Topic 4

Stoichiometry

- Chemical formula
- Chemical equation
- Chemical calculations
- The mole
- Empirical formula and molecular formula

Paper 2

1. Which compound has the largest relative molecular mass, *Mr*? **J. 02 (9)**

A. CO_2
B. NO_2
C. SiO_2
D. SO_2

2. What is the formula of copper(II) oxide and of sulfur hexafluoride? **J. 02 (10)**

	copper(II) oxide	sulphur hexafluoride
A	CuO	S_6F
B	CuO	SF_6
C	Cu_2O	S_6F
D	Cu_2O	SF_6

3. The relative atomic mass of oxygen is 16 and that of hydrogen is 1. **J. 03 (9)**

This means that …(i)… of oxygen has the same mass as …(ii)… of hydrogen.

Which words correctly complete the gaps?

	gap (i)	gap (ii)
A	an atom	thirty-two molecules
B	an atom	eight molecules
C	a molecule	sixteen atoms
D	a molecule	eight atoms

4. Water is formed when 48 g of oxygen combine with 6 g of hydrogen. **J. 03 (11)**

What mass of oxygen combines with 2 g of hydrogen?

A. 12 g **B.** 16 g **C.** 96 g **D.** 144 g

5. Two gases react as shown. **N. 03 (10)**

$$\underset{\text{reactants}}{X_2 + Y_2} \rightarrow \underset{\text{product}}{2XY}$$

When measured at the same temperature and pressure, what is the value of

$$\frac{\text{volume of product}}{\text{volume of reactants}} ?$$

A. 1/2
B. 1
C. 2
D. 4

6. Carbon and chlorine form a chloride. **N. 03 (11)** **N. 08 (11)**

What is the formula of this chloride?

A. CCl_2
B. CCl_4
C. $CaCl_2$
D. $CaCl_4$

7. The compound ethyl mercaptan, C_2H_5SH, has a very unpleasant smell. **J. 04 (10)**

What is its relative molecular mass?

A. 34 **B.** 50 **C.** 61 **D.** 62

8. When propane is burned, carbon dioxide and water are formed, as shown. **N. 04 (9)**

$$C_3H_8 + 5O_2 \longrightarrow r\,CO_2 + s\,H_2O$$

Which values of r and s balance the equation?

	r	*s*
A	1	3
B	1	5
C	3	4
D	3	8

9. For which compound is the formula correct? **J 05 (10)**

	compound	formula
A	ammonia	NH_4
B	carbon monoxide	CO_2
C	iron(III) oxide	Fe_3O_2
D	zinc hydroxide	$Zn(OH)_2$

10. The equation shows the reaction that occurs when ethanol burns in air. **N. 05 (9)**

$$C_2H_5OH + x\,O_2 \rightarrow y\,CO_2 + z\,H_2O$$

Which values of x, y and z are needed to balance this equation?

	x	y	z
A	2	2	2
B	2	2	3
C	2	3	3
D	3	2	3

11. The diagrams show the molecules of three elements. **J. 06 (9)**

1 2 3

Which of these elements are present in water?

