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{NO} + \text{H}_2\text{O}$
18.  $\text{HNO}_3 + \text{Cu} \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{NO}_2 + \text{H}_2\text{O}$
19.  $\text{H}_3\text{PO}_4 + \text{NaOH} \rightarrow \text{NaH}_2\text{PO}_4 + \text{H}_2\text{O}$
20.  $\text{H}_3\text{PO}_4 + \text{NaOH} \rightarrow \text{Na}_3\text{PO}_4 + \text{H}_2\text{O}$
21.  $\text{H}_3\text{PO}_4 + \text{NaOH} \rightarrow \text{Na}_2\text{HPO}_4 + \text{H}_2\text{O}$
22.  $\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaClO}_3 + \text{NaCl} + \text{H}_2\text{O}$
23.  $\text{N}_2 + \text{H}_2 \rightarrow \text{NH}_3$
24.  $\text{NaBr} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{HBr}$
25.  $\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{O} + \text{SO}_2 + \text{Br}_2$
26.  $\text{C}_2\text{H}_5\text{OH} + \text{PCl}_3 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{H}_3\text{PO}_3$
27.  $\text{Fe}_3\text{O}_4 + \text{H}_2 \rightarrow \text{Fe} + \text{H}_2\text{O}$
28.  $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$
29.  $\text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{CO}_2\text{H} \rightarrow \text{CH}_3\text{CO}_2\text{C}_2\text{H}_5 + \text{H}_2\text{O}$
30.  $\text{KMnO}_4 + \text{HCl} \rightarrow \text{KCl} + \text{MnCl}_2 + \text{H}_2\text{O} + \text{Cl}_2$

#### Exercise 6b: What's Wrong Here?

Identify and correct the errors in the following equations.

1.  $\text{Na}(\text{s}) + \text{H}_2\text{O}(\text{aq}) \rightarrow \text{NaOH}(\text{aq}) + \text{H}(\text{g})$
2.  $\text{PbNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{PbCl}(\text{s}) + \text{NaNO}_3(\text{aq})$
3.  $\text{CaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{CaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
4.  $\text{C}_2\text{H}_4(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
5.  $\text{MgCO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
6.  $\text{Cu}(\text{NO}_3)_2(\text{s}) \rightarrow \text{CuO}(\text{s}) + \text{NO}_2(\text{g}) + \text{O}_3(\text{g})$
7.  $\text{Pb}(\text{s}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{Pb}(\text{NO}_3)_2(\text{aq}) + \text{AgCl}(\text{s})$
8.  $\text{AlCl}_2(\text{s}) + \text{KOH}(\text{aq}) \rightarrow \text{Al}(\text{OH})_2(\text{s}) + \text{KCl}(\text{aq})$
9.  $\text{NaCO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
10.  $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{aq}) + \text{NaNO}_3(\text{aq})$

#### Exercise 6c: Writing Equations in Symbols from Equations in Words

Write balanced symbol equations for the following reactions described in words.

1. Zinc + copper(II) sulphate → copper + zinc sulphate
2. Calcium hydroxide + ammonium chloride → calcium chloride + water + ammonia
3. Lead(II) nitrate → lead(II) oxide + nitrogen dioxide + oxygen
4. Silicon tetrachloride + water → silicon dioxide + hydrogen chloride
5. Calcium hydrogen carbonate → calcium carbonate + water + carbon dioxide
6. Octane + oxygen → carbon dioxide + water
7. Sodium hydroxide + chlorine (or bromine or iodine) → sodium chlorate(V) (or bromate or iodate) + sodium chloride (or bromide or iodide) + water
8. Metal (Li, Na, K, Rb, Cs) + water → metal hydroxide + hydrogen
9. Tin(II) chloride + mercury(II) chloride → mercury(I) chloride + tin(IV) chloride
10. Sulphuric acid + potassium iodide → iodine + hydrogen sulphide + potassium hydrogen sulphate + water

### Exercise 7: Writing equations from experimental data

1. When a solution containing 2.67 g of aluminium chloride was treated with excess silver nitrate solution, 4.30 g of silver chloride were precipitated. Write an equation for the reaction which has taken place.
2. When a solution containing 1.94 g of potassium chromate(VI) was treated with excess lead(II) nitrate solution, 3.23 g of lead(II) chromate(VI) was precipitated. Write an equation for the reaction which took place.
3. On heating, 3.40 g of silver nitrate decomposed to give 2.16 g of silver. Write an equation for the reaction which took place.
4. Phosphoric(V) acid,  $\text{H}_3\text{PO}_4$ , reacts with sodium hydroxide solution in three distinct stages depending upon the quantity of sodium hydroxide solution used:
  - When  $25\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  phosphoric(V) acid is treated with  $25\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  sodium hydroxide solution, the resulting solution has a pH of about 2.
  - When  $25\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  phosphoric(V) acid is treated with  $50\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  sodium hydroxide solution, the resulting solution has a pH of about 7.
  - When  $25\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  phosphoric(V) acid is treated with  $75\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  sodium hydroxide solution, the resulting solution has a pH of about 13.
  - i) How many moles of phosphoric(V) acid are present in  $25\text{ cm}^3$  of a  $0.1\text{ mol dm}^{-3}$  solution?
  - ii) How many moles of sodium hydroxide are present in  $25\text{ cm}^3$  of a  $0.1\text{ mol dm}^{-3}$  solution?
  - iii) Write equations for the three reactions that take place.
  - iv) What volume of  $0.1\text{ mol dm}^{-3}$  sodium hydroxide solution would be required to completely neutralise  $25\text{ cm}^3$  of  $0.1\text{ mol dm}^{-3}$  phosphoric(V) acid?
5. 2.495 g of hydrated copper(II) sulphate,  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ , was heated to drive off the water of crystallisation. The anhydrous copper(II) sulphate remaining had a mass of 1.595 g. Find the value of x and write an equation for the reaction taking place.
6. 2.495 g of hydrated copper(II) sulphate was dissolved in water and the solution treated with excess barium chloride solution. 2.33 g of barium sulphate was precipitated. Confirm that the value of x is the same as that found in question 5 and write an equation for the reaction between copper(II) sulphate solution and barium chloride solution.
7. When 0.085 g of ammonia gas was passed over heated copper(II) oxide, 0.72 g of copper was produced. Write an equation for the reaction which took place.

8. When 0.68 g of an organic compound containing carbon, hydrogen, and oxygen only was burnt in excess oxygen, 0.88 g of carbon dioxide and 0.72 g of water were produced. Find the empirical formula of the compound and write an equation for the reaction which took place.

