PART 01:

Group 1: Writing and Balancing Chemical Equations

1. Write the chemical equations for these reactions:
   (a) Hydrogen reacts with copper oxide to form copper and water.
   (b) Carbon reacts with carbon dioxide to produce carbon monoxide.
   (c) Carbon combines with oxygen to yield carbon dioxide.
   (d) Magnesium reacts with sulfuric acid to produce hydrogen and magnesium sulfate.
   (e) Copper reacts with chlorine to form copper(II) chloride.

2. Write balanced chemical equations for the following reactions:
   (a) Calcium reacts with water to produce hydrogen and calcium hydroxide solution.
   (b) Copper combines with oxygen to form copper(II) oxide.
   (c) Sodium reacts with oxygen to produce sodium oxide.
   (d) Iron reacts with hydrochloric acid to form iron(II) chloride solution and hydrogen.
   (e) Iron reacts with chlorine to produce iron(III) chloride.

3. Balance the following chemical equations:
   (a) $Na_2O(s) + H_2O(l) \rightarrow NaOH(aq)$
   (b) $KClO_3(s) \rightarrow KCl(s) + O_2(g)$
   (c) $H_2O_2(aq) \rightarrow H_2O(l) + O_2(g)$
   (d) $Fe(s) + O_2(g) \rightarrow Fe_3O_4(s)$
   (e) $Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$
   (f) $NH_3(g) + O_2(g) \rightarrow N_2(g) + H_2O(g)$
   (g) $Fe(s) + H_2O(g) \rightarrow Fe_3O_4(s) + H_2(g)$
   (h) $H_2S(g) + O_2(g) \rightarrow H_2O(g) + SO_2(g)$
   (i) $H_2S(g) + SO_2(g) \rightarrow H_2O(l) + S(s)$

Group 2: Relative Formula Mass Calculations

1. Determine the relative formula masses of these compounds:
   (a) $Mg(OH)_2$ (b) NaOH (c) KNO_3 (d) $MgCO_3$ (e) $PbCl_2$ (f) $MgCl_2$ (g) $Mg(NO_3)_2$ (h) $Zn(OH)_2$, (i)$ZnSO_4$ (j) H_2SO_4 (k) HNO_3 (l) $MgSO_4 \cdot 7H_2O$ (m) $CaSO_4$ (n) Pb_3O_4 (o) P_2O_5 (p) Na_2CO_3, (r)$Ca(OH)_2$ (s) $CuCO_3$ (t) $CuSO_4$ (u) $Ca(HCO_3)_2$ (v) $CuSO_4 \cdot 5H_2O$ (w) $Al_2(SO_4)_3$, (x) $Na_2CO_3 \cdot 10H_2O$ (y) $FeSO_4 \cdot 7H_2O$ (z) $KClO_3$

2. Find the relative formula masses of these compounds: carbon dioxide, sulfuric acid, hydrogen chloride, and sodium hydroxide. Then calculate:
   (a) The mass of 1 mole of carbon dioxide.
   (b) The mass of 1 mole of sulfuric acid.
   (c) The mass of 1 mole of hydrogen chloride.
   (d) The mass of 1 mole of sodium hydroxide.

3. Calculate the relative formula masses of these compounds and determine:
   (a) The mass of 1 mole of sodium chloride.
   (b) The mass of 0.5 mole of potassium hydroxide.
   (c) The mass of 4 moles of iron(II) chloride.
   (d) The mass of 2.5 moles of sodium carbonate.
   (e) The mass of 0.1 mole of zinc chloride.

4. 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^3 at s.t.p.
   (b) 8.0 g of gas B occupies 2.8 dm^3 at s.t.p.
   (c) 4.0 g of gas C occupies 560 cm^3 at s.t.p.
   (d) 1.0 g of gas D occupies 1.4 dm^3 at s.t.p.
   (e) 4.0 g of gas E occupies 3.2 dm^3 at s.t.p.
   (f) 1.7 g of gas F occupies 2.24 dm^3 at s.t.p.

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 ($KHCO_3$).

3. Find the percentage by mass of:
   (a) Nitrogen and oxygen in nitrogen monoxide (NO).
   (b) Carbon and hydrogen in ethane (C_2H_6).
   (c) Sodium, oxygen, and hydrogen in sodium hydroxide (NaOH).
   (d) Sulphur and oxygen in sulfur trioxide (SO_3).
   (e) Carbon and hydrogen in propyne (C_3H_4).

4. Determine the percentage by mass of:
   (a) Carbon and hydrogen in heptane (C_7H_{16}).
   (b) Magnesium and nitrogen in magnesium nitride (Mg_3N_2).
   (c) Calcium and bromine in calcium bromide ($CaBr_2$).

5. Calculate the percentage by mass of:
   (a) Carbon and hydrogen in pentene (C_5H_{10}).
   (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 ($H_2C_2O_4$).

6. Find the percentage by mass of:
   (a) Iron, sulfur, and oxygen in iron(III) sulphate.
   (b) Carbon, hydrogen, and oxygen in propanol (C_3H_7OH).
   (c) Carbon, hydrogen, and oxygen in ethanoic acid (CH_3COOH).

7. Determine the percentage of nitrogen in pure ammonium nitrate (NH_4NO_3).

8. Identify which compound has the largest percentage by mass of nitrogen:
   (a) Ammonium chloride (NH_4Cl)
   (b) Ammonium nitrate (NH_4NO_3)
   (c) Ammonium sulphate ($(NH_4)_2SO_4$)
   (d) Ammonia (NH_3)

9. If ammonium sulfate ($(NH_4)_2SO_4$) and sodium nitrate ($NaNO_3$) cost the same per ton, determine which is the cheaper source of nitrogen.

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

(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

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

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 $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(g)$, calculate the mass of copper obtained from:
(a) 79.5 g of copper(II) oxide
(b) 15.9 g of copper(II) oxide
Use 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.

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 $CuO(s) + C(s) \rightarrow Cu(s) + CO(g)$.
14. For the reaction $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$, 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 (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 $2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$.
17. Determine the mass of carbon dioxide produced from 15 g of calcium carbonate reacting with acid in the reaction $CaCO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + CaCl_2(aq) + H_2O(l)$.
18. Calculate the mass of sodium hydroxide needed to neutralize a solution containing 7.3 g of hydrogen chloride in the reaction $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$.
19. Find the mass of sodium sulfate formed when 49 g of sulfuric acid is neutralized by sodium hydroxide in the reaction $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$.
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 $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$.
22. Calculate the mass of sodium nitrate needed to produce 126 g of nitric acid in the reaction $NaNO_3(s) + H_2SO_4(l) \rightarrow HNO_3(l) + NaHSO_4(s)$.
23. Calculate the mass of copper(II) sulfate crystals ($CuSO_4 \cdot 5H_2O$) theoretically obtainable from 8.0 g of copper(II) oxide.
24. Determine the theoretical yield of hydrated zinc sulfate crystals ($ZnSO_4 \cdot 7H_2O$) 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 ($CuSO_4 \cdot 5H_2O$). (Cu = 64)
26. For the reaction $4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$, 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 ($C + O_2 \rightarrow CO_2$), 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 ($2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$) and loses 6.2 g, calculate the mass of each salt in the original mixture.