A. 1 and 2 only

B. 1 and 3 only

C. 2 and 3 only

D. 1, 2 and 3

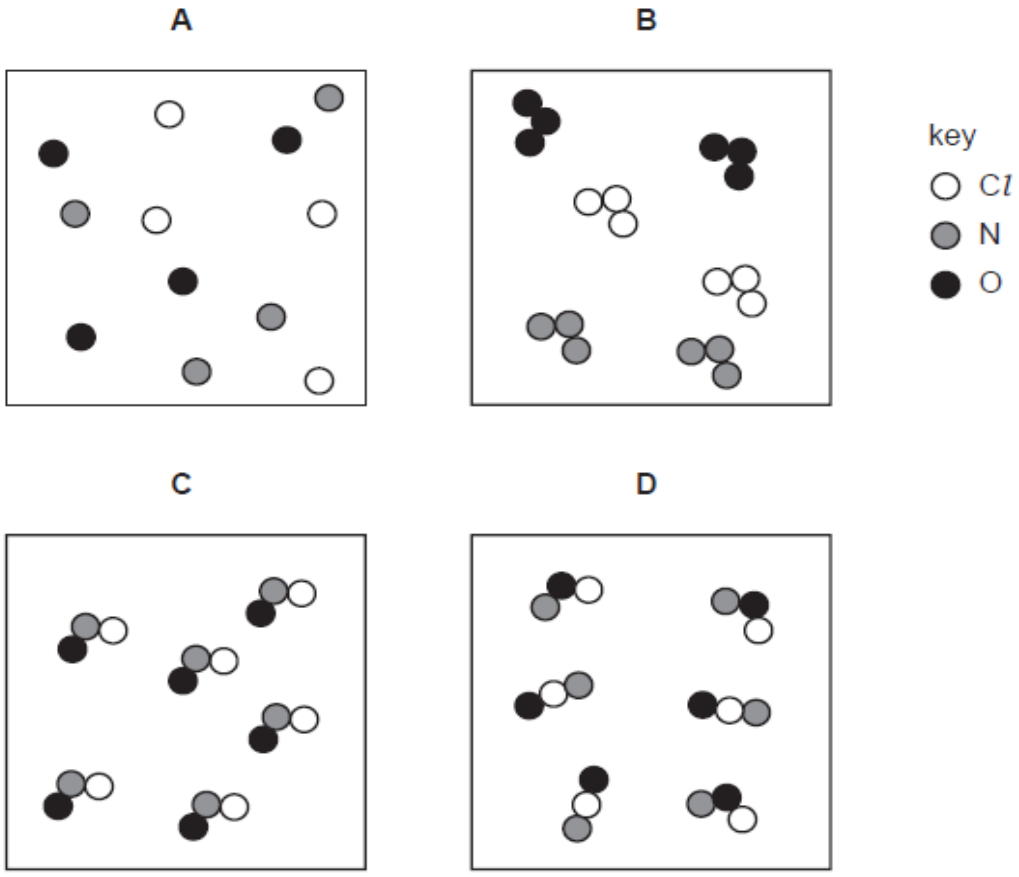
12. Magnesium and sulfur each form a chloride. **N 06 (9)**

What could be the formulae of these chlorides?

	magnesium	sulphur
A	Mg_2Cl	S_2Cl
B	Mg_2Cl	SCl_2
C	$MgCl_2$	S_2Cl
D	$MgCl_2$	SCl_2

13. A gas has the molecular formula NOCl. **N. 06 (10)**

Which diagram could show molecules of the pure gas NOCl ?



14. Boron, B, forms an oxide. **J. 07 (10)**

Which equation is correctly balanced?

A. $2B + 3O_2 \rightarrow B_2O_3$
B. $2B + 3O_2 \rightarrow 2B_2O_3$
C. $4B + 2O_2 \rightarrow 2B_2O_3$
D. $4B + 3O_2 \rightarrow 2B_2O_3$

15. For which compound is the formula correct? **J. 08 (10)**

	compound	formula
A	ammonium chloride	NH_3Cl
B	copper(II) sulphide	CuS
C	iron(II) sulphide	Fe_3S
D	silver nitrate	Ag_2NO_3

16. **J. 08 (18)**

When written as formulae, which compound has the greatest number of oxygen atoms?

A. calcium oxide

B. copper(II) oxide

C. iron(III) oxide

D. potassium oxide

17. Nitrogen and hydrogen react together to form ammonia. **J. 09 (10)**

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

When completely converted, 7 tonnes of nitrogen gives 8.5 tonnes of ammonia.

How much nitrogen will be needed to produce 34 tonnes of ammonia?

A 7 tonnes B 8.5 tonnes C 28 tonnes D 34 tonnes

18. Which relative molecular mass, Mr, is not correct for the molecule given? **J. 09 (11)**

	molecule	M_r
A	ammonia, NH_3	17
B	carbon dioxide, CO_2	44
C	methane, CH_4	16
D	oxygen, O_2	16

19. Hydrogen and chlorine react as shown.

1 molecule of hydrogen + 1 molecule of chlorine → 2 molecules of hydrogen chloride

What is the equation for this reaction?