9. When 0.278 g of hydrated iron(II) sulphate,  $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ , was heated gently until no further change occurred, 0.152 g of anhydrous iron(II) sulphate remained. Does this support the idea that  $x = 7$ ?

10. When 0.278 g of hydrated iron(II) sulphate was strongly heated, a mixture of gases was given off and a solid remained. The solid was found to be iron(III) oxide with a mass of 0.080 g. Write an equation for the reaction that took place.

#### Exercise 8: Calculations of amounts of products/reactants based on equations

1. What mass of iron can be obtained by the reduction of 32 g of iron(III) oxide with carbon monoxide?

2. What mass of barium sulphate can be precipitated when excess barium chloride solution is added to 25 cm<sup>3</sup> of a 0.1 mol dm<sup>-3</sup> solution of sodium sulphate?

3. In the production of ethyl ethanoate, 0.46 g of ethanol is mixed with an excess of ethanoic acid. What mass of each reactant is present in the equilibrium mixture?

4. What mass of iron(II) sulphate can be obtained by the action of 100 tonnes of 1 mol dm<sup>-3</sup> sulphuric acid on an excess of iron?

5. What mass of sodium chloride can be obtained when hydrogen chloride gas is passed into 100 cm<sup>3</sup> of a saturated solution of sodium chloride containing 36 g of sodium chloride?

6. What mass of sodium hydroxide and copper(II) hydroxide can be obtained when 100 cm<sup>3</sup> of a 1 mol dm<sup>-3</sup> solution of sodium hydroxide is added to 100 cm<sup>3</sup> of a 0.25 mol dm<sup>-3</sup> solution of copper(II) sulphate?

7. What volume of hydrogen, measured at RTP, can be obtained when 4.8 g of magnesium reacts with excess 1 mol dm<sup>-3</sup> sulphuric acid?

8. What mass of calcium nitrate and what volume of carbon dioxide at RTP can be obtained by the action of 100 cm<sup>3</sup> of 1 mol dm<sup>-3</sup> nitric acid on an excess of calcium carbonate?

9. What volume of gas (nitrogen dioxide and oxygen) is obtained when 3.31 g of lead(II) nitrate is heated? (Assume all volumes are measured at RTP.)

10. What mass of hydrated magnesium sulphate,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ , can be obtained from 1.2 g of magnesium? Write an equation for the reaction that takes place.

11. What mass of lead(II) iodide can be obtained when excess potassium iodide solution is added to 100 cm<sup>3</sup> of a 0.1 mol dm<sup>-3</sup> solution of lead(II) nitrate?

12. What mass of sodium carbonate is needed to produce 100 g of sodium oxide when heated?

13. What mass of ethanol is needed to produce 1 dm<sup>3</sup> of carbon dioxide at RTP when the ethanol undergoes fermentation?

14. Calculate the mass of:

i) zinc hydroxide

ii) aluminium hydroxide

iii) magnesium hydroxide

precipitated when 100 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> sodium hydroxide solution is added to separate 100 cm<sup>3</sup> portions of 0.25 mol dm<sup>-3</sup> solutions of zinc sulphate, aluminium sulphate, and magnesium sulphate.

15. What volume of carbon dioxide is produced when 1 g of calcium carbonate is treated with excess 1 mol dm<sup>-3</sup> hydrochloric acid? (All gas volumes measured at RTP.)

16. What mass of magnesium is needed to produce 100 cm<sup>3</sup> of hydrogen at RTP when treated with excess 1 mol dm<sup>-3</sup> hydrochloric acid?
17. What masses of sodium chloride and sodium chlorate(V) are produced when 10 g of sodium hydroxide reacts with excess chlorine?
18. What volumes of nitrogen and hydrogen, measured at RTP, are required to produce 1 tonne of ammonia?
19. What mass of nitric acid and what volume of oxygen (measured at RTP) can be obtained from 36 tonnes of ammonia?
20. What mass of calcium carbonate and what volume of 10 mol dm<sup>-3</sup> hydrochloric acid are required to produce 1 dm<sup>3</sup> of carbon dioxide at RTP?

### Exercise 9: Calculations based on equations involving only gases

#### Section (a)

Assuming all volumes are measured under the same conditions of temperature and pressure, calculate the volumes of gaseous reactants and products in the following:

1. The combustion of 10 cm<sup>3</sup> of methane, CH<sub>4</sub>.
2. The combustion of 10 cm<sup>3</sup> of ethane, C<sub>2</sub>H<sub>6</sub>.
3. The combustion of 10 cm<sup>3</sup> of propane, C<sub>3</sub>H<sub>8</sub>.
4. The combustion of 10 cm<sup>3</sup> of octane vapour, C<sub>8</sub>H<sub>18</sub>.
5. The synthesis of 20 cm<sup>3</sup> of ammonia, NH<sub>3</sub>, from nitrogen and hydrogen.

#### Section (b)

Assuming all volumes are measured at RTP unless otherwise stated:

1. What volume of oxygen is required to convert 1 dm<sup>3</sup> of nitrogen monoxide, NO, into nitrogen dioxide, NO<sub>2</sub>?
2. What volume of air (assume 20% oxygen by volume) is required to convert 100 cm<sup>3</sup> of sulphur dioxide into sulphur trioxide?
3. What volume of ammonia reacting with excess air (assume 20% oxygen by volume) will produce 2 dm<sup>3</sup> of nitrogen monoxide?
4. What volume of oxygen is required to burn completely 6.5 mol of methane?
5. What volume of hydrogen, measured at RTP, is required to reduce 8 g of copper(II) oxide to copper?
6. 10 cm<sup>3</sup> of carbon monoxide is mixed with 20 cm<sup>3</sup> of oxygen and ignited. What volume of gas remains?
7. 50 cm<sup>3</sup> of propane is mixed with 200 cm<sup>3</sup> of oxygen and ignited. What is the final volume of the gas mixture?
8. 50 cm<sup>3</sup> of methane is mixed with 50 cm<sup>3</sup> of oxygen and ignited. What is the final volume of the gas mixture?
9. 10 cm<sup>3</sup> of nitrogen is mixed with 50 cm<sup>3</sup> of hydrogen and a spark applied. Assuming all the nitrogen reacts, what volume of gas remains?
10. 10 cm<sup>3</sup> of hydrogen is mixed with 10 cm<sup>3</sup> of oxygen and ignited. What volume of gas remains?