Group 7: Gas Volume Calculations

1. Calculate the volume of carbon dioxide (at s.t.p.) produced by combusting 12 g of carbon. Write the equation and determine:
   (a) Moles of CO_2 from 1 mole of carbon.
   (b) Volume of CO_2 from 1 mole of carbon.
   (c) Moles of carbon in 12 g.
   (d) Volume of CO_2 produced.

2. Determine the volume of hydrogen (at s.t.p.) produced when 12 g of magnesium reacts with excess acid. Write the equation and calculate:
   (a) Moles of H_2 from 1 mole of Mg.
   (b) Volume of H_2 from 1 mole.
   (c) Moles of Mg in 12 g.
   (d) Volume of H_2 produced.

3. 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:
   (a) Moles of H_2 from 1 mole of Zn.
   (b) Volume of H_2 from 1 mole.
   (c) Moles of Zn in 6.5 g.
   (d) Volume of H_2 produced.

4. Calculate the volume of carbon dioxide (at s.t.p.) produced by heating 10 g of calcium carbonate. Write the equation and determine:
   (a) Moles of CO_2 from 1 mole of $CaCO_3$.
   (b) Volume of CO_2 from 1 mole.
   (c) Moles of $CaCO_3$ in 10 g.
   (d) Volume of CO_2 produced.

5. Determine the volume of oxygen (at s.t.p.) needed for the complete combustion of 125 cm^3 of methane, and the volume of carbon dioxide produced. Write the equation and calculate:
   (a) Moles of O_2 per mole of CH_4.
   (b) Volumes of O_2 per volume of CH_4.
   (c) Volume of O_2 for 125 cm^3 of CH_4.
   (d) Moles of CO_2 per mole of CH_4.
   (e) Volumes of CO_2 per volume of CH_4.
   (f) Volume of CO_2 produced.

6. Calculate the volume of oxygen (at s.t.p.) reacting with 10 g of carbon and the volume of carbon dioxide formed.

7. For the reaction $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$, calculate the mass of marble needed to produce 10.00 g of CO_2 and the volume of CO_2 at s.t.p.

8. For $Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$, determine the mass of zinc needed to produce 100 g of hydrogen and the volume of H_2 at (a) s.t.p. and (b) room temperature and 1 atm.

9. For $PbO(s) + H_2(g) \rightarrow Pb(s) + H_2O(g)$, 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.

10. For $2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$, calculate the volume of oxygen (at s.t.p.) from decomposing 3.31 g of lead(II) nitrate.

11. For $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$, calculate the volume of oxygen (at s.t.p.) from decomposing 1.7 g of hydrogen peroxide.

12. For $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$, determine the mass of potassium chlorate(V) needed to produce 112 cm^3 of oxygen at s.t.p.

13. Calculate the volume of oxygen needed to convert 123 cm^3 of hydrogen into water via explosion.

14. For $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$, calculate the volume of oxygen (at s.t.p.) needed to combust 44 g of propane and the volume of CO_2 formed.

15. For $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$, calculate the volume of 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 cm^3 of propene (C_3H_6) to propane (C_3H_8).

17. Calculate the volume of carbon dioxide (at s.t.p.) from combusting 250 cm^3 of butane (C_4H_{10}) at s.t.p.

18. Calculate the volume of oxygen (at s.t.p.) from 50 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 $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$:
    (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 $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$:
    (a) Calculate the volume of oxygen used and CO_2 produced from burning 100 cm^3 of butane at room temperature and pressure (adjusted to original conditions).
    (b) Calculate (i) the number of molecules in 5600 cm^3 of hydrogen at s.t.p., and (ii) the number of atoms in 20 g of calcium. (1 mole = 22400 cm^3 at s.t.p.; Avogadro's constant = 6.02×10^{23})

22. For $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$, calculate the volume of residual gases after exploding 20 cm^3 of ethane with 100 cm^3 of oxygen, adjusted to original room temperature and pressure.

23. For $2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$, 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 $(NH_4)_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2NH_3 + 2H_2O$, calculate the volume of ammonia at room temperature and pressure from 0.1 mol of ammonium sulfate.

25. For $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$, calculate (a) the mass and (b) the volume at s.t.p. of CO_2 from decomposing 4.20 g of sodium hydrogencarbonate.

26. For $2Ag_2CO_3 \rightarrow 4Ag + 2CO_2 + O_2$, 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. (Ag = 108; 1 mole = 24 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

3. Find the empirical formulas of compounds formed when:
(a) 0.69 g sodium forms 0.93 g of sodium oxide
(b) 10.35 g lead forms 11.41 g of lead oxide
(c) 0.035 g nitrogen forms 0.115 g of nitrogen oxide
(d) 2.54 g copper forms 2.86 g of copper oxide
(e) 11.2 g iron forms 25.4 g of iron chloride
(f) 14.0 g iron combines with 26.6 g chlorine

4. Determine the empirical formulas of compounds formed when:
(a) 0.24 g carbon combines with 0.64 g oxygen
(b) 20.7 g lead forms 23.9 g of lead oxide
(c) 15.9 g copper combines with 17.7 g chlorine
(d) 6 g magnesium combines with 4 g oxygen
(e) 1.8 g magnesium forms 2.5 g of magnesium nitride
(f) 9 g aluminum forms 89 g of aluminum bromide

5. Calculate the empirical formulas of these hydrates:
(a) Magnesium sulfate crystals: 48.8% $MgSO_4$, 51.2% water
(b) Copper sulfate crystals: 63.9% $CuSO_4$, 36.1% water
(c) Chromium(III) nitrate crystals: 59.5% $Cr(NO_3)_3$, 40.5% water

6. Determine the empirical formulas of compounds with these compositions:
(a) 20% magnesium, 26.6% sulfur, 53.3% oxygen
(b) 35% nitrogen, 5% hydrogen, 60% oxygen
(c) 60% carbon, 13.3% hydrogen, 26.7% oxygen
(d) 40% carbon, 6.7% hydrogen, 53.3% oxygen

7. 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.

8. For 1.23 g of hydrated magnesium sulfate losing 0.63 g on heating, calculate the empirical formula of the crystals.

9. Butane has an empirical formula of C_2H_5 and a relative molecular mass of 58. Find its molecular formula and one possible structural formula. For benzene (empirical formula CH, $M_r = 78$), determine its molecular formula and a possible structural formula.

10. A hydrocarbon with 85.7% carbon and a relative molecular mass of 28: Calculate its empirical formula, (a) molecular formula, and (b) structural formula.

11. Two oxides of metal M ($A_r = 207$) contain 7.18% and 13.4% oxygen. Calculate their empirical formulas.

12. For 0.61 g of $BaCl_2 \cdot xH_2O$ losing water to leave 0.52 g of anhydrous $BaCl_2$, calculate the empirical formula of the crystals.

13. A hydrocarbon with 7.7% hydrogen: Calculate its empirical formula and suggest a structural formula.

14. For 4.17 g of a phosphorus chloride containing 3.55 g chlorine ($A_r(P) = 31$, $A_r(Cl) = 35.5$), find its empirical formula.

15. For an oxide (A) of chromium: (a) 5 g yields 2.6 g Cr on reduction ($A_r(Cr) = 52$, $A_r(O) = 16$); 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).

16. 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.

17. 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^3 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^3 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^3: Determine its molecular formula.