A. $2H + 2Cl \rightarrow 2HCl$

B. $2H + 2Cl \rightarrow H_2Cl_2$

C. $H_2 + Cl_2 \rightarrow 2HCl$

D. $H_2 + Cl_2 \rightarrow H_2Cl_2$

J. 2016 p 21 (8-9)

20 A compound, X, contains 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

The relative molecular mass, M_r, of X is 60.

What is the molecular formula of X?

A CH_2O **B** CH_4O **C** C_2H_4O **D** $C_2H_4O_2$

21 25 cm^3 of 0.1 mol/dm^3 hydrochloric acid exactly neutralise 20 cm^3 of aqueous sodium hydroxide.

The equation for this reaction is:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

What is the concentration of the sodium hydroxide solution?

A 0.080 mol/dm^3

B 0.800 mol/dm^3

C 0.125 mol/dm^3

D 1.25 mol/dm^3

J. 2016 p 22 (8-9)

22 A sample of 16.0 g of a metal oxide, MO, is reduced to 12.8 g of the metal, M.

What is the relative atomic mass, A_r, of M?

A 32 **B** 64 **C** 80 **D** 128

23 The equation for the reaction between calcium carbonate and hydrochloric acid is shown.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

How many moles of calcium carbonate will give 24 cm^3 of carbon dioxide when reacted with an excess of the acid?

A 1 mol **B** 0.1 mol **C** 0.01 mol **D** 0.001 mol

J. 2016 p 23 (8-9)

24 Analysis of a compound formed between magnesium and nitrogen showed it contained 14.4 g of magnesium and 5.6 g of nitrogen.

What is the empirical formula of the compound?

A Mg_2N_3 **B** Mg_3N_2 **C** Mg_4N_6 **D** Mg_6N_4

25 An excess of zinc is added to 100 cm^3 of 1.0 mol / dm^3 hydrochloric acid.

The equation for the reaction is:

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

What is the maximum volume of hydrogen evolved at room temperature and pressure?

A 1.2 dm^3 **B** 2.0 dm^3 **C** 2.4 dm^3 **D** 24 dm^3

Paper 4

1. **N. 01 (2. c)**

(c) Potassium chlorate, which has a formula of the type, $KClO_n$, decomposes to form oxygen. 2.45 g of the chlorate produced 1.49 g of potassium chloride and 0.72dm^3 of oxygen at r.t.p. Find the value of n.

$$KClOn \longrightarrow KCl + O_2$$

Mass of one mole of KCl = 74.5 g

Number of moles of KCl formed = ...

Number of moles of oxygen molecules formed = ...

Number of moles of oxygen atoms = ...

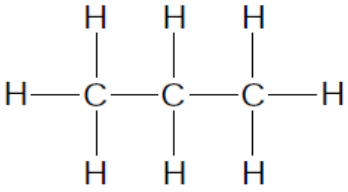
Mole ratio KCl : O is .....

n = ...

[4]

2. **N. 01 (3. a)**

Propane is an alkane. It has the structural formula:



(a) The equation for the complete combustion of propane is given below. Insert the two missing volumes.

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(l)}$$

Volume of gas/cm^3	.....	.....	15

3. **J. 02 (5. c, d)**

(c) A 20 cm^3 sample of butyne, C_4H_6, is burnt in 150 cm^3 of oxygen. This is an excess of oxygen.

$$2C_4H_{6(g)} + 11O_{2(g)} \longrightarrow 8CO_{2(g)} + 6H_2O_{(l)}$$

(i) What volume of oxygen reacts?

…….....[1]

(ii) What volume of carbon dioxide is produced?

…….....[1]

(iii) What is the total volume of gases left at the end of the reaction?

…….....[1]

(d) Calculate the mass of water formed when 9.0 g of butyne is burnt. The mass of one mole of butyne is 54 g.

from the above equation, 1 mole of butyne forms 3 moles of water

number of moles of butyne reacted .....

number of moles of water formed .....

mass of water formed ..... g [3]

4. **N. 02 (1. c)**

(c) The results of an investigation into the action of heat on copper(II) sulphate-5-water, a blue crystalline solid, are given below.

The formula is $CuSO_4.5H_2O$ and the mass of one mole is 250 g

A 5.0 g sample of the blue crystals is heated to form 3.2 g of a white powder. With further heating this decomposes into a black powder and sulfur trioxide.

