PRACTICE EXAMINATION QUESTIONS FOR 1.2 AMOUNT OF SUBSTANCE

1. Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

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(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas .....

Total moles of gas .....

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(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine .....

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Mass of nitroglycerine .....

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(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.
(The gas constant $R = 8.31$ J $K^{-1}mol^{-1}$)

Ideal gas equation .....

Pressure .....

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(4)
(Total 11 marks)

2. Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(a) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

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(b) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

…… Cl_2 + …… NaOH → …… NaCl + $NaClO_3$ + $3H_2O$

(3)
(Total 3 marks)

3. Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

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(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.
State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation .....

Moles of oxygen .....

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(5)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

(i) State what is meant by the term *empirical formula*.

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(ii) Use the data above to calculate the empirical formula of **Y**.

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(4)

(c) Deduce an equation for the decomposition of KNO_3 into **Y** and oxygen.

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(1)
(Total 10 marks)

4. The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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(4)
(Total 4 marks)

5. When aluminium is added to an aqueous solution of copper(II) chloride, $CuCl_2$, copper metal and aluminium chloride, $AlCl_3$, are formed. Write an equation to represent this reaction.

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(1)
(Total 1 mark)

6. (a) Lead(II) nitrate may be produced by the reaction between nitric acid and lead(II) oxide as shown by the equation below.

$$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$$

An excess of lead(II) oxide was allowed to react with 175 cm^3 of 1.50 mol dm^{-3} nitric acid. Calculate the maximum mass of lead(II) nitrate which could be obtained from this reaction.

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(4)

(b) An equation representing the thermal decomposition of lead(II) nitrate is shown below.

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

A sample of lead(II) nitrate was heated until the decomposition was complete. At a temperature of 500 K and a pressure of 100 kPa, the total volume of the gaseous mixture produced was found to be 1.50×10^{-4} m^3.

(i) State the ideal gas equation and use it to calculate the total number of moles of gas produced in this decomposition.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation .....

Total number of moles of gas .....

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(ii) Deduce the number of moles, and the mass, of NO_2 present in this gaseous mixture.
(If you have been unable to calculate the total number of moles of gas in part (b)(i), you should assume this to be 2.23×10^{-3} mol. This is not the correct answer.)

Number of moles of NO_2 .....

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Mass of NO_2 .....

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(7)
(Total 11 marks)

7. (a) Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

Write an equation for the reaction between ammonia and sodium.

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(1)

(b) A salt, **X**, contains 16.2% by mass of magnesium, 18.9% by mass of nitrogen and 64.9% by mass of oxygen.

(i) State what is meant by the term *empirical formula*.

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(ii) Determine the empirical formula of **X**.

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(3)
(Total 4 marks)

8. (a) Ammonium sulphate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulphate was heated with 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide. To ensure that all the ammonium sulphate reacted, an excess of sodium hydroxide was used.
Heating was continued until all of the ammonia had been driven off as a gas.
The unreacted sodium hydroxide remaining in the solution required 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid for neutralisation.

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

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(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

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(iii) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

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(iv) Use your answers from parts (a) (i) and (a) (iii) to calculate the number of moles of NaOH which reacted with the ammonium sulphate.

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(v) Use your answer in part (a) (iv) to calculate the number of moles and the mass of ammonium sulphate in the sample.
(If you have been unable to obtain an answer to part (a) (iv), you may assume that the number of moles of NaOH which reacted with ammonium sulphate equals 2.78×10^{-2} mol. This is not the correct answer.)

Moles of ammonium sulphate .....

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Mass of ammonium sulphate .....

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(7)

(b) A 0.143g gaseous sample of ammonia occupied a volume of 2.86×10^{-4} m^3 at a temperature ***T*** and a pressure of 100 kPa.

State the ideal gas equation, calculate the number of moles of ammonia present and deduce the value of the temperature ***T***.

(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation .....

Moles of ammonia .....

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*Value of **T*** .....

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(4)

(Total 11 marks)

9. Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation .....

Calculation .....

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(Total 5 marks)

10. A hydrocarbon, **W,** contains 92.3% carbon by mass. The relative molecular mass of **W** is 78.0

(a) Calculate the empirical formula of **W**.

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(b) Calculate the molecular formula of **W**.

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(4)
(Total 4 marks)

11. (a) One isotope of sodium has a relative mass of 23.

Calculate the mass, in grams, of a single atom of this isotope of sodium.
(The Avogadro constant, L, is 6.023×1023 mol^{-1})

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(2)
(Total 2 marks)

12. (a) State what is meant by the term *empirical formula.*

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(b) A chromium compound contains 28.4% of sodium and 32.1% of chromium by mass, the remainder being oxygen.
Calculate the empirical formula of this compound.