### Exercise 10: Ionic Equations

Write the balanced ionic equations for the following reactions.

1.  $\text{Pb}^{2+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{Pb}(\text{OH})_2(\text{s})$
2.  $\text{Al}^{3+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{Al}(\text{OH})_3(\text{s})$

3.  $\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^-(\text{aq}) \rightarrow \text{AlO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
4.  $\text{Cl}_2(\text{g}) + \text{OH}^-(\text{aq}) \rightarrow \text{ClO}_3^-(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
5.  $\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + \text{I}^-(\text{aq})$
6.  $\text{Cu}^{2+}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$
7.  $\text{CO}_3^{2-}(\text{s}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
8.  $\text{Zn}(\text{s}) + \text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
9.  $\text{Zn}(\text{s}) + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Pb}(\text{s}) + \text{Zn}^{2+}(\text{aq})$
10.  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
11.  $\text{Mg}(\text{s}) + \text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
12.  $\text{CO}_3^{2-}(\text{s}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
13.  $\text{CuO}(\text{s}) + \text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
14.  $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$
15.  $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$
16.  $\text{Zn}(\text{s}) + \text{Ag}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Ag}(\text{s})$
17.  $\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
18.  $\text{KOH}(\text{aq}) + \text{HNO}_3(\text{aq}) \rightarrow \text{KNO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$
19.  $\text{NaOH}(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l})$
20.  $\text{KOH}(\text{aq}) + \text{CH}_3\text{CO}_2\text{H}(\text{aq}) \rightarrow \text{CH}_3\text{CO}_2\text{K}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

#### Exercise 11a: Calculations Based on Concentrations in Solution

Calculate the number of moles or mass based on the given concentrations and volumes.

1. Number of moles in 25 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> NaOH
2. Number of moles in 50 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> HCl
3. Number of moles in 25 cm<sup>3</sup> of 2.5 mol dm<sup>-3</sup> H<sub>2</sub>SO<sub>4</sub>
4. Number of moles in 10 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> NaCl
5. Number of moles in 100 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> KOH
6. Number of moles in 250 cm<sup>3</sup> of 0.1 mol dm<sup>-3</sup> NH<sub>3</sub>
7. Number of moles in 50 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> CaCl<sub>2</sub>
8. Number of moles in 20 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> AgNO<sub>3</sub>
9. Number of moles in 25 cm<sup>3</sup> of 0.05 mol dm<sup>-3</sup> KMnO<sub>4</sub>
10. Number of moles in 50 cm<sup>3</sup> of 0.1 mol dm<sup>-3</sup> CuSO<sub>4</sub>
11. Mass of solute in 25 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> NaCl
12. Mass of solute in 25 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> NaNO<sub>3</sub>

13. Mass of solute in 50 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> NaOH
14. Mass of solute in 10 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> AgNO<sub>3</sub>
15. Mass of solute in 100 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> Na<sub>2</sub>SO<sub>4</sub>
16. Mass of solute in 25 cm<sup>3</sup> of 0.4 mol dm<sup>-3</sup> H<sub>2</sub>SO<sub>4</sub>
17. Mass of solute in 20 cm<sup>3</sup> of 0.1 mol dm<sup>-3</sup> KMnO<sub>4</sub>
18. Mass of solute in 50 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> CuSO<sub>4</sub>
19. Mass of solute in 10 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> NH<sub>4</sub>Cl
20. Mass of solute in 25 cm<sup>3</sup> of 0.2 mol dm<sup>-3</sup> FeSO<sub>4</sub>
21. Concentration of a solution containing 2.0 g of NaOH in 100 cm<sup>3</sup>
22. Concentration of a solution containing 9.8 g of H<sub>2</sub>SO<sub>4</sub> in 100 cm<sup>3</sup>
23. Concentration of a solution containing 1.59 g of CuSO<sub>4</sub> in 100 cm<sup>3</sup>
24. Concentration of a solution containing 8.5 g of NaNO<sub>3</sub> in 100 cm<sup>3</sup>
25. Concentration of a solution containing 4.14 g of Pb(NO<sub>3</sub>)<sub>2</sub> in 100 cm<sup>3</sup>
26. Concentration of a solution containing 5.28 g of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> in 100 cm<sup>3</sup>
27. Concentration of a solution containing 16 g of NaOH in 100 cm<sup>3</sup>
28. Concentration of a solution containing 39.2 g of H<sub>2</sub>SO<sub>4</sub> in 100 cm<sup>3</sup>
29. Concentration of a solution containing 25 g of FeSO<sub>4</sub> in 100 cm<sup>3</sup>
30. Concentration of a solution containing 0.331 g of Pb(NO<sub>3</sub>)<sub>2</sub> in 100 cm<sup>3</sup>
31. Concentration of a solution containing 0.535 g of NH<sub>4</sub>Cl in 100 cm<sup>3</sup>
32. Concentration of a solution containing 10 g of H<sub>2</sub>SO<sub>4</sub> in 50 cm<sup>3</sup>
33. Concentration of a solution containing 2.12 g of Na<sub>2</sub>CO<sub>3</sub> in 100 cm<sup>3</sup>
34. Concentration of a solution containing 0.395 g of KMnO<sub>4</sub> in 50 cm<sup>3</sup>
35. Concentration of a solution containing 25 g of NaCl in 60 cm<sup>3</sup>

#### **Exercise 11b: Simple Volumetric Calculations**

**Perform the following volumetric calculations based on the given data.**

1. Concentration of a solution when 4.2 g of NaOH is dissolved in 100 cm<sup>3</sup>
2. Concentration of a solution when 6.8 g of Na<sub>2</sub>CO<sub>3</sub> is dissolved in 100 cm<sup>3</sup>
3. Concentration of a solution when 5.88 g of NaCl is dissolved in 100 cm<sup>3</sup>
4. Concentration of a solution when 9.8 g of H<sub>2</sub>SO<sub>4</sub> is dissolved in 25 cm<sup>3</sup>
5. Concentration of a solution when 6.0 g of NaOH is dissolved in 100 cm<sup>3</sup>
6. Concentration of a solution when 4.0 g of NaOH is dissolved in 100 cm<sup>3</sup>
7. Concentration of a solution when 0.4 g of NaOH is dissolved in 100 cm<sup>3</sup>