Group 9: Avogadro's Constant and Number of Particles

1. Using Avogadro's constant (6×10^{23} 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) 6×10^{23} atoms
   (b) 6×10^{20} atoms
3. Determine the mass of aluminum containing:
   (a) 2alie$\times 10^{23}$ atoms
   (b) 6×10^{20} atoms
4. Find the mass of carbon containing:
   (a) 6×10^{23} atoms
   (b) 2×10^{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 = 6×10^{23} particles, calculate:
   (a) The number of molecules in 3.4 g ammonia
   (b) The mass of copper deposited from $CuSO_4$ by 2×10^{23} electrons

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Group 10: Preparation of Compounds and Related Calculations

1. (a) Describe how to prepare dry hydrated copper(II) sulfate crystals ($CuSO_4 \cdot 5H_2O$) from copper(II) oxide and dilute sulfuric acid. Calculate the mass of crystals from 0.01 mole of CuO.
   (b) Describe what happens when the crystals are heated until no mass change occurs, and calculate the percentage change in mass.

2. (a) Describe how to prepare dry hydrated sodium sulfate crystals ($Na_2SO_4 \cdot 10H_2O$) from dilute sodium hydroxide and sulfuric acid.
   (b) Calculate the mass of crystals from 0.05 mole of NaOH.

3. (a) Describe how to prepare dry hydrated zinc sulfate crystals ($ZnSO_4 \cdot 7H_2O$) from zinc oxide and dilute sulfuric acid.
   (b) Calculate the mass of crystals from 0.05 mole of ZnO.
   (c) For 0.01 mole of $ZnSO_4$ crystals dissolved and treated with excess $BaCl_2$, describe observations, write the ionic equation, and calculate the mass of the dry solid product.

4. Describe how to prepare reasonably dry hydrated zinc sulfate crystals ($ZnSO_4 \cdot 7H_2O$) from zinc oxide, and calculate the theoretical yield from 4.05 g of ZnO.

5. (a) Draw a labeled diagram of an apparatus to determine the formula of water by reducing dry copper(II) oxide with dry hydrogen.
   (b) Using results (CuO before = 15.80 g, Cu after = 12.60 g, water collector before = 65.06 g, after = 68.66 g), determine the formula of water.
   (c) Suggest why early work deduced H and O relative atomic masses as 1 and 8.

Group 11: Electrolysis and Charge Calculations

1. Which requires the largest quantity of electricity for discharge at an electrode?
   (a) 1 mole of Zn^{2+}
   (b) 2 moles of Fe^{3+}
   (c) 3 moles of OH^-
   (d) 4 moles of Cl^-
   (e) 5 moles of Ag^+

2. Calculate the number of coulombs required to liberate:
   (a) 54 g aluminum
   (b) 54 g silver
   (Faraday constant = 96500 coulombs/mole)

Group 12: Concentration and Titration Calculations

1. A sodium hydroxide solution contains 8.0 g dm^{-3}. 25.0 cm^3 of this neutralizes 35.0 cm^3 of nitric acid. Calculate:
   (a) Concentration of NaOH in mol dm^{-3}
   (b) Concentration of HNO_3 in mol dm^{-3}
   (c) Concentration of HNO_3 in g dm^{-3}

2. Calculate the volume of 1.5 mol dm^{-3} sulfuric acid needed to react with 7.95 g of copper(II) oxide.

3. For $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$, find the volume of 0.25 mol dm^{-3} HCl needed to neutralize the NaOH from 0.23 g of sodium.

4. In a titration, 25.0 cm^3 of HCl neutralizes 20.0 cm^3 of 0.25 mol dm^{-3} Na_2CO_3. Calculate:
   (a) Moles of Na_2CO_3 used
   (b) Moles of HCl used
   (c) Concentration of HCl in mol dm^{-3}

5. For 2.1 g of $NaHCO_3$ reacting with HCl, calculate the volume of 0.50 mol dm^{-3} HCl needed to liberate maximum CO_2, and the volume of CO_2 at s.t.p.

6. A solution of Na_2CO_3 contains 53.0 g in 250 cm^3. Calculate:
   (a) Concentration in mol dm^{-3}
   (b) Volume of 0.25 mol dm^{-3} HCl needed to neutralize 25.0 cm^3 of the solution

PART 02

Exercise 1:

Calculation of the Molar Mass of Compounds

Calculate the molar mass of the following compounds

1. H_2O

2. CO_2

3. NH_3

4. C_2H_5OH

5. C_2H_4

6. SO_2

7. SO_3

8. HBr

9. H_2SO_4

10. HNO_3

11. NaCl

12. $NaNO_3$

13. Na_2CO_3

14. NaOH

15. Na_2SO_4

16. $KMnO_4$

17. K_2CrO_4

18. $KHCO_3$

19. KI

20. $CsNO_3$

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_3O_4

36. $Pb(NO_3)_2$

37. $PbCl_2$

38. $PbSO_4$

39. $CuCl$

40. $CuCl_2$

41. $CuSO_4$

42. $ZnCl_2$

43. $AgNO_3$

44. NH_4Cl

45. $(NH_4)_2SO_4$

46. NH_4VO_3

47. $KClO_3$

48. KIO_3

49. $NaClO$

50. $NaNO_2$

51. $CuSO_4 \cdot 5H_2O$

52. $FeSO_4 \cdot 7H_2O$

53. $(NH_4)_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$

54. $Na_2S_2O_3 \cdot 5H_2O$

55. $(COOH)_2 \cdot 2H_2O$

56. $MgSO_4 \cdot 7H_2O$

57. $Cu(NH_3)_4SO_4 \cdot 2H_2O$

58. CH_3CO_2H

59. CH_3COCH_3

60. $C_6H_5CO_2H$

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. H_2O

2. CO_2

3. 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. $PbCl_2$

37. $PbSO_4$

38. $Cu(NO_3)_2$

39. $CuCl$

40. $CuCl_2$

41. $CuSO_4$

42. $ZnCl_2$

43. $AgNO_3$

44. NH_4Cl

45. $(NH_4)_2SO_4$

46. NH_4VO_3

47. $KClO_3$

48. KIO_3

49. $NaClO$

50. $NaNO_2$

51. C_2H_6

52. C_4H_{10}

53. C_8H_{18}

54. $(NH_4)_2CO_3$

55. $KMnO_4$

56. K_2CrO_4

57. $KHCO_3$

58. KI

59. $Co(NO_3)_2$

60. 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 H_2O

2. 88 g of CO_2

3. 1.7 g of NH_3

4. 230 g of C_2H_5OH

5. 560 g of C_2H_4

6. 0.64 g of SO_2

7. 80 g of SO_3

8. 17.82 g of HBr

9. 0.098 g of H_2SO_4

10. 3.15 g of HNO_3

11. 19.305 g of NaCl

12. 21.25 g of $NaNO_3$

13. 2.226 g of Na_2CO_3

14. 0.8 g of NaOH

15. 17.75 g of Na_2SO_4

16. 3.16 g of $KMnO_4$

17. 32.478 g of K_2CrO_4

18. 2.0 g of $KHCO_3$

19. 3.32 g of KI

20. 3.9 g of $CsNO_3$

21. 0.111 g of $CaCl_2$

22. 41 g of $Ca(NO_3)_2$

23. 1.48 g of $Ca(OH)_2$

24. 0.34 g of $CaSO_4$

25. 41.6 g of $BaCl_2$

26. 20.8 g of $BaCl_2$

27. 13.35 g of $AlCl_3$

28. 1.811 g of $Al_2(SO_4)_3$

29. 39.52 g of $FeSO_4$

30. 13.208 g of $FeCl_2$

31. 32.5 g of $FeCl_3$

32. 32.8 g of $Fe_2(SO_4)_3$

33. 11.15 g of PbO

34. 319.46 g of PbO_2

35. 17.12 g of Pb_3O_4

36. 67.524 g of $Pb(NO_3)_2$

37. 19.726 g of $PbCl_2$

38. 3.03 g of $PbSO_4$

39. 4.95 g of CuCl

40. 34.18 g of $CuCl_2$

41. 1.995 g of $CuSO_4$

42. 20.73 g of $ZnCl_2$

43. 17 g of $AgNO_3$

44. 2.83 g of NH_4Cl

45. 0.5676 g of $(NH_4)_2SO_4$

46. 4.212 g of NH_4VO_3

47. 32.585 g of $KClO_3$

48. 5.136 g of KIO_3

49. 1.8625 g of NaClO

50. 108.786 g of $NaNO_2$

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 H_2O

2. 3 moles of CO_2

3. 2.8 moles of NH_3

4. 0.5 moles of C_2H_5OH

5. 1.2 moles of C_2H_4

6. 0.64 moles of SO_2

7. 3 moles of SO_3

8. 1 mole of HBr

9. 0.016 moles of H_2SO_4

10. 0.15 moles of HNO_3

11. 0.45 moles of NaCl

12. 0.25 moles of $NaNO_3$

13. 0.14 moles of Na_2CO_3

14. 2 moles of NaOH

15. 0.9 moles of Na_2SO_4

16. 0.05 moles of $KMnO_4$

17. 0.18 moles of K_2CrO_4

18. 1 mole of $KHCO_3$

19. 1.5 moles of KI

20. 0.12 moles of $CsNO_3$

21. 0.1 moles of $CaCl_2$

22. 0.25 moles of $Ca(NO_3)_2$

23. 0.004 moles of $Ca(OH)_2$

24. 0.1 moles of $CaSO_4$

25. 0.21 moles of $BaCl_2$

26. 0.072 moles of $AlCl_3$

27. 0.357 moles of $Al(NO_3)_3$

28. 0.0293 moles of $Al_2(SO_4)_3$

29. 0.117 moles of $FeSO_4$

30. 0.6 moles of $FeCl_2$

31. 0.018 moles of $FeCl_3$

32. 0.1 moles of $Fe_2(SO_4)_3$

33. 0.09 moles of PbO

34. 3.1 moles of PbO_2

35. 0.00029 moles of Pb_3O_4

36. 0.15 moles of $Pb(NO_3)_2$

37. 0.1 moles of $PbCl_2$

38. 0.0159 moles of $PbSO_4$

39. 0.04 moles of CuCl

40. 0.9 moles of $CuCl_2$

41. 3 moles of $CuSO_4$

42. 0.165 moles of $ZnCl_2$

43. 0.06 moles of $AgNO_3$

44. 0.08 moles of NH_4Cl

45. 0.0739 moles of $(NH_4)_2SO_4$

46. 0.037 moles of NH_4VO_3

47. 0.078 moles of $KClO_3$

48. 0.07 moles of KIO_3

49. 1 mole of NaClO

50. 5 moles of $NaNO_2$

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

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

1. 1 mole of CH_4

2. 0.1 moles of O_2

3. 0.5 moles of N_2

4. 2 moles of H_2

5. 0.12 moles of CO_2

6. 3.4 moles of SO_2

7. 0.11 moles of SO_3

8. 0.004 moles of HBr

9. 10 moles of NH_3

10. 0.45 moles of NO

11. 0.0056 moles of NO_2

12. 0.009 moles of N_2O

13. 0.04 moles of Cl_2

14. 0.123 moles of HCl

15. 0.0023 moles of H_2S

16. 8 moles of CH_4

17. 0.00001 moles of O_2

18. 6 moles of N_2

19. 0.0076 moles of CO

20. 3 moles of $H_2O(g)$

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 cm^3) at standard conditions (1 mole = 24,000 cm^3).

1. 200 cm^3 of CH_4

2. 500 cm^3 of O_2

3. 1,000 cm^3 of N_2

4. 1,280 cm^3 of H_2

5. 235 cm^3 of CO_2

6. 225 cm^3 of SO_2

7. 255 cm^3 of SO_3

8. 80 cm^3 of HBr

9. 2,000 cm^3 of NH_3

10. 2,400 cm^3 of NO

11. 700 cm^3 of NO_2

12. 5,600 cm^3 of N_2O

13. 2,200 cm^3 of Cl_2

14. 210 cm^3 of HCl

15. 800 cm^3 of H_2S

16. 80 cm^3 of CH_4

17. 1.92 cm^3 of O_2

18. 20,000 cm^3 of N_2

19. 420 cm^3 of CO

20. 900 cm^3 of $H_2O(g)$

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

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

1. 200 cm^3 of CH_4

2. 500 cm^3 of O_2

3. 1,000 cm^3 of N_2

4. 1,280 cm^3 of H_2

5. 235 cm^3 of CO_2

6. 225 cm^3 of SO_2

7. 255 cm^3 of SO_3

8. 80 cm^3 of HBr

9. 2,000 cm^3 of NH_3

10. 2,400 cm^3 of NO

11. 700 cm^3 of NO_2

12. 5,600 cm^3 of N_2O

13. 2,200 cm^3 of Cl_2

14. 210 cm^3 of HCl

15. 800 cm^3 of H_2S

16. 80 cm^3 of CH_4

17. 1.92 cm^3 of O_2

18. 20,000 cm^3 of N_2

19. 420 cm^3 of CO

20. 900 cm^3 of $H_2O(g)$

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

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

1. 5.76 g of CH_4

2. 13.2 g of O_2

3. 10 g of N_2

4. 0.5 g of H_2

5. 0.352 g of CO_2

6. 0.448 g of SO_2

7. 2.25 g of SO_3

8. 16.2 g of HBr

9. 680 g of NH_3

10. 135 g of NO

11. 136 g of NO_2

12. 700 g of N_2O

13. 159.5 g of Cl_2

14. 7.3 g of HCl

15. 5.95 g of H_2S

16. 1.6 g of CH_4

17. 0.5 g of O_2

18. 2 g of N_2

19. 18.55 g of CO

20. 80 g of $H_2O(g)$

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

Calculate the relative molecular mass (M_r) of the following gases given their mass and volume at standard conditions (1 mole = 24,000 cm^3).

1. 0.8 g occupies 120 cm^3

2. 1.6 g occupies 600 cm^3

3. 0.5 g occupies 150 cm^3

4. 0.71 g occupies 240 cm^3

5. 0.02 g occupies 2,400 cm^3

6. 0.14 g occupies 120 cm^3

7. 0.075 g occupies 60 cm^3

8. 0.29 g occupies 120 cm^3

9. 0.08 g occupies 60 cm^3

10. 0.56 g occupies 480 cm^3

11. 0.17 g occupies 120 cm^3

12. 0.085 g occupies 120 cm^3

13. 0.19 g occupies 120 cm^3

14. 0.07 g occupies 60 cm^3

15. 0.22 g occupies 120 cm^3

16. 0.16 g occupies 120 cm^3

17. 0.844 g occupies 96 cm^3

18. 0.365 g occupies 240 cm^3

19. 0.405 g occupies 120 cm^3

20. 0.32 g occupies 60 cm^3

Exercise 6a: Balancing Equations

Balance the following chemical equations.