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(4)
(Total 4 marks)

13. (a) Titanium(IV) chloride reacted with water as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \rightarrow 4HCl(aq) + TiO_2(s)$$

The reaction produced 200 cm^3 of a 1.20M solution of hydrochloric acid. Calculate the number of moles of HCl in the solution and use your answer to find the original mass of $TiCl_4$

Moles of HCl......

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Mass of $TiCl_4$.....

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(4)

(b) Calculate the volume of 1.10 M sodium hydroxide solution which would be required to neutralise a 100 cm^3 portion of the 1.20 M solution of hydrochloric acid.

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(3)

(c) An excess of magnesium metal was added to a 100 cm^3 portion of the 1.20 M solution of hydrochloric acid. Calculate the volume of hydrogen gas produced at 98 kPa and 20°C.

$$Mg(s) + 2HCl(aq) \rightarrow 4\ MgCl_2(aq) + H_2(g)$$

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(4)
(Total 11 marks)

14.

(a) Calculate the maximum mass of sodium sulphide that can be obtained from 10.0 g of sulphur.

(2)

(b) Calculate the minimum volume of hydrogen, in cm^3, at 298 K and 101.3 kPa, that is needed to form 5.00 g of hydrogen sulphide.

(3)
(Total 5 marks)

15. When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

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(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

*Moles of **X*** .....

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*Relative molecular mass of **X*** .....

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(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

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(3)

(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

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(1)
(Total 9 makrs)

16. (a) Calculate the concentration, in mol dm^{-3}, of the solution formed when 19.6 g of hydrogen chloride, HCl, are dissolved in water and the volume made up to 250 cm^3.

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(3)

(b) The carbonate of metal **M** has the formula M_2CO_3. The equation for the reaction of this carbonate with hydrochloric acid is given below.

$$M_2CO_3 + 2HCl \rightarrow 2MCl + CO_2 + H_2O$$

A sample of M_2CO_3, of mass 0.394 g, required the addition of 21.7 cm^3 of a 0.263 mol dm^{-3} solution of hydrochloric acid for complete reaction.

(i) Calculate the number of moles of hydrochloric acid used.

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(ii) Calculate the number of moles of M_2CO_3 in 0.394 g.

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(iii) Calculate the relative molecular mass of M_2CO_3

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(iv) Deduce the relative atomic mass of **M** and hence suggest its identity.

*Relative atomic mass of **M*** .....

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*Identity of **M*** .....

(6)
(Total 9 marks)

17. (a) The mass of one mole of $_1H$ atoms is 1.0078 g and that of one $_1H$ atom is 1.6734×10^{-24} g.
Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

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(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

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(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa. Calculate the number of moles of ammonia in the sample.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

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(3)

(d) A solution containing 0.732 mol of ammonia was made up to 250 cm^3 in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

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(2)

(e) A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

In a titration, 25.0 cm^3 of a 1.24 mol dm^{-3} solution of sulphuric acid required 30.8 cm_3 of this ammonia solution for complete reaction.

(i) Calculate the concentration of ammonia in this solution.

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(ii) Calculate the mass of ammonium sulphate in the solution at the end of this titration.

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(6)

(f) The reaction of magnesium nitride, Mg_3N_2, with water produces ammonia and magnesium hydroxide. Write an equation for this reaction.

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(2)
(Total 16 marks)

18. (a) Define the term *relative molecular mass*.

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(2)

(b) Give the meaning of the term *empirical formula*.

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(1)

(c) Compound **X** contains 32.9% by mass of carbon and 1.40% by mass of hydrogen; the remainder is oxygen.

(i) Calculate the empirical formula of **X.**

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(ii) The relative molecular mass of **X** is 146. Deduce its molecular formula.

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(4)

(d) A 1.0 kg sample of methane was burned in air. It reacted as follows:

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O(g)$$

(i) Calculate the number of moles in 1.0 kg of methane.

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(ii) Calculate the volume of oxygen gas, measured at 298 K and 100 kPa, which would be required for the complete combustion of 1.0 kg of methane.

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(6)
(Total 13 marks)

19. Give the meaning of the term *mole* as used in the phrase 'one mole of molecules'.

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(1)
(Total 1 mark)

20. (a) What is the name given to the number of molecules in one mole of carbon dioxide?

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(1)

(b) (i) State the ideal gas equation.

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(ii) Calculate the volume of 1.00 mol of carbon dioxide gas at 298 K and 100 kPa. (The gas constant $R = 8.31$ J mol^{-1} K^{-1})

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(iii) Calculate the mass of carbon dioxide gas at 273 K and 500 kPa contained in a cylinder of volume 0.00500 m^3.