8. Concentration of a solution when 0.535 g of  $\text{NH}_4\text{Cl}$  is dissolved in  $100 \text{ cm}^3$
9. Concentration of a solution when 13.25 g of  $(\text{NH}_4)_2\text{SO}_4$  is dissolved in  $100 \text{ cm}^3$
10. Concentration of a solution when 39.2 g of  $\text{H}_2\text{SO}_4$  is dissolved in  $100 \text{ cm}^3$
11. Concentration of a solution when 8.5 g of  $\text{NaNO}_3$  is dissolved in  $100 \text{ cm}^3$
12. Concentration of a solution when 25 g of  $\text{NaCl}$  is dissolved in  $100 \text{ cm}^3$
13. Concentration of a solution when 5.65 g of  $\text{Na}_2\text{CO}_3$  is dissolved in  $100 \text{ cm}^3$
14. Concentration of a solution when 4.95 g of  $\text{CuSO}_4$  is dissolved in  $100 \text{ cm}^3$
15. Concentration of a solution when 8.775 g of  $\text{Na}_2\text{SO}_4$  is dissolved in  $100 \text{ cm}^3$
16. pH of a solution with a hydrogen ion concentration of  $0.001 \text{ mol dm}^{-3}$
17. Concentration of a solution when  $25 \text{ cm}^3$  of  $0.1 \text{ mol dm}^{-3}$   $\text{NaOH}$  reacts with  $25 \text{ cm}^3$  of  $\text{HCl}$
18. Volume of  $0.1 \text{ mol dm}^{-3}$   $\text{HCl}$  required to neutralize  $25 \text{ cm}^3$  of  $0.2 \text{ mol dm}^{-3}$   $\text{NaOH}$
19. Volume of  $0.5 \text{ mol dm}^{-3}$   $\text{H}_2\text{SO}_4$  required to neutralize  $100 \text{ cm}^3$  of  $0.25 \text{ mol dm}^{-3}$   $\text{NaOH}$
20. Volume of  $0.2 \text{ mol dm}^{-3}$   $\text{NaOH}$  required to neutralize  $25 \text{ cm}^3$  of  $0.2 \text{ mol dm}^{-3}$   $\text{HCl}$
21. Mass of  $\text{NaCl}$  produced when  $25 \text{ cm}^3$  of  $0.1 \text{ mol dm}^{-3}$   $\text{NaOH}$  reacts with excess  $\text{HCl}$
22. Mass of  $\text{CaCO}_3$  required to produce  $100 \text{ cm}^3$  of  $\text{CO}_2$  at STP when reacted with excess  $\text{HCl}$
23. Volume of  $\text{CO}_2$  produced at STP when 1.0 g of  $\text{CaCO}_3$  reacts with excess  $\text{HCl}$
24. Mass of  $\text{Mg}$  and volume of  $\text{H}_2$  produced at STP when  $25 \text{ cm}^3$  of  $0.2 \text{ mol dm}^{-3}$   $\text{HCl}$  reacts with excess  $\text{Mg}$
25. Volume of  $\text{H}_2$  produced at STP when 0.48 g of  $\text{Mg}$  reacts with excess  $\text{HCl}$

## **PART 02- Answers from the Original Document**

### Exercise 1

**1**	18	**21**	111	**41**	159.5
**2**	44	**22**	164	**42**	161.4
**3**	17	**23**	74	**43**	170
**4**	46	**24**	136	**44**	53.5
**5**	28	**25**	208	**45**	132
**6**	64	**26**	1335	**46**	117.0
**7**	80	**27**	213	**47**	122.5
**8**	81	**28**	342	**48**	166.0
**9**	98	**29**	152	**49**	74.5
**10**	63	**30**	127	**50**	69.0

\*\*11\*\*	58.5	\*\*31\*\*	162.5	\*\*51\*\*	249.5
\*\*12\*\*	85	\*\*32\*\*	400	\*\*52\*\*	278
\*\*13\*\*	106	\*\*33\*\*	223	\*\*53\*\*	964
\*\*14\*\*	40	\*\*34\*\*	239	\*\*54\*\*	248
\*\*15\*\*	142	\*\*35\*\*	685	\*\*55\*\*	126
\*\*16\*\*	158	\*\*36\*\*	331	\*\*56\*\*	246
\*\*17\*\*	194	\*\*37\*\*	278	\*\*57\*\*	2635
\*\*18\*\*	100	\*\*38\*\*	303	\*\*58\*\*	60
\*\*19\*\*	166	\*\*39\*\*	99.0	\*\*59\*\*	58
\*\*20\*\*	195	\*\*40\*\*	134.5	\*\*60\*\*	122

## Exercise 2

1	NaCl	21	BaSO<sub>4</sub>	41	PbCO<sub>3</sub>	61	PCl<sub>3</sub>
2	NaOH	22	AlCl<sub>3</sub>	42	PbO	62	PCl<sub>5</sub>
3	Na<sub>2</sub>CO<sub>3</sub>	23	Al<sub>2</sub>O<sub>3</sub>	43	PbO<sub>2</sub>	63	P<sub>2</sub>O<sub>3</sub>
4	Na<sub>2</sub>SO<sub>4</sub>	24	Al(OH)<sub>3</sub>	44	PbCl<sub>2</sub>	64	P<sub>2</sub>O<sub>5</sub>
5	Na<sub>3</sub>PO<sub>4</sub>	25	Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>	45	PbCl<sub>4</sub>	65	H<sub>3</sub>PO<sub>4</sub>
6	KCl	26	CuSO<sub>4</sub>	46	PbS	66	H<sub>2</sub>SO<sub>4</sub>
7	KBr	27	CuO	47	SnCl<sub>2</sub>	67	HNO<sub>3</sub>
8	KI	28	CuCl<sub>2</sub>	48	SnCl<sub>4</sub>	68	HCl
9	KHCO<sub>3</sub>	29	Cu(NO<sub>3</sub>)<sub>2</sub>	49	FeSO<sub>4</sub>	69	CCl<sub>4</sub>
10	KNO<sub>2</sub>	30	Cu<sub>2</sub>O	50	FeCl<sub>2</sub>	70	SiCl<sub>4</sub>
11	MgCl<sub>2</sub>	31	CuCl	51	Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>	71	SiO<sub>2</sub>
12	Mg(NO<sub>3</sub>)<sub>2</sub>	32	Zn(NO<sub>3</sub>)<sub>2</sub>	52	FeCl<sub>3</sub>	72	SO<sub>2</sub>
13	Mg(OH)<sub>2</sub>	33	ZnCO<sub>3</sub>	53	Fe(OH)<sub>3</sub>	73	SO<sub>3</sub>
14	MgO	34	ZnO	54	Fe(OH)<sub>2</sub>	74	H<sub>2</sub>S
15	MgCO<sub>3</sub>	35	AgCl	55	NH<sub>4</sub>Cl	75	Cl<sub>2</sub>O
16	CaO	36	AgBr	56	(NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>	76	NO<sub>2</sub>
17	CaCl<sub>2</sub>	37	AgI	57	NH<sub>4</sub>OH	77	NO
18	CaSO<sub>4</sub>	38	AgNO<sub>3</sub>	58	NH<sub>4</sub>NO<sub>3</sub>	78	CO<sub>2</sub>
19	CaCO<sub>3</sub>	39	Ag<sub>2</sub>O	59	(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>	79	CO
20	BaCl<sub>2</sub>	40	Pb(NO<sub>3</sub>)<sub>2</sub>	60	(NH<sub>4</sub>)<sub>3</sub>PO<sub>4</sub>	80	HOH / H<sub>2</sub>O