1. $H_2 + O_2 \rightarrow H_2O$

2. $BaCl_2 + NaOH \rightarrow Ba(OH)_2 + NaCl$

3. $H_2SO_4 + KOH \rightarrow K_2SO_4 + H_2O$

4. $K_2CO_3 + HCl \rightarrow KCl + H_2O + CO_2$

5. $CaCO_3 + HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

6. $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

7. $Pb(NO_3)_2 + NaI \rightarrow PbI_2 + NaNO_3$

8. $Al_2(SO_4)_3 + NaOH \rightarrow Al(OH)_3 + Na_2SO_4$

9. $Al(OH)_3 + NaOH \rightarrow NaAlO_2 + H_2O$

10. $Pb(NO_3)_2 \rightarrow PbO + NO_2 + O_2$

11. $FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3$

12. $NH_4NO_3 \rightarrow N_2O + H_2O$

13. $NaNO_3 \rightarrow NaNO_2 + O_2$

14. $CH_4 + O_2 \rightarrow CO_2 + H_2O$

15. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$

16. $PCl_3 + H_2O \rightarrow H_3PO_3 + HCl$

17. $HNO_3 + Cu \rightarrow Cu(NO_3)_2 + NO + H_2O$

18. $HNO_3 + Cu \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$

19. $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

20. $H_3PO_4 + NaOH \rightarrow Na_3PO_4 + H_2O$

21. $H_3PO_4 + NaOH \rightarrow Na_2HPO_4 + H_2O$

22. $NaOH + Cl_2 \rightarrow NaClO_3 + NaCl + H_2O$

23. $N_2 + H_2 \rightarrow NH_3$

24. $NaBr + H_2SO_4 \rightarrow Na_2SO_4 + HBr$

25. $HBr + H_2SO_4 \rightarrow H_2O + SO_2 + Br_2$

26. $C_2H_5OH + PCl_3 \rightarrow C_2H_5Cl + H_3PO_3$

27. $Fe_3O_4 + H_2 \rightarrow Fe + H_2O$

28. $Fe_2O_3 + CO \rightarrow Fe + CO_2$

29. $C_2H_5OH + CH_3CO_2H \rightarrow CH_3CO_2C_2H_5 + H_2O$

30. $KMnO_4 + HCl \rightarrow KCl + MnCl_2 + H_2O + Cl_2$

Exercise 6b: What's Wrong Here?

Identify and correct the errors in the following equations.

1. $Na(s) + H_2O(aq) \rightarrow NaOH(aq) + H(g)$

2. $PbNO_3(aq) + NaCl(aq) \rightarrow PbCl(s) + NaNO_3(aq)$

3. $CaOH(aq) + HCl(aq) \rightarrow CaCl(aq) + H_2O(l)$

4. $C_2H_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$

5. $MgCO_3(s) + HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

6. $Cu(NO_3)_2(s) \rightarrow CuO(s) + NO_2(g) + O_3(g)$

7. $Pb(s) + AgNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + AgCl(s)$

8. $AlCl_2(s) + KOH(aq) \rightarrow Al(OH)_2(s) + KCl(aq)$

9. $NaCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$

10. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(aq) + NaNO_3(aq)$

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, H_3PO_4, reacts with sodium hydroxide solution in three distinct stages depending upon the quantity of sodium hydroxide solution used:

- When 25 cm^3 of 0.1 mol dm^{-3} phosphoric(V) acid is treated with 25 cm^3 of 0.1 mol dm^{-3} sodium hydroxide solution, the resulting solution has a pH of about 2.

- When 25 cm^3 of 0.1 mol dm^{-3} phosphoric(V) acid is treated with 50 cm^3 of 0.1 mol dm^{-3} sodium hydroxide solution, the resulting solution has a pH of about 7.

- When 25 cm^3 of 0.1 mol dm^{-3} phosphoric(V) acid is treated with 75 cm^3 of 0.1 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 cm^3 of a 0.1 mol dm^{-3} solution?

ii) How many moles of sodium hydroxide are present in 25 cm^3 of a 0.1 mol dm^{-3} solution?

iii) Write equations for the three reactions that take place.

iv) What volume of 0.1 mol dm^{-3} sodium hydroxide solution would be required to completely neutralise 25 cm^3 of 0.1 mol dm^{-3} phosphoric(V) acid?

5. 2.495 g of hydrated copper(II) sulphate, $CuSO_4 \cdot xH_2O$, 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, $FeSO_4 \cdot xH_2O$, 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^3 of a 0.1 mol dm^{-3} 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^{-3} 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^3 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^3 of a 1 mol dm^{-3} solution of sodium hydroxide is added to 100 cm^3 of a 0.25 mol dm^{-3} 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^{-3} 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^3 of 1 mol dm^{-3} 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, $MgSO_4 \cdot 7H_2O$, 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^3 of a 0.1 mol dm^{-3} 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^3 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^3 of 0.5 mol dm^{-3} sodium hydroxide solution is added to separate 100 cm^3 portions of 0.25 mol dm^{-3} 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^{-3} hydrochloric acid? (All gas volumes measured at RTP.)

16. What mass of magnesium is needed to produce 100 cm^3 of hydrogen at RTP when treated with excess 1 mol dm^{-3} 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^{-3} hydrochloric acid are required to produce 1 dm^3 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^3 of methane, CH_4.

2. The combustion of 10 cm^3 of ethane, C_2H_6.

3. The combustion of 10 cm^3 of propane, C_3H_8.

4. The combustion of 10 cm^3 of octane vapour, C_8H_{18}.

5. The synthesis of 20 cm^3 of ammonia, NH_3, 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^3 of nitrogen monoxide, NO, into nitrogen dioxide, NO_2?

2. What volume of air (assume 20% oxygen by volume) is required to convert 100 cm^3 of sulphur dioxide into sulphur trioxide?

3. What volume of ammonia reacting with excess air (assume 20% oxygen by volume) will produce 2 dm^3 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^3 of carbon monoxide is mixed with 20 cm^3 of oxygen and ignited. What volume of gas remains?

7. 50 cm^3 of propane is mixed with 200 cm^3 of oxygen and ignited. What is the final volume of the gas mixture?

8. 50 cm^3 of methane is mixed with 50 cm^3 of oxygen and ignited. What is the final volume of the gas mixture?

9. 10 cm^3 of nitrogen is mixed with 50 cm^3 of hydrogen and a spark applied. Assuming all the nitrogen reacts, what volume of gas remains?

10. 10 cm^3 of hydrogen is mixed with 10 cm^3 of oxygen and ignited. What volume of gas remains?

Exercise 10: Ionic Equations

Write the balanced ionic equations for the following reactions.