(i) Name the white powder.

.....[1]

(ii) What is observed when water is added to the white powder?

.....[1]

(iii) Name the black powder.

.....[1]

(iv) Calculate the mass of the black powder. Show your working.

.....

.....

.....[3]

4. **N. 02 (3. f)**

(f) Sodium reacts with sulfur to form sodium sulfide.

$$2Na + S \longrightarrow Na_2S$$

An 11.5 g sample of sodium is reacted with 10 g of sulfur. All of the sodium reacted but there was an excess of sulfur.

Calculate the mass of sulfur left unreacted.

(i) Number of moles of sodium atoms reacted = ...

[2 moles of Na react with 1 mole of S]

(ii) Number of moles of sulfur atoms that reacted = ...

(iii) Mass of sulfur reacted = ...g

(iv) Mass of sulfur left unreacted = ...g [4]

5. **J. 03 (2. c)**

(c) Each tablet contains the same number of moles of $CaCO_3$ and $MgCO_3$. One tablet reacted with excess hydrochloric acid to produce 0.24 dm^3 of carbon dioxide at r.t.p.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

$$MgCO_3 + 2HCl \longrightarrow MgCl_2 + CO_2 + H_2O$$

(i) Calculate how many moles of $CaCO_3$ there are in one tablet.

number of moles CO_2 = ...

number of moles of $CaCO_3$ and $MgCO_3$ = ...

number of moles of $CaCO_3$ = ...

[3]

(ii) Calculate the volume of hydrochloric acid, 1.0 mol /dm^3, needed to react with one tablet.

number of moles of $CaCO_3$ and $MgCO_3$ in one tablet = ...

Use your answer to **(c)(i)**.

number of moles of HC*l* needed to react with one tablet = ...

volume of hydrochloric acid, 1.0 mol /dm^3, needed to

react with one tablet = ...

[2]

6. **N. 03 (5. d)**

(d) Sulfur dioxide reacts with chlorine in an addition reaction to form sulfuryl chloride.

$$SO_2 + Cl_2 \longrightarrow SO_2Cl_2$$

8.0 g of sulfur dioxide was mixed with 14.2 g of chlorine. The mass of one mole of SO_2Cl_2 is 135 g.

Calculate the mass of sulfuryl chloride formed by this mixture.

Calculate the number of moles of SO_2 in the mixture = ……

Calculate the number of moles of Cl_2 in the mixture = ……

Which reagent was not in excess? …….

How many moles of $SO_2C\mathit{l}_2$ were formed = …….

Calculate the mass of sulfuryl chloride formed = ……. g [5]

7. **J. 04 (3. a)**

An organic compound decomposes to form nitrogen.

$$C_6H_5N_2Cl_{(aq)} \rightarrow C_6H_5Cl_{(l)} + N_{2(g)}$$

(a) Explain the state symbols.

aq……..

l ……..

g ……. [2]

8. **J. 04 (7)**

Chemists use the concept of the mole to calculate the amounts of chemicals involved in a reaction.

(a) Define mole.

……[1]

(b) 3.0 g of magnesium was added to 12.0 g of ethanoic acid.

$$Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$$

The mass of one mole of Mg is 24 g.

The mass of one mole of CH3COOH is 60 g.

(i) Which one, magnesium or ethanoic acid, is in excess? You must show your reasoning.

.....……..……

……..…….

……[3]

(ii) How many moles of hydrogen were formed?

……..[1]

(iii) Calculate the volume of hydrogen formed, measured at r.t.p

……

……[2]

(c) In an experiment, 25.0cm^3 of aqueous sodium hydroxide, 0.4mol /dm^3 was neutralised by 20.0cm^3 of aqueous oxalic acid, $H_2C_2O_4$.

$$2NaOH + H_2C_2O_4 \rightarrow Na_2C_2O_4 + 2H_2O$$

Calculate the concentration of the oxalic acid in mol /dm^3

(i) Calculate the number of moles of NaOH in 25.0 cm^3 of 0.4 mol /dm^3 solution.

…… [1]

(ii) Use your answer to (i) and the mole ratio in the equation to find out the number of moles of $H_2C_2O_4$ in 20 cm^3 of solution.