### Exercise 3

1. Water
2. Carbon dioxide
3. Ammonia
4. Oxygen
5. Hydrogen
6. Sulphur dioxide (or sulphur(IV) oxide)
7. Sulphur trioxide (or sulphur(VI) oxide)
8. Hydrogen chloride
9. Hydrogen iodide
10. Hydrogen fluoride
11. Methane
12. Hydrogen sulphide
13. Hydrogen bromide
14. Sulphuric acid
15. Nitric acid
16. Sodium chloride
17. Sodium nitrate
18. Sodium carbonate
19. Sodium hydroxide
20. Sodium sulphate
21. Calcium chloride
22. Calcium nitrate
23. Calcium hydroxide
24. Calcium sulphate
25. Barium chloride
26. Aluminium chloride
27. Aluminium nitrate
28. Aluminium sulphate
29. Iron(II) sulphate
30. Iron(II) chloride

31. Iron(III) chloride
32. Iron(III) sulphate
33. Lead(II) oxide
34. Lead(IV) oxide
35. Lead(II) nitrate
36. Lead(II) chloride
37. Lead(II) sulphate
38. Copper(II) nitrate
39. Copper(I) chloride
40. Copper(II) chloride
41. Copper(II) sulphate
42. Zinc chloride
43. Silver nitrate
44. Ammonium chloride
45. Ammonium sulphate
46. Ammonium vanadate(V)
47. Potassium chlorate(V)
48. Potassium iodate
49. Sodium chlorate(I)
50. Sodium nitrite
51. Ethane
52. Butane
53. Octane
54. Ammonium carbonate
55. Potassium manganate(VII)
56. Potassium chromate(VI)
57. Potassium hydrogencarbonate
58. Potassium iodide
59. Cobalt(II) nitrate
60. Potassium astatide

#### **Exercise 4a**

1	0.50	26	0.10
2	2.0	27	0.10
3	0.10	28	0.0085
4	5.0	29	0.26
5	20	30	0.104
6	0.010	31	0.20
7	1.0	32	0.082
8	0.22	33	0.050
9	0.0010	34	1.34
10	0.050	35	0.025
11	0.33	36	0.204
12	0.25	37	0.071
13	0.021	38	0.010
14	0.020	39	0.050
15	0.125	40	0.254
16	0.020	41	0.0125
17	0.167	42	0.152
18	1.0	43	0.10
19	0.046	44	0.053
20	0.020	45	0.0043
21	0.0010	46	0.036
22	0.25	47	0.266
23	0.02	48	0.024
24	0.0025	49	0.025
25	0.20	50	1.574

**Exercise 4b**

1	36 g	26	14.95 g
2	132 g	27	76.2 g
3	47.6 g	28	10.03 g
4	23 g	29	17.82 g
5	33.6 g	30	145.2 g
6	40.96 g	31	2.925 g

7	240 g	32	12.25 g
8	81 g	33	21.4 g
9	1.152 g	34	745 g
10	9.45 g	35	0.069 g
11	26.3 g	36	49.9 g
12	59.5 g	37	27.8 g
13	11.66 g	38	4.82 g
14	80.0 g	39	9.92 g
15	127.8 g	40	302.4 g
16	7.9 g	41	756.5 g
17	34.92 g	42	39.53 g
18	90 g	43	10.2 g
19	249 g	44	11.6 g
20	23.4 g	45	9.76 g
21	12.2 g	46	4.34 g
22	672.4 g	47	9.59 g
23	0.296 g	48	41.0 g
24	13.6 g	49	304 g
25	43.68 g	50	1397 g

#### **Exercise 4c**

1	24000 cm<sup>3</sup>	11	134.4 cm<sup>3</sup>
2	2400 cm<sup>3</sup>	12	216 cm<sup>3</sup>
3	12000 cm<sup>3</sup>	13	960 cm<sup>3</sup>
4	48000 cm<sup>3</sup>	14	2952 cm<sup>3</sup>
5	2880 cm<sup>3</sup>	15	55.2 cm<sup>3</sup>
6	81600 cm<sup>3</sup>	16	192000 cm<sup>3</sup>
7	2640 cm<sup>3</sup>	17	0.24 cm<sup>3</sup>
8	96 cm<sup>3</sup>	18	144000 cm<sup>3</sup>
9	240000 cm<sup>3</sup>	19	182.4 cm<sup>3</sup>
10	10800 cm<sup>3</sup>	20	72000 cm<sup>3</sup>

#### **Exercise 4d**

| 1 | 0.0083 mol | 11 | 0.0292 mol |

2	0.0208 mol	12	0.2333 mol
3	0.0416 mol	13	0.0917 mol
4	0.0533 mol	14	0.0088 mol
5	0.0098 mol	15	0.0333 mol
6	0.0094 mol	16	0.0033 mol
7	0.0106 mol	17	0.000080 mol
8	0.0033 mol	18	0.8333 mol
9	0.0833 mol	19	0.0175 mol
10	0.10 mol	20	0.0375 mol

#### **Exercise 4e**

1	0.367 g	11	0.875 g
2	0.354 g	12	10.27 g
3	1.166 g	13	2.38 g
4	5.333 g	14	0.263 g
5	0.78 g	15	1.217 g
6	0.763 g	16	0.270 g
7	0.757 g	17	0.011 g
8	0.233 g	18	38.33 g
9	0.167 g	19	0.683 g
10	3.20 g	20	1.05 g