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

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

3. $Al(OH)_3(s) + OH^-(aq) \rightarrow AlO_2^-(aq) + H_2O(l)$

4. $Cl_2(g) + OH^-(aq) \rightarrow ClO_3^-(aq) + Cl^-(aq) + H_2O(l)$

5. $S_2O_3^{2-}(aq) + I_2(s) \rightarrow S_4O_6^{2-}(aq) + I^-(aq)$

6. $Cu^{2+}(aq) + OH^-(aq) \rightarrow Cu(OH)_2(s)$

7. $CO_3^{2-}(s) + H^+(aq) \rightarrow H_2O(l) + CO_2(g)$

8. $Zn(s) + H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

9. $Zn(s) + Pb^{2+}(aq) \rightarrow Pb(s) + Zn^{2+}(aq)$

10. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

11. $Mg(s) + H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

12. $CO_3^{2-}(s) + H^+(aq) \rightarrow H_2O(l) + CO_2(g)$

13. $CuO(s) + H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$

14. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

15. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

16. $Zn(s) + Ag^+(aq) \rightarrow Zn^{2+}(aq) + Ag(s)$

17. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

18. $KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$

19. $NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$

20. $KOH(aq) + CH_3CO_2H(aq) \rightarrow CH_3CO_2K(aq) + H_2O(l)$

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^3 of 1.0 mol dm^{-3} NaOH

2. Number of moles in 50 cm^3 of 0.5 mol dm^{-3} HCl

3. Number of moles in 25 cm^3 of 2.5 mol dm^{-3} H_2SO_4

4. Number of moles in 10 cm^3 of 0.5 mol dm^{-3} NaCl

5. Number of moles in 100 cm^3 of 0.25 mol dm^{-3} KOH

6. Number of moles in 250 cm^3 of 0.1 mol dm^{-3} NH_3

7. Number of moles in 50 cm^3 of 0.25 mol dm^{-3} $CaCl_2$

8. Number of moles in 20 cm^3 of 0.5 mol dm^{-3} $AgNO_3$

9. Number of moles in 25 cm^3 of 0.05 mol dm^{-3} $KMnO_4$

10. Number of moles in 50 cm^3 of 0.1 mol dm^{-3} $CuSO_4$

11. Mass of solute in 25 cm^3 of 0.5 mol dm^{-3} NaCl

12. Mass of solute in 25 cm^3 of 0.25 mol dm^{-3} $NaNO_3$

13. Mass of solute in 50 cm^3 of 1.0 mol dm^{-3} NaOH

14. Mass of solute in 10 cm^3 of 1.0 mol dm^{-3} $AgNO_3$

15. Mass of solute in 100 cm^3 of 0.5 mol dm^{-3} Na_2SO_4

16. Mass of solute in 25 cm^3 of 0.4 mol dm^{-3} H_2SO_4

17. Mass of solute in 20 cm^3 of 0.1 mol dm^{-3} $KMnO_4$

18. Mass of solute in 50 cm^3 of 0.25 mol dm^{-3} $CuSO_4$

19. Mass of solute in 10 cm^3 of 0.5 mol dm^{-3} NH_4Cl

20. Mass of solute in 25 cm^3 of 0.2 mol dm^{-3} $FeSO_4$

21. Concentration of a solution containing 2.0 g of NaOH in 100 cm^3

22. Concentration of a solution containing 9.8 g of H_2SO_4 in 100 cm^3

23. Concentration of a solution containing 1.59 g of $CuSO_4$ in 100 cm^3

24. Concentration of a solution containing 8.5 g of $NaNO_3$ in 100 cm^3

25. Concentration of a solution containing 4.14 g of $Pb(NO_3)_2$ in 100 cm^3

26. Concentration of a solution containing 5.28 g of $(NH_4)_2SO_4$ in 100 cm^3

27. Concentration of a solution containing 16 g of NaOH in 100 cm^3

28. Concentration of a solution containing 39.2 g of H_2SO_4 in 100 cm^3

29. Concentration of a solution containing 25 g of $FeSO_4$ in 100 cm^3

30. Concentration of a solution containing 0.331 g of $Pb(NO_3)_2$ in 100 cm^3

31. Concentration of a solution containing 0.535 g of NH_4Cl in 100 cm^3

32. Concentration of a solution containing 10 g of H_2SO_4 in 50 cm^3

33. Concentration of a solution containing 2.12 g of Na_2CO_3 in 100 cm^3

34. Concentration of a solution containing 0.395 g of $KMnO_4$ in 50 cm^3

35. Concentration of a solution containing 25 g of NaCl in 60 cm^3

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^3

2. Concentration of a solution when 6.8 g of Na_2CO_3 is dissolved in 100 cm^3

3. Concentration of a solution when 5.88 g of NaCl is dissolved in 100 cm^3

4. Concentration of a solution when 9.8 g of H_2SO_4 is dissolved in 25 cm^3

5. Concentration of a solution when 6.0 g of NaOH is dissolved in 100 cm^3

6. Concentration of a solution when 4.0 g of NaOH is dissolved in 100 cm^3

7. Concentration of a solution when 0.4 g of NaOH is dissolved in 100 cm^3

8. Concentration of a solution when 0.535 g of NH_4Cl is dissolved in 100 cm^3

9. Concentration of a solution when 13.25 g of $(NH_4)_2SO_4$ is dissolved in 100 cm^3

10. Concentration of a solution when 39.2 g of H_2SO_4 is dissolved in 100 cm^3

11. Concentration of a solution when 8.5 g of $NaNO_3$ is dissolved in 100 cm^3

12. Concentration of a solution when 25 g of NaCl is dissolved in 100 cm^3

13. Concentration of a solution when 5.65 g of Na_2CO_3 is dissolved in 100 cm^3

14. Concentration of a solution when 4.95 g of $CuSO_4$ is dissolved in 100 cm^3

15. Concentration of a solution when 8.775 g of Na_2SO_4 is dissolved in 100 cm^3

16. pH of a solution with a hydrogen ion concentration of 0.001 mol dm^{-3}

17. Concentration of a solution when 25 cm^3 of 0.1 mol dm^{-3} NaOH reacts with 25 cm^3 of HCl

18. Volume of 0.1 mol dm^{-3} HCl required to neutralize 25 cm^3 of 0.2 mol dm^{-3} NaOH

19. Volume of 0.5 mol dm^{-3} H_2SO_4 required to neutralize 100 cm^3 of 0.25 mol dm^{-3} NaOH

20. Volume of 0.2 mol dm^{-3} NaOH required to neutralize 25 cm^3 of 0.2 mol dm^{-3} HCl

21. Mass of NaCl produced when 25 cm^3 of 0.1 mol dm^{-3} NaOH reacts with excess HCl

22. Mass of $CaCO_3$ required to produce 100 cm^3 of CO_2 at STP when reacted with excess HCl

23. Volume of CO_2 produced at STP when 1.0 g of $CaCO_3$ reacts with excess HCl

24. Mass of Mg and volume of H_2 produced at STP when 25 cm^3 of 0.2 mol dm^{-3} HCl reacts with excess Mg

25. Volume of H_2 produced at STP when 0.48 g of Mg reacts with excess 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 | $BaSO_4$ | 41 | $PbCO_3$ | 61 | PCl_3 |