…….. [1]

(ii) Calculate the concentration, mol /dm^3, of the aqueous oxalic acid.

……

…… [2]

9. **N. 04 (7. c)**

(c) Iron(III) sulfate decomposes when heated. Calculate the mass of iron(III) oxide formed and the volume of sulfur trioxide produced when 10.0 g of iron(III) sulfate was heated.

Mass of one mole of $Fe_2(SO_4)_3$ is 400 g.

$$Fe_2(SO_4)_{3\,(s)} \longrightarrow Fe_2O_{3\,(s)} + 3SO_{3\,(g)}$$

Number of moles of $Fe_2(SO_4)_3$ = ……

Number of moles of Fe_2O_3 formed = ……..

Mass of iron(III) oxide formed = …….. g

Number of moles of SO_3 produced = ……

Volume of sulfur trioxide at r.t.p. = …….. dm^3 [5]

10. **J. 05 (1. c, d)**

(c) 0.015 moles of iodine react with 0.045 moles of chlorine to form 0.030 moles of a single product. Complete the equation.

$$I_2 + \text{……..}\ Cl_2 \longrightarrow \text{.....}$$

[2]

(d) Traces of chlorine can be separated from bromine vapour by diffusion.

Which gas would diffuse the faster and why?

…….

…….[2]

11. **J. 05 (4. d)**

(d) Gypsum is hydrated calcium sulfate, $CaSO_4.xH_2O$. It contains 20.9% water by mass. Calculate x.
Mr: $CaSO_4$, 136; H_2O, 18.

79.1 g of $CaSO_4$ = ……moles

20.9 g of H_2O = ……..… moles

x = …….. [3]

12. **N. 05 (6. a)**

(a) The following method is used to make crystals of hydrated nickel sulfate.

An excess of nickel carbonate, 12.0 g, was added to 40 cm^3 of sulfuric acid, 2.0 mol/dm^3. The unreacted nickel carbonate was filtered off and the filtrate evaporated to obtain the crystals.

$$NiCO_3 + H_2SO_4 \longrightarrow NiSO_4 + CO_2 + H_2O$$

$$NiSO_4 + 7H_2O \longrightarrow NiSO_4.7H_2O$$

Mass of one mole of $NiSO_4.7H_2O$ = 281 g

Mass of one mole of $NiCO_3$ = 119 g

(i) Calculate the mass of unreacted nickel carbonate.

Number of moles of H_2SO_4 in 40 cm_3 of 2.0 mol/dm_3 acid = 0.08

Number of moles of $NiCO_3$ reacted =……

Mass of nickel carbonate reacted =…….. g

Mass of unreacted nickel carbonate = …….. g [3]

(ii) The experiment produced 10.4 g of hydrated nickel sulfate. Calculate the percentage yield.

The maximum number of moles of $NiSO_4 .7H_2O$ that could be formed =……

The maximum mass of $NiSO_4 .7H_2O$ that could be formed =…….. g

The percentage yield =…….. % [3]

13. **J. 06 (7. d)**

(d) Propene reacts with hydrogen iodide to form 2 - iodopropane.

$$CH_3{-}CH{=}CH_2 \quad + \quad HI \longrightarrow CH_3{-}CHI{-}CH_3$$

1.4 g of propene produced 4.0 g of 2 - iodopropane.

Calculate the percentage yield.

moles of $CH_3–CH=CH_2$ reacted = ……

maximum moles of $CH_3–CHI–CH_3$ that could be formed =……..

mass of one mole of $CH_3–CHI–CH_3$ = 170 g

maximum mass of 2 - iodopropane that could be formed =……

percentage yield ……..% [4]

14. **N. 06 (3. b)**

(b) When calcium carbonate is heated strongly, it decomposes.

$$CaCO_3 \quad \rightarrow \quad CaO \quad + \quad CO_2$$

(i) Calculate the relative formula mass of:

$CaCO_3$ ……

CaO …… [2]

(ii) 7.00 kg of calcium oxide was formed. What mass of calcium carbonate was heated?

……..

…… ……[2]

15. **N. 06 (6. a)**

An ore of copper is the mineral, chalcopyrite. This is a mixed sulfide of iron and copper.

