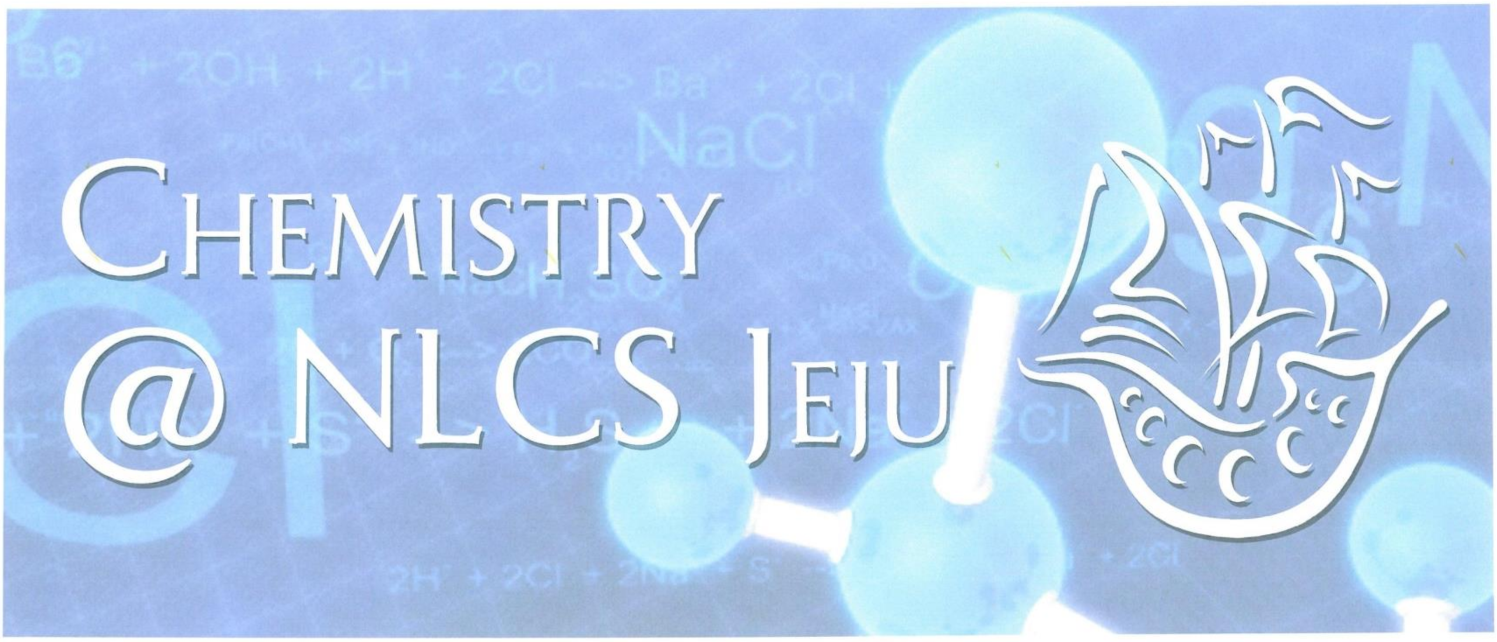
Topic 1

HIGHER Level



Summer & Winter Papers

Summer 1999 to Summer 2013

Name:________________________________

Topic Exam Statistics (Paper 2):

Section	Marks	% of All Marks	Last four exams marks	Last four exams %
A	163/1080	**15%**	/160	%
B	25/2700	**1%**	/400	%
TOTAL	188/3780	**5%**	/560	%

Total number of papers represented here is 27, each with 40 marks of Section A and 100 marks of section B (4 questions from which you chose to answer only 2)

1. Two groups of students (Group A and Group B) carried out a project* on the chemistry of some group 7 elements (the halogens) and their compounds.

(a) In the first part of the project, the two groups had a sample of iodine monochloride (a corrosive brown liquid) prepared for them by their teacher using the following reaction.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$$

The following data were recorded.

Mass of $I_2(s)$	10.00 g
Mass of $Cl_2(g)$	2.24 g
Mass of $ICl(l)$ obtained	8.60 g

(i) State the number of significant figures for the masses of $I_2(s)$ and $ICl(l)$. *[1]*

$I_2(s)$: . . . .

$ICl(l)$: . . . .

(ii) The iodine used in the reaction was in excess. Determine the theoretical yield, in g, of $ICl(l)$. *[3]*

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(iii) Calculate the percentage yield of $ICl(l)$. *[1]*

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HL SECTION A 12w

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1. Two groups of students (Group A and Group B) carried out a project* on the chemistry of some group 7 elements (the halogens) and their compounds.

(a) In the first part of the project, the two groups had a sample of iodine monochloride (a corrosive brown liquid) prepared for them by their teacher using the following reaction.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$$

The following data were recorded.