| 2 | NaOH | 22 | $AlCl_3$ | 42 | PbO | 62 | PCl_5 |

| 3 | Na_2CO_3 | 23 | Al_2O_3 | 43 | PbO_2 | 63 | P_2O_3 |

| 4 | Na_2SO_4 | 24 | $Al(OH)_3$ | 44 | $PbCl_2$ | 64 | P_2O_5 |

| 5 | Na_3PO_4 | 25 | $Al_2(SO_4)_3$ | 45 | $PbCl_4$ | 65 | H_3PO_4 |

| 6 | KCl | 26 | $CuSO_4$ | 46 | PbS | 66 | H_2SO_4 |

| 7 | KBr | 27 | CuO | 47 | $SnCl_2$ | 67 | HNO_3 |

| 8 | KI | 28 | $CuCl_2$ | 48 | $SnCl_4$ | 68 | HCl |

| 9 | $KHCO_3$ | 29 | $Cu(NO_3)_2$ | 49 | $FeSO_4$ | 69 | CCl_4 |

| 10 | KNO_2 | 30 | Cu_2O | 50 | $FeCl_2$ | 70 | $SiCl_4$ |

| 11 | $MgCl_2$ | 31 | CuCl | 51 | $Fe_2(SO_4)_3$ | 71 | SiO_2 |

| 12 | $Mg(NO_3)_2$ | 32 | $Zn(NO_3)_2$ | 52 | $FeCl_3$ | 72 | SO_2 |

| 13 | $Mg(OH)_2$ | 33 | $ZnCO_3$ | 53 | $Fe(OH)_3$ | 73 | SO_3 |

| 14 | MgO | 34 | ZnO | 54 | $Fe(OH)_2$ | 74 | H_2S |

| 15 | $MgCO_3$ | 35 | AgCl | 55 | NH_4Cl | 75 | Cl_2O |

| 16 | CaO | 36 | AgBr | 56 | $(NH_4)_2CO_3$ | 76 | NO_2 |

| 17 | $CaCl_2$ | 37 | AgI | 57 | NH_4OH | 77 | NO |

| 18 | $CaSO_4$ | 38 | $AgNO_3$ | 58 | NH_4NO_3 | 78 | CO_2 |

| 19 | $CaCO_3$ | 39 | Ag_2O | 59 | $(NH_4)_2SO_4$ | 79 | CO |

| 20 | $BaCl_2$ | 40 | $Pb(NO_3)_2$ | 60 | $(NH_4)_3PO_4$ | 80 | HOH / H_2O |

Exercise 3

1. Water
2. Carbon dioxide
3. Ammonia
4. Oxygen
5. Hydrogen
6. Sulphur dioxide (or sulphur(IV) oxide)
7. Sulphur trioxide (or sul[phur(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^3 | 11 | 134.4 cm^3 |

| 2 | 2400 cm^3 | 12 | 216 cm^3 |

| 3 | 12000 cm^3 | 13 | 960 cm^3 |

| 4 | 48000 cm^3 | 14 | 2952 cm^3 |

| 5 | 2880 cm^3 | 15 | 55.2 cm^3 |

| 6 | 81600 cm^3 | 16 | 192000 cm^3 |

| 7 | 2640 cm^3 | 17 | 0.24 cm^3 |

| 8 | 96 cm^3 | 18 | 144000 cm^3 |

| 9 | 240000 cm^3 | 19 | 182.4 cm^3 |

| 10 | 10800 cm^3 | 20 | 72000 cm^3 |

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^3 | 11 | 56000 cm^3 |

| 2 | 7059 cm^3 | 12 | 30545 cm^3 |

| 3 | 8571 cm^3 | 13 | 20308 cm^3 |

| 4 | 7500 cm^3 | 14 | 16000 cm^3 |

| 5 | 702 cm^3 | 15 | 5260 cm^3 |

| 6 | 670 cm^3 | 16 | 2370 cm^3 |

| 7 | 3380 cm^3 | 17 | 375 cm^3 |

| 8 | 30000 cm^3 | 18 | 12000 cm^3 |

| 9 | 2400000 cm^3 | 19 | 26526 cm^3 |

| 10 | 180000 cm^3 | 20 | 77143 cm^3 |

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. $CaCO_3$

2. Na_2SO_4

3. $Na_2S_2O_3$

4. PbO

5. Pb_3O_4

6. H_3PO_3

7. H_2SO_3

8. CH_4

9. C_3H_8

10. HO (giving H_2O_2)

11. $H_4N_2O_3$ (NH_4NO_3)

12. $FeSO_4 \cdot 7H_2O$ ($FeSO_{11}H_{14}$)

Section (b)

1. C_2H_4

2. C_3H_6

3. P_2I_4

4. $N_2H_4S_2O_8$

5. P_4O_{10}

6. $C_2H_4O_2$ (CH_3COOH)

7. C_4H_{10}

8. Fe_2O_3

9. $H_2S_2O_8$

10. C_6H_6

Section (c)

1. PbO

2. KO_2

3. C_2H_2

4. $AlCl_3$

5. CH_4

6. Yes

7. $CuSO_4 \cdot 5H_2O$

8. PCl_5, PCl_3, Cl_2

Exercise 6a

1. $2H_2 + O_2 \rightarrow 2H_2O$

2. $BaCl_2 + 2NaOH \rightarrow Ba(OH)_2 + 2NaCl$

3. $H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

4. $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$

5. $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

6. $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

7. $Pb(NO_3)_2 + 2NaI \rightarrow PbI_2 + 2NaNO_3$

8. $Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$

9. $Al(OH)_3 + NaOH \rightarrow NaAlO_2 + 2H_2O$

10. $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

11. $2FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3$

12. $NH_4NO_3 \rightarrow N_2O + 2H_2O$

13. $2NaNO_3 \rightarrow 2NaNO_2 + O_2$

14. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

15. $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

16. $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$

17. $8HNO_3 + 3Cu \rightarrow 3Cu(NO_3)_2 + 3NO + 4H_2O$

18. $4HNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

19. $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

20. $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$

21. $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$

22. $6NaOH + 3Cl_2 \rightarrow NaClO_3 + 5NaCl + 3H_2O$

23. $N_2 + 3H_2 \rightarrow 2NH_3$

24. $2NaBr + H_2SO_4 \rightarrow Na_2SO_4 + 2HBr$

25. $2HBr + H_2SO_4 \rightarrow 2H_2O + SO_2 + Br_2$

26. $3C_2H_5OH + PCl_3 \rightarrow 3C_2H_5Cl + H_3PO_3$

27. $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

28. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

29. $C_2H_5OH + CH_3CO_2H \rightarrow CH_3CO_2C_2H_5 + H_2O$

30. $2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$

Exercise 6b

1. Hydrogen is not H but H_2, which gives: $2Na(s) + 2H_2O(aq) \rightarrow 2NaOH(aq) + H_2(g)$

2. Since the valency of lead is 2 not 1, lead nitrate is not $PbNO_3$ but $Pb(NO_3)_2$ and also lead chloride is $PbCl_2$: $Pb(NO_3)_2(aq) + 2NaCl(aq) \rightarrow PbCl_2(s) + 2NaNO_3(aq)$

3. Calcium hydroxide is $Ca(OH)_2$: $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$

4. This does not balance: $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$

5. A magnesium compound cannot give a calcium compound!

6. Ozone O_3 is not produced by heating a nitrate, O_2 is: $2Cu(NO_3)_2(s) \rightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$

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: $AlCl_3(s) + 3KOH(aq) \rightarrow Al(OH)_3(s) + 3KCl(aq)$

9. Sodium has a valency of 1 not 2 as in this equation: $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

10. Silver chloride is not soluble in water. Thus the AgCl needs a (s) symbol: $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Exercise 6c