(a) Analysis of a sample of this ore shows that 13.80 g of the ore contained

4.80g of copper, 4.20 g of iron and the rest sulfur.

Complete the table and calculate the empirical formula of chalcopyrite.

	copper	iron	sulphur
composition by mass / g	4.80	4.20	
number of moles of atoms			
simplest mole ratio of atoms			

[3]

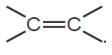
The empirical formula is…… [1]

16. **J. 07 (7. d)**

(d) A better way of measuring the degree of unsaturation is to find the iodine number of the unsaturated compound.

This is the mass of iodine that reacts with all the double bonds in 100 g of the fat. Use the following information to calculate the number of double bonds in one molecule of the fat.

Mass of one mole of the fat is 884 g.

One mole of I_2 reacts with one mole 

The iodine number of the fat is 86.2 g.

Complete the following calculation.

100 g of fat reacts with 86.2 g of iodine.

884 g of fat reacts with ……..….g of iodine.

One mole of fat reacts with…….. moles of iodine molecules.

Number of double bonds in one molecule of fat is…….. [3]

17. **N. 07 (7. b)**

(ii) One piece of marble, 0.3 g, was added to 5 cm^3 of hydrochloric acid, concentration 1.00 mol / dm^3.

Which reagent is in excess? Give a reason for your choice.

mass of one mole of $CaCO_3$ = 100 g

number of moles of $CaCO_3$ =……

number of moles of HCl =…….

reagent in excess is……..

reason……..…

.....…….…… [4]

(iii) Use your answer to (ii) to calculate the maximum volume of carbon dioxide produced measured at r.t.p.

… ……[1]

18. **J. 08 (7. b)**

(b) Using 25.0 cm^3 of aqueous sodium hydroxide, 2.24 mol / dm^3, 3.95 g of crystals were obtained. Calculate the percentage yield.

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

$$Na_2SO_4 + 10H_2O \longrightarrow Na_2SO_4.10H_2O$$

Number of moles of NaOH used =……

Maximum number of moles of $Na_2SO_4.10H_2O$ that could be formed =…….

Mass of one mole of $Na_2SO_4.10H_2O$ = 322 g

Maximum yield of sodium sulphate-10-water =…… g

Percentage yield =…….…. % [4]

19. **N. 08 (3. c)**

(c) **(i)** Calculate the mass of one mole of $Fe_2O_3.2H_2O$.

……[1]

(ii) Use your answer to (i) to calculate the percentage of iron in rust.

……..

……..[2]

20. **N. 08 (4. b)**

(b) Benzene contains 92.3% of carbon and its relative molecular mass is 78.

(i) What is the percentage of hydrogen in benzene?

……[1]

(ii) Calculate the ratio of moles of C atoms: moles of H atoms in benzene.

……

……[2]

(iii) Calculate its empirical formula and then its molecular formula.

The empirical formula of benzene is…….

The molecular formula of benzene is……..

…….. [2]

21. **N. 08 (7. a)**

alkanes are generally unreactive. Their reactions include combustion, substitution and cracking.

(a) The complete combustion of an alkane gives carbon dioxide and water.

(i) 10 cm^3 of butane is mixed with 100 cm^3 of oxygen, which is an excess. The mixture is ignited. What is the volume of unreacted oxygen left and what is the volume of carbon dioxide formed?

$$C_4H_{10(g)} + 6.5\ O_{2\ (g)} \longrightarrow 4CO_{2(g)} + 5H_2O_{(l)}$$

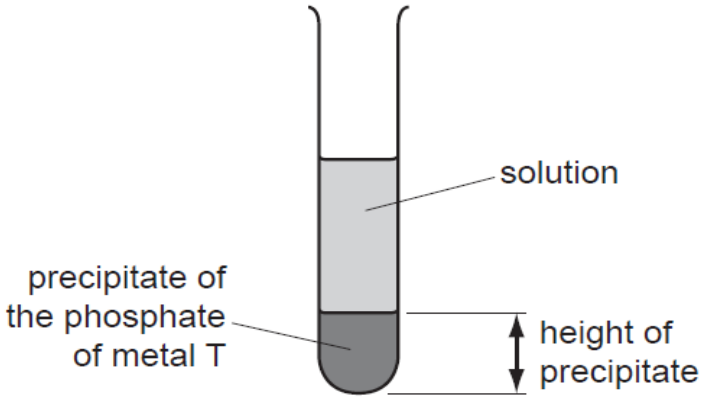
Volume of oxygen left = ……cm^3

Volume of carbon dioxide formed = ……..cm^3 [2]