#### **Exercise 4f**

1	1091 cm<sup>3</sup>	11	56000 cm<sup>3</sup>
2	7059 cm<sup>3</sup>	12	30545 cm<sup>3</sup>
3	8571 cm<sup>3</sup>	13	20308 cm<sup>3</sup>
4	7500 cm<sup>3</sup>	14	16000 cm<sup>3</sup>
5	702 cm<sup>3</sup>	15	5260 cm<sup>3</sup>
6	670 cm<sup>3</sup>	16	2370 cm<sup>3</sup>
7	3380 cm<sup>3</sup>	17	375 cm<sup>3</sup>
8	30000 cm<sup>3</sup>	18	12000 cm<sup>3</sup>
9	2400000 cm<sup>3</sup>	19	26526 cm<sup>3</sup>
10	180000 cm<sup>3</sup>	20	77143 cm<sup>3</sup>

**Exercise 4g**

- | 1 | 160 | 11 | 34 |
- | 2 | 64 | 12 | 17 |
- | 3 | 80 | 13 | 38 |
- | 4 | 71 | 14 | 28 |
- | 5 | 2.0 | 15 | 44 |
- | 6 | 28 | 16 | 32 |
- | 7 | 30 | 17 | 211 |
- | 8 | 58 | 18 | 36.5 |
- | 9 | 32 | 19 | 81 |
- | 10 | 28 | 20 | 128 |

**Exercise 5****Section (a)**

1.  $\text{CaCO}_3$
2.  $\text{Na}_2\text{SO}_4$
3.  $\text{Na}_2\text{S}_2\text{O}_3$
4.  $\text{PbO}$
5.  $\text{Pb}_3\text{O}_4$
6.  $\text{H}_3\text{PO}_3$
7.  $\text{H}_2\text{SO}_3$
8.  $\text{CH}_4$
9.  $\text{C}_3\text{H}_8$
10. HO (giving  $\text{H}_2\text{O}_2$ )
11.  $\text{H}_4\text{N}_2\text{O}_3$  ( $\text{NH}_4\text{NO}_3$ )
12.  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  ( $\text{FeSO}_{11}\text{H}_{14}$ )

**Section (b)**

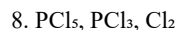
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2.  $\text{C}_3\text{H}_6$
3.  $\text{P}_2\text{I}_4$
4.  $\text{N}_2\text{H}_4\text{S}_2\text{O}_8$
5.  $\text{P}_4\text{O}_{10}$
6.  $\text{C}_2\text{H}_4\text{O}_2$  ( $\text{CH}_3\text{COOH}$ )



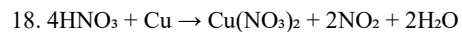
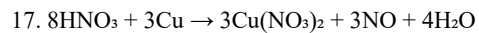
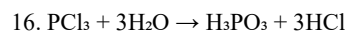
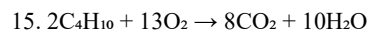
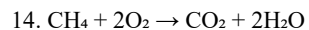
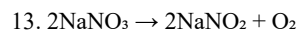
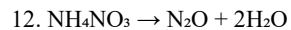
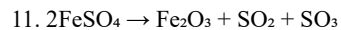
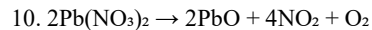
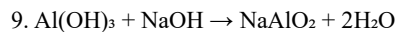
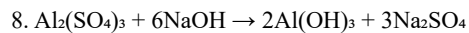
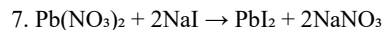
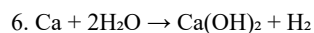
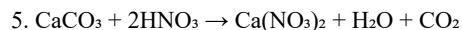
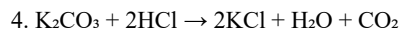
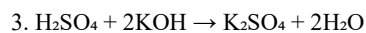
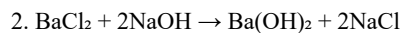
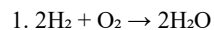
**Section (c)**



6. Yes



**Exercise 6a**



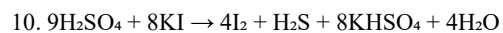
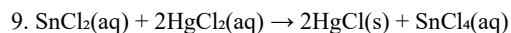
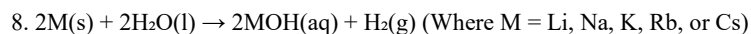
19.  $\text{H}_3\text{PO}_4 + \text{NaOH} \rightarrow \text{NaH}_2\text{PO}_4 + \text{H}_2\text{O}$
20.  $\text{H}_3\text{PO}_4 + 3\text{NaOH} \rightarrow \text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O}$
21.  $\text{H}_3\text{PO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{HPO}_4 + 2\text{H}_2\text{O}$
22.  $6\text{NaOH} + 3\text{Cl}_2 \rightarrow \text{NaClO}_3 + 5\text{NaCl} + 3\text{H}_2\text{O}$
23.  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$
24.  $2\text{NaBr} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HBr}$
25.  $2\text{HBr} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{SO}_2 + \text{Br}_2$
26.  $3\text{C}_2\text{H}_5\text{OH} + \text{PCl}_3 \rightarrow 3\text{C}_2\text{H}_5\text{Cl} + \text{H}_3\text{PO}_3$
27.  $\text{Fe}_3\text{O}_4 + 4\text{H}_2 \rightarrow 3\text{Fe} + 4\text{H}_2\text{O}$
28.  $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
29.  $\text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{CO}_2\text{H} \rightarrow \text{CH}_3\text{CO}_2\text{C}_2\text{H}_5 + \text{H}_2\text{O}$
30.  $2\text{KMnO}_4 + 16\text{HCl} \rightarrow 2\text{KCl} + 2\text{MnCl}_2 + 8\text{H}_2\text{O} + 5\text{Cl}_2$