1. $Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$

2. $Ca(OH)_2(s) + 2NH_4Cl(s) \rightarrow CaCl_2(s) + 2H_2O(g) + 2NH_3(g)$

3. $2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

4. $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(g)$

5. $Ca(HCO_3)_2(aq) \rightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$

6. $2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

7. $6NaOH(aq) + 3Cl_2(g) \rightarrow NaClO_3(aq) + 5NaCl(aq) + 3H_2O(l)$

   $6NaOH(aq) + 3Br_2(g) \rightarrow NaBrO_3(aq) + 5NaBr(aq) + 3H_2O(l)$

$6NaOH(aq) + 3I_2(g) \rightarrow NaIO_3(aq) + 5NaI(aq) + 3H_2O(l)$

8. $2M(s) + 2H_2O(l) \rightarrow 2MOH(aq) + H_2(g)$ (Where M = Li, Na, K, Rb, or Cs)

9. $SnCl_2(aq) + 2HgCl_2(aq) \rightarrow 2HgCl(s) + SnCl_4(aq)$

10. $9H_2SO_4 + 8KI \rightarrow 4I_2 + H_2S + 8KHSO_4 + 4H_2O$

Exercise 7

1. $AlCl_3 + 3AgNO_3 \rightarrow Al(NO_3)_3 + 3AgCl$

2. $K_2CrO_4 + Pb(NO_3)_2 \rightarrow PbCrO_4 + 2KNO_3$

3. $2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

4. i) 1 mole

ii) 2 moles

iii) $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

$H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$

iv) 75 cm^3

5. x = 3

6. x = 5; $CuSO_4 \cdot 5H_2O \rightarrow CuSO_4 + 5H_2O$

7. $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

8. $C_5H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

9. It is

10. $FeSO_4 \cdot 7H_2O \rightarrow Fe_2O_3 + SO_2 + SO_3 + 14H_2O$

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 cm^3

8. 54.7 g of calcium nitrate, 8.0 dm^3 of carbon dioxide

9. 6 dm^3 total (4.8 dm^3 of nitrogen dioxide and 1.2 dm^3 of oxygen)

10. $Mg + H_2SO_4 + 7H_2O \rightarrow MgSO_4 \cdot 7H_2O + H_2$; 41.0 g

11. 31.9 g

12. 324.3 g

13. 5.11 g of ethanol, 2.67 dm^3 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^3

16. 0.100 g

17. 2.94 g of sodium chloride, 1.065 g of sodium chlorate(V)

18. 4.15×10^6 dm^3 of nitrogen, 12.5×10^6 dm^3 of hydrogen

19. 63 tonnes of nitric acid, 4.8×10^7 dm^3 of oxygen

20. 2198 g of calcium carbonate, 4.395 dm^3 of 10 M HCl

Exercise 9

Section (a)

1. 20 cm^3 O_2, 10 cm^3 CO_2, 20 cm^3 $H_2O(g)$

2. 30 cm^3 O_2, 20 cm^3 CO_2, 20 cm^3 $H_2O(g)$

3. 25 cm^3 O_2, 20 cm^3 CO_2, 10 cm^3 $H_2O(g)$

4. 125 cm^3 O_2, 80 cm^3 CO_2, 90 cm^3 $H_2O(g)$

5. 30 cm^3 H_2, 20 cm^3 NH_3

Section (b)

1. 500 cm^3 O_2 ($2NO + O_2 \rightarrow 2NO_2$)

2. 375 cm^3 air ($2SO_2 + O_2 \rightarrow 2SO_3$)

3. 2500 cm^3 NH_3 needed, $5/4 \times 2500 = 3125$ cm^3 $O_2 \rightarrow 15625$ cm^3 air

4. 6.5×24000 $cm^3 = 156$ m^3

5. 24000 cm^3

6. Final volume = 20 cm^3 (10 cm^3 CO_2 + 10 cm^3 unused O_2)

7. Final volume = 77.5 cm^3 (40 cm^3 CO_2 + 37.5 cm^3 unused O_2)

8. This time the CH_4 is in excess. We must assume that CO_2 is produced (not CO or C)! Final volume = 60 cm^3 (30 cm^3 CO_2 + 30 cm^3 CH_4)

9. $N_2 + 3H_2 \rightarrow 2NH_3$; 10 cm^3, 30 cm^3, 20 cm^3 + 30 cm^3 excess; 20 cm^3 NH_3 produced + 30 cm^3 excess H_2

10. $2H_2 + O_2 \rightarrow 2H_2O$; 10 cm^3, 5 cm^3 + 5 cm^3 excess; Final volume = 5 cm^3 (all excess O_2)

Exercise 10

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

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

3. $Al(OH)_3(s) + OH^-(aq) \rightarrow AlO_2^-(aq) + 2H_2O(l)$

4. $Cl_2(g) + 6OH^-(aq) \rightarrow ClO_3^-(aq) + 5Cl^-(aq) + 3H_2O(l)$

5. $2S_2O_3^{2-}(aq) + I_2(s) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

6. $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$

7. $CO_3^{2-}(s) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g)$

8. $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

9. $Zn(s) + Pb^{2+}(aq) \rightarrow Pb(s) + Zn^{2+}(aq)$

10. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

11. $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

12. $CO_3^{2-}(s) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g)$

13. $CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$

14. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

15. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

16. $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$

17–20. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ (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^{-3} |

| 4 | 0.005 moles | 22 | 1.0 mol dm^{-3} |

| 5 | 0.025 moles | 23 | 0.03 mol dm^{-3} |

| 6 | 0.025 moles | 24 | 0.1 mol dm^{-3} |

| 7 | 0.0125 moles | 25 | 0.03 mol dm^{-3} |

| 8 | 0.01 moles | 26 | 0.04 mol dm^{-3} |

| 9 | 0.00125 moles | 27 | 0.40 mol dm^{-3} |

| 10 | 0.005 moles | 28 | 0.40 mol dm^{-3} |

| 11 | 0.9125 g | 29 | 0.152 mol dm^{-3} |

| 12 | 1.463 g | 30 | 0.0102 mol dm^{-3} |

| 13 | 2 g | 31 | 0.01 mol dm^{-3} |

| 14 | 1.70 g | 32 | 0.2 mol dm^{-3} |

| 15 | 5.2 g | 33 | 0.02 mol dm^{-3} |

| 16 | 0.98 g | 34 | 0.005 mol dm^{-3} |

| 17 | 0.08 g | 35 | 0.417 mol dm^{-3} |

| 18 | 0.97 g | | |

Exercise 11b

| 1 | 0.168 mol dm^{-3} | 16 | 3.0 |

| 2 | 0.136 mol dm^{-3} | 17 | 0.02 mol dm^{-3} |

| 3 | 0.118 mol dm^{-3} | 18 | 50 cm^3 |

| 4 | 1.0 mol dm^{-3} | 19 | 50 cm^3 |

| 5 | 0.12 mol dm^{-3} | 20 | 25 cm^3 |

| 6 | 0.040 mol dm^{-3} | 21 | 0.359 g |

| 7 | 0.0080 mol dm^{-3} | 22 | 1.0 g |

| 8 | 0.010 mol dm^{-3} | 23 | 240 cm^3 |

| 9 | 0.10 mol dm^{-3} | 24 | 0.12 g Mg, 120 cm^3 H_2 |

| 10 | 0.40 mol dm^{-3} | 25 | 480 cm^3 |

| 11 | 0.050 mol dm^{-3} | | |

| 12 | 0.167 mol dm^{-3} | | |

| 13 | 2.26 g dm^{-3} | | |

| 14 | 0.099 mol dm^{-3} | | |

| 15 | 1.755 g dm^{-3} | | |

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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