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(7)

(c) Hydrogen can be made by the reaction of hydrochloric acid with magnesium according to the equation

$$2HCl + Mg \rightarrow MgCl_2 + H_2$$

What mass of hydrogen is formed when 100cm^3 of hydrochloric acid of concentration 5.0 mol dm^{-3} reacts with an excess of magnesium?

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(3)

(d) A compound of iron contains 38.9% by mass of iron and 16.7% by mass of carbon, the remainder being oxygen.

(i) Determine the empirical formula of the iron compound.

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(ii) When one mole of this iron compound is heated, it decomposes to give one mole of iron(II) oxide, FeO, one mole of carbon dioxide and one mole of another gas. Identify this other gas. (The molecular formula of the iron compound is the same as its empirical formula.)

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(4)

(Total 15 marks)

21. Ammonium nitrate can be prepared by the reaction between ammonia and nitric acid:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

(a) The concentration of a nitric acid solution is 2.00 mol dm^{-3}. Calculate the volume of this solution which would be required to react with exactly 20.0 g of ammonia.

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(4)

(b) A sample of ammonium nitrate decomposed on heating as shown in the equation below.

$$NH_4NO_3 \rightarrow 2H_2O + N_2 + \tfrac{1}{2}O_2$$

On cooling the resulting gases to 298 K, the volume of nitrogen and oxygen together was found to be 0.0500 m^3 at a pressure of 95.0 kPa.

(i) State the ideal gas equation and use it to calculate the total number of moles of nitrogen and oxygen formed. (The gas constant R = 8.31 J mol^{-1} K^{-1})

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(ii) Using your answer to part (b)(i), deduce the number of moles of ammonium nitrate decomposed and hence calculate the mass of ammonium nitrate in the sample.

Moles of ammonium nitrate .....

Mass of ammonium nitrate .....

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(6)
(Total 10 marks)

22. The mass of one atom of ^{12}C is 1.99×10^{-23} g. Use this information to calculate a value for the Avogadro constant. Show your working.

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(2)
(Total 2 marks)

23. The equation below represents the thermal decomposition of $KClO_3$.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

(a) Calculate the mass of oxygen which could be produced by the complete decomposition of 1.47 g of $KClO_3$.

(2)

(b) Calculate the mass of $KClO_3$ required to produce 1.00 dm^3 (at 20 °C and 101.3 kPa) of oxygen.

(3)
(Total 5 marks)

24. (a) What experimental data are required in order to calculate the empirical formula of a compound?

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(1)

(b) Give the meaning of the term *molecular formula.*

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(1)

(c) When barium nitrate is heated it decomposes as follows:

$$Ba(NO_3)_2(s) \rightarrow BaO(s) + 2NO_2(g) + ½\ O_2(g)$$

(i) Calculate the total volume, measured at 298 K and 100 kPa, of gas which is produced by decomposing 5.00 g of barium nitrate.

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(ii) Calculate the volume of 1.20 M hydrochloric acid which is required to neutralise exactly the barium oxide formed by decomposition of 5.00 g of barium nitrate. Barium oxide reacts with hydrochloric acid as follows

$$BaO(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + H_2O(l)$$

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(7)
(Total 9 marks)

25. The mass spectrum of a compound has a molecular ion peak at m/z = 168.
Elemental analysis shows it to contain 42.9% carbon, 2.4% hydrogen and 16.7% nitrogen by mass.
The remainder is oxygen.

Calculate the empirical and molecular formulae of this compound

(4)
(Total 4 marks)

26. Compound **X** contains only boron and hydrogen. The percentage by mass of boron in **X** is 81.2%. In the mass spectrum of **X** the peak at the largest value of *m/z* occurs at 54.

(a) Use the percentage by mass data to calculate the empirical formula of **X**.

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(b) Deduce the molecular formula of **X**.

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(4)
(Total 4 marks)

27. (a) Define the term *relative molecular* mass.

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(2)

(b) The mass of one atom of ^{12}C is 1.993×10^{-23} g. Use this mass to calculate a value for the Avogadro constant (L) showing your working.

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(1)
(Total 3 marks)

28. When iodine reacts directly with fluorine, a compound containing 57.2% by mass of iodine is formed.

(a) Determine the empirical formula of this compound.

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(b) The empirical formula of this compound is the same as the molecular formula. Write a balanced equation for the formation of this compound.

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(4)
(Total 4 marks)

29. Compound **A** ($M_r = 215.8$) contains 22.24% carbon, 3.71% hydrogen and 74.05% bromine by mass. Show that the molecular formula of **A** is $C_4H_8Br_2$.

(3)
(Total 3 marks)