#### Exercise 6b

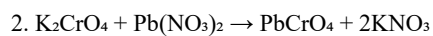
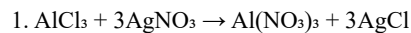
1. Hydrogen is not H but  $\text{H}_2$ , which gives:  $2\text{Na(s)} + 2\text{H}_2\text{O(aq)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$
2. Since the valency of lead is 2 not 1, lead nitrate is not  $\text{PbNO}_3$  but  $\text{Pb(NO}_3)_2$  and also lead chloride is  $\text{PbCl}_2$ :  $\text{Pb(NO}_3)_2\text{(aq)} + 2\text{NaCl(aq)} \rightarrow \text{PbCl}_2\text{(s)} + 2\text{NaNO}_3\text{(aq)}$
3. Calcium hydroxide is  $\text{Ca(OH)}_2$ :  $\text{Ca(OH)}_2\text{(aq)} + 2\text{HCl(aq)} \rightarrow \text{CaCl}_2\text{(aq)} + 2\text{H}_2\text{O(l)}$
4. This does not balance:  $\text{C}_2\text{H}_4\text{(g)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)}$
5. A magnesium compound cannot give a calcium compound!
6. Ozone  $\text{O}_3$  is not produced by heating a nitrate,  $\text{O}_2$  is:  $2\text{Cu(NO}_3)_2\text{(s)} \rightarrow 2\text{CuO(s)} + 4\text{NO}_2\text{(g)} + \text{O}_2\text{(g)}$
7. This reaction does not take place and so no equation can be written.
8. Aluminium has a valency of 3 not 2 as in this equation:  $\text{AlCl}_3\text{(s)} + 3\text{KOH(aq)} \rightarrow \text{Al(OH)}_3\text{(s)} + 3\text{KCl(aq)}$
9. Sodium has a valency of 1 not 2 as in this equation:  $\text{Na}_2\text{CO}_3\text{(s)} + 2\text{HCl(aq)} \rightarrow 2\text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$
10. Silver chloride is not soluble in water. Thus the  $\text{AgCl}$  needs a (s) symbol:  $\text{AgNO}_3\text{(aq)} + \text{NaCl(aq)} \rightarrow \text{AgCl(s)} + \text{NaNO}_3\text{(aq)}$

#### Exercise 6c

1.  $\text{Zn(s)} + \text{CuSO}_4\text{(aq)} \rightarrow \text{Cu(s)} + \text{ZnSO}_4\text{(aq)}$
2.  $\text{Ca(OH)}_2\text{(s)} + 2\text{NH}_4\text{Cl(s)} \rightarrow \text{CaCl}_2\text{(s)} + 2\text{H}_2\text{O(g)} + 2\text{NH}_3\text{(g)}$
3.  $2\text{Pb(NO}_3)_2\text{(s)} \rightarrow 2\text{PbO(s)} + 4\text{NO}_2\text{(g)} + \text{O}_2\text{(g)}$
4.  $\text{SiCl}_4\text{(l)} + 2\text{H}_2\text{O(l)} \rightarrow \text{SiO}_2\text{(s)} + 4\text{HCl(g)}$
5.  $\text{Ca(HCO}_3)_2\text{(aq)} \rightarrow \text{CaCO}_3\text{(s)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$
6.  $2\text{C}_8\text{H}_{18}\text{(g)} + 25\text{O}_2\text{(g)} \rightarrow 16\text{CO}_2\text{(g)} + 18\text{H}_2\text{O(l)}$
7.  $6\text{NaOH(aq)} + 3\text{Cl}_2\text{(g)} \rightarrow \text{NaClO}_3\text{(aq)} + 5\text{NaCl(aq)} + 3\text{H}_2\text{O(l)}$   
 $6\text{NaOH(aq)} + 3\text{Br}_2\text{(g)} \rightarrow \text{NaBrO}_3\text{(aq)} + 5\text{NaBr(aq)} + 3\text{H}_2\text{O(l)}$

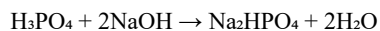
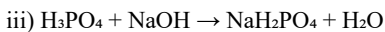


#### Exercise 7



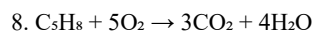
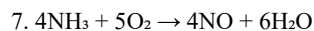
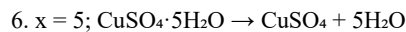
4. i) 1 mole

ii) 2 moles

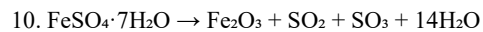


iv)  $75 \text{ cm}^3$

5.  $x = 3$



9. It is



#### Exercise 8

1. 11.2 g

2. 21.6 g

3. 0.682 g of ethanoic acid and 0.523 g of ethanol

4. 143 tonnes

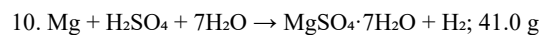
5. 14.5 g

6. 8.0 g of sodium hydroxide, 9.75 g of copper hydroxide

7.  $12000 \text{ cm}^3$

8. 54.7 g of calcium nitrate,  $8.0 \text{ dm}^3$  of carbon dioxide

9.  $6 \text{ dm}^3$  total ( $4.8 \text{ dm}^3$  of nitrogen dioxide and  $1.2 \text{ dm}^3$  of oxygen)



11. 31.9 g

12. 324.3 g

13. 5.11 g of ethanol, 2.67 dm<sup>3</sup> of carbon dioxide
14. (i) 12.30 g of zinc hydroxide  
(ii) 9.12 g of aluminium hydroxide  
(iii) 9.67 g of magnesium hydroxide
15. 0.600 dm<sup>3</sup>
16. 0.100 g
17. 2.94 g of sodium chloride, 1.065 g of sodium chlorate(V)
18.  $4.15 \times 10^6$  dm<sup>3</sup> of nitrogen,  $12.5 \times 10^6$  dm<sup>3</sup> of hydrogen
19. 63 tonnes of nitric acid,  $4.8 \times 10^7$  dm<sup>3</sup> of oxygen
20. 2198 g of calcium carbonate, 4.395 dm<sup>3</sup> of 10 M HCl

### Exercise 9

#### Section (a)

1. 20 cm<sup>3</sup> O<sub>2</sub>, 10 cm<sup>3</sup> CO<sub>2</sub>, 20 cm<sup>3</sup> H<sub>2</sub>O(g)
2. 30 cm<sup>3</sup> O<sub>2</sub>, 20 cm<sup>3</sup> CO<sub>2</sub>, 20 cm<sup>3</sup> H<sub>2</sub>O(g)
3. 25 cm<sup>3</sup> O<sub>2</sub>, 20 cm<sup>3</sup> CO<sub>2</sub>, 10 cm<sup>3</sup> H<sub>2</sub>O(g)
4. 125 cm<sup>3</sup> O<sub>2</sub>, 80 cm<sup>3</sup> CO<sub>2</sub>, 90 cm<sup>3</sup> H<sub>2</sub>O(g)
5. 30 cm<sup>3</sup> H<sub>2</sub>, 20 cm<sup>3</sup> NH<sub>3</sub>