Mass of $I_2(s)$	10.00 g
Mass of $Cl_2(g)$	2.24 g
Mass of $ICl(l)$ obtained	8.60 g

(c) The students reacted $ICl(l)$ with $CsBr(s)$ to form a yellow solid, $CsICl_2(s)$, as one of the products. $CsICl_2(s)$ has been found to produce very pure $CsCl(s)$ which is used in cancer treatment.

To confirm the composition of the yellow solid, Group A determined the amount of iodine in 0.2015 g of $CsICl_2(s)$ by titrating it with 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$. The following data were recorded for the titration.

Mass of $CsICl_2(s)$ taken (in g ± 0.0001)	0.2015
Initial burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	1.05
Final burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	25.25

(i) Calculate the percentage of iodine by mass in $CsICl_2(s)$, correct to **three** significant figures. *[1]*

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(ii) State the volume, in cm^3, of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ used in the titration. *[1]*

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(iii) Determine the amount, in mol, of 0.0500 mol dm^{-3} $Na_2S_2O_3$(aq) added in the titration. *[1]*

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(iv) The overall reaction taking place during the titration is:

$$CsICl_2(s) + 2Na_2S_2O_3(aq) \rightarrow NaCl(aq) + Na_2S_4O_6(aq) + CsCl(aq) + NaI(aq)$$

Calculate the amount, in mol, of iodine atoms, I, present in the sample of $CsICl_2$(s). *[1]*

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(v) Calculate the mass of iodine, in g, present in the sample of $CsICl_2$(s). *[1]*

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(vi) Determine the percentage by mass of iodine in the sample of $CsICl_2$(s), correct to **three** significant figures, using your answer from (v). *[1]*

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(d) Group B heated the yellow solid, $CsICl_2(s)$, which turned white and released a brown gas which condensed into a brown liquid.

Group B identified the white solid as $CsCl(s)$. Suggest the identity of the brown liquid. *[1]*

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HL SECTION A 11w

1. Airbags are an important safety feature in vehicles. Sodium azide, potassium nitrate and silicon dioxide have been used in one design of airbag.

[Source: www.hilalairbag.net]

Sodium azide, a toxic compound, undergoes the following decomposition reaction under certain conditions.

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

Two students looked at data in a simulated computer-based experiment to determine the volume of nitrogen generated in an airbag.

(b) Using the simulation programme, the students entered the following data into the computer.

Temperature (T) / °C	**Mass of NaN_3(s) (m) / kg**	**Pressure (p) / atm**
25.00	0.0650	1.08

(i) State the number of significant figures for the temperature, mass and pressure data. *[1]*

T: . . . .

m: . . . .

p: . . . .

(ii) Calculate the amount, in mol, of sodium azide present. *[1]*

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(iii) Determine the volume of nitrogen gas, in dm^3, produced under these conditions based on this reaction. *[4]*

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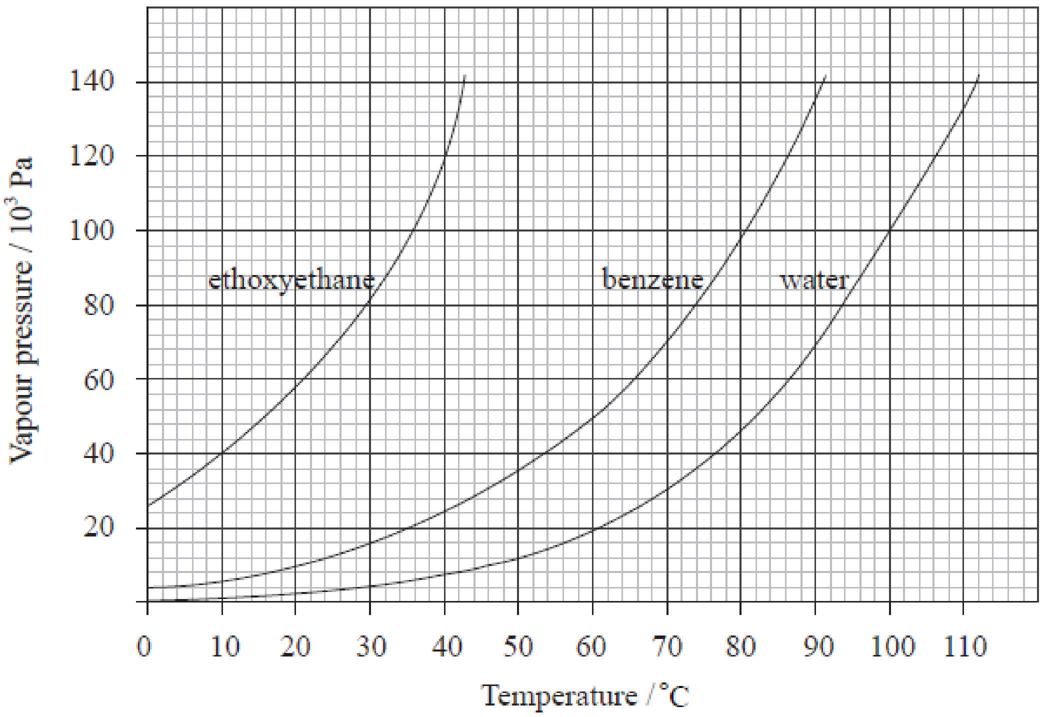
HL SECTION A 11s

5. The graph below illustrates how the vapour pressures of ethoxyethane, $CH_3CH_2OCH_2CH_3$, benzene, C_6H_6, and water, H_2O, change with temperature.