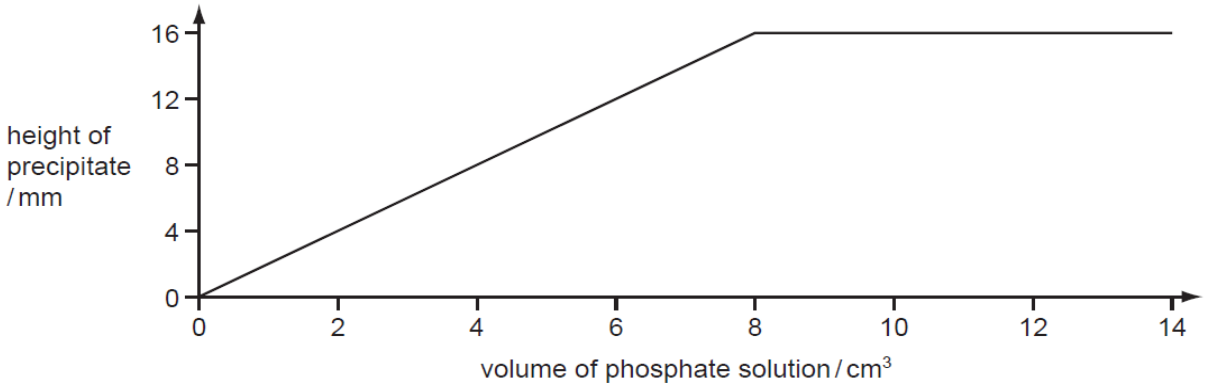
22. **J. 09 (5. b)**

(b) The formulae of insoluble compounds can be found by precipitation reactions.

To 12.0 cm^3 of an aqueous solution of the nitrate of metal T was added 2.0 cm^3 of aqueous sodium phosphate, Na_3PO_4. The concentration of both solutions was 1.0 mol / dm^3. When the precipitate had settled, its height was measured.



The experiment was repeated using different volumes of the phosphate solution. The results are shown on the following graph.



What is the formula of the phosphate of metal T ? Give your reasoning.

……

……

…….. [3]

23. **J. 09 (9)**

Quantities of chemicals, expressed in moles, can be used to find the formula of a compound, to establish an equation and to determine reacting masses.

(a) A compound contains 72% magnesium and 28% nitrogen. What is its empirical formula?

……

……..……[2]

(b) A compound contains only aluminium and carbon. 0.03 moles of this compound reacted with excess water to form 0.12 moles of $Al(OH)_3$ and 0.09 moles of CH_4

Write a balanced equation for this reaction.

……..……

……...[2]

(c) 0.07 moles of silicon reacts with 7.2 g of fluorine.

$$Si + 2F_2 \longrightarrow SiF_4$$

(i) Which one is the limiting reagent? Explain your choice.

…..……..

… ……[3]

(ii) How many moles of SiF_4 are formed?

…….. . ……[1]

24. **J. 2011 (32)[7, b,i]**

(b) Phosphorus trichloride reacts with water to form two acids.

(i) Balance the equation for this reaction.

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

[1]

25. **N. 2011 (33) [1, b and c]**

(b) Predict the formula of each of the following compounds.

(i) germanium oxide .....

(ii) tellurium bromide ..... [2]

(c) Give the formula of each of the following ions.

(i) strontium .....

(ii) fluoride ..... [2]

26. **N. 2012 (31) [2, c]**

(c) Fluorine, the most reactive halogen, forms compounds with the other halogens. It forms two compounds with bromine.

Deduce their formulae from the following information.

Compound 1

The mass of one mole of this compound is 137 g.

Its formula is …… ..... [1]

Compound 2

0.02 moles of this compound contain 0.02 moles of bromine atoms and 0.1 moles of fluorine atoms.

Its formula is …… ..... [1]