#### Section (b)

1. 500 cm<sup>3</sup> O<sub>2</sub> ( $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ )
2. 375 cm<sup>3</sup> air ( $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$ )
3. 2500 cm<sup>3</sup> NH<sub>3</sub> needed,  $\frac{5}{4} \times 2500 = 3125$  cm<sup>3</sup> O<sub>2</sub>  $\rightarrow$  15625 cm<sup>3</sup> air
4.  $6.5 \times 24000$  cm<sup>3</sup> = 156 m<sup>3</sup>
5. 24000 cm<sup>3</sup>
6. Final volume = 20 cm<sup>3</sup> (10 cm<sup>3</sup> CO<sub>2</sub> + 10 cm<sup>3</sup> unused O<sub>2</sub>)
7. Final volume = 77.5 cm<sup>3</sup> (40 cm<sup>3</sup> CO<sub>2</sub> + 37.5 cm<sup>3</sup> unused O<sub>2</sub>)
8. This time the CH<sub>4</sub> is in excess. We must assume that CO<sub>2</sub> is produced (not CO or C)! Final volume = 60 cm<sup>3</sup> (30 cm<sup>3</sup> CO<sub>2</sub> + 30 cm<sup>3</sup> CH<sub>4</sub>)
9.  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ ; 10 cm<sup>3</sup>, 30 cm<sup>3</sup>, 20 cm<sup>3</sup> + 30 cm<sup>3</sup> excess; 20 cm<sup>3</sup> NH<sub>3</sub> produced + 30 cm<sup>3</sup> excess H<sub>2</sub>
10.  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ ; 10 cm<sup>3</sup>, 5 cm<sup>3</sup> + 5 cm<sup>3</sup> excess; Final volume = 5 cm<sup>3</sup> (all excess O<sub>2</sub>)

### Exercise 10

1.  $\text{Pb}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Pb}(\text{OH})_2(\text{s})$
2.  $\text{Al}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Al}(\text{OH})_3(\text{s})$

3.  $\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^-(\text{aq}) \rightarrow \text{AlO}_2^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
4.  $\text{Cl}_2(\text{g}) + 6\text{OH}^-(\text{aq}) \rightarrow \text{ClO}_3^-(\text{aq}) + 5\text{Cl}^-(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$
5.  $2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^-(\text{aq})$
6.  $\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$
7.  $\text{CO}_3^{2-}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
8.  $\text{Zn}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
9.  $\text{Zn}(\text{s}) + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Pb}(\text{s}) + \text{Zn}^{2+}(\text{aq})$
10.  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
11.  $\text{Mg}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
12.  $\text{CO}_3^{2-}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
13.  $\text{CuO}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
14.  $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$
15.  $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$
16.  $\text{Zn}(\text{s}) + 2\text{Ag}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{Ag}(\text{s})$
- 17–20.  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$  (In every case the reaction is the same)

#### Exercise 11a

- |                   |                                  |
|-------------------|----------------------------------|
| 1   0.025 moles   | 19   0.079 g                     |
| 2   0.025 moles   | 20   0.828 g                     |
| 3   0.0625 moles  | 21   0.1 mol dm <sup>-3</sup>    |
| 4   0.005 moles   | 22   1.0 mol dm <sup>-3</sup>    |
| 5   0.025 moles   | 23   0.03 mol dm <sup>-3</sup>   |
| 6   0.025 moles   | 24   0.1 mol dm <sup>-3</sup>    |
| 7   0.0125 moles  | 25   0.03 mol dm <sup>-3</sup>   |
| 8   0.01 moles    | 26   0.04 mol dm <sup>-3</sup>   |
| 9   0.00125 moles | 27   0.40 mol dm <sup>-3</sup>   |
| 10   0.005 moles  | 28   0.40 mol dm <sup>-3</sup>   |
| 11   0.9125 g     | 29   0.152 mol dm <sup>-3</sup>  |
| 12   1.463 g      | 30   0.0102 mol dm <sup>-3</sup> |
| 13   2 g          | 31   0.01 mol dm <sup>-3</sup>   |
| 14   1.70 g       | 32   0.2 mol dm <sup>-3</sup>    |
| 15   5.2 g        | 33   0.02 mol dm <sup>-3</sup>   |
| 16   0.98 g       | 34   0.005 mol dm <sup>-3</sup>  |

| 17 | 0.08 g | 35 | 0.417 mol dm<sup>-3</sup> |

| 18 | 0.97 g | | |

### Exercise 11b

| 1 | 0.168 mol dm<sup>-3</sup> | 16 | 3.0 |

| 2 | 0.136 mol dm<sup>-3</sup> | 17 | 0.02 mol dm<sup>-3</sup> |

| 3 | 0.118 mol dm<sup>-3</sup> | 18 | 50 cm<sup>3</sup> |

| 4 | 1.0 mol dm<sup>-3</sup> | 19 | 50 cm<sup>3</sup> |

| 5 | 0.12 mol dm<sup>-3</sup> | 20 | 25 cm<sup>3</sup> |

| 6 | 0.040 mol dm<sup>-3</sup> | 21 | 0.359 g |

| 7 | 0.0080 mol dm<sup>-3</sup> | 22 | 1.0 g |

| 8 | 0.010 mol dm<sup>-3</sup> | 23 | 240 cm<sup>3</sup> |

| 9 | 0.10 mol dm<sup>-3</sup> | 24 | 0.12 g Mg, 120 cm<sup>3</sup> H<sub>2</sub> |

| 10 | 0.40 mol dm<sup>-3</sup> | 25 | 480 cm<sup>3</sup> |

| 11 | 0.050 mol dm<sup>-3</sup> | |

| 12 | 0.167 mol dm<sup>-3</sup> | |

| 13 | 2.26 g dm<sup>-3</sup> | |

| 14 | 0.099 mol dm<sup>-3</sup> | |

| 15 | 1.755 g dm<sup>-3</sup> | |

### Table of Relative Atomic Masses Extracted from the Document

Element	Symbol	Ar	Element	Symbol	Ar	Element	Symbol	Ar
Hydrogen	H	1	Sodium	Na	23	Iron	Fe	55.8*
Carbon	C	12	Magnesium	Mg	24	Copper	Cu	63.5
Nitrogen	N	14	Aluminium	Al	27	Zinc	Zn	65.4*
Oxygen	O	16	Silicon	Si	28	Silver	Ag	108*
Fluorine	F	19*	Phosphorus	P	31	Iodine	I	127*
Chlorine	Cl	35.5	Sulphur	S	32	Cesium	Cs	133*
Potassium	K	39	Calcium	Ca	40	Barium	Ba	137*
Cobalt	Co	59*	Manganese	Mn	55*	Lead	Pb	207

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