(a) Using data from the graph, explain the difference in vapour pressure of ethoxyethane, benzene and water at 30 °C. *[4]*

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(b) Use the graph to determine the boiling point of benzene at standard pressure. *[1]*

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HL SECTION A 09w NOT with Q1a

This balanced redox equation is needed to answer the question that follows:

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

1. The data below is from an experiment used to determine the percentage of iron present in a sample of iron ore. This sample was dissolved in acid and all of the iron was converted to Fe^{2+}. The resulting solution was titrated with a standard solution of potassium manganate(VII), $KMnO_4$. This procedure was carried out three times. In acidic solution, MnO_4^- reacts with Fe^{2+} ions to form Mn^{2+} and Fe^{3+} and the end point is indicated by a slight pink colour.

Titre	**1**	**2**	**3**
Initial burette reading / cm^3	1.00	23.60	10.00
Final burette reading / cm^3	24.60	46.10	32.50

Mass of iron ore / g	3.682×10^{-1}
Concentration of $KMnO_4$ solution / $mol\,dm^{-3}$	2.152×10^{-2}

(c) Calculate the amount, in moles, of MnO_4^- used in the titration. *[2]*

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(d) Calculate the amount, in moles, of Fe present in the 3.682×10^{-1} g sample of iron ore. *[2]*

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(e) Determine the percentage by mass of Fe present in the 3.682×10^{-1} g sample of iron ore. *[2]*

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1. The value of x in $Fe(NH_4)_2(SO_4)_2 . xH_2O$ can be found by determining the amount, in moles, of sulfate in the compound.
A 0.982 g sample was dissolved in water and excess $BaCl_2(aq)$ was added.
The precipitate of $BaSO_4$ was separated and dried and found to weigh 1.17 g.

(a) Calculate the amount, in moles of $BaSO_4$ in the 1.17 g precipitate. *[2]*

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(b) Calculate the amount, in moles, of sulfate in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[1]*

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(c) Calculate the amount, in moles, of iron in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[1]*

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(d) Determine the mass of the following present in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[3]*

(i) Iron

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(ii) Ammonium

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(iii) Sulfate

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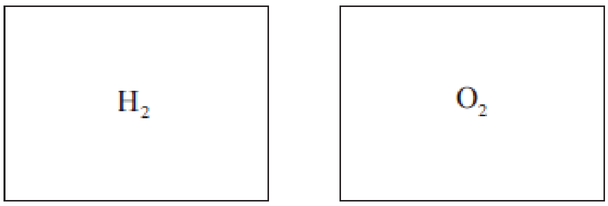
(e) Use your answer from part (d) to determine the amount, in moles, of water present in the 0.982g sample of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$. *[2]*

(f) Determine the amount, in moles, of $Fe(NH_4)_2(SO_4)_2$ and hence the value of x. *[2]*

HL SECTION A 08s

5. Two 1.00 dm^3 containers **A** and **B** each contain 2.00 g of the gas indicated at 25.0°C.



A **B**

(a) Calculate the pressure in container **B**. *[3]*

(b) Deduce **without** calculation whether the pressure in **A** is higher or lower than container **B** and explain your answer. *[2]*

1. 0.502 g of an alkali metal sulfate is dissolved in water and excess barium chloride solution, $BaCl_2(aq)$ is added to precipitate all the sulfate ions as barium sulfate, $BaSO_4(s)$. The precipitate is filtered and dried and weighs 0.672 g.

(a) Calculate the amount (in mol) of barium sulfate formed. *[2]*

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(b) Determine the amount (in mol) of the alkali metal sulfate present. *[1]*

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(c) Determine the molar mass of the alkali metal sulfate and state its units. *[2]*

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(d) Deduce the identity of the alkali metal, showing your workings. *[2]*

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(e) Write an equation for the precipitation reaction, including state symbols. *[2]*

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HL SECTION A 07w

3. Two flasks of equal volume are at the same temperature. One contains oxygen gas and the other contains an equal mass of methane gas.

(a) Compare the average kinetic energy of oxygen molecules with those of methane molecules and explain your reasoning. *[2]*

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(b) Identify whether oxygen or methane molecules will have the **greater** average velocity at this temperature and explain your choice. *[2]*

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(c) Deduce whether the pressure in the flask containing methane is less than, greater than, or equal to, the pressure in the flask containing oxygen. Explain your choice. *[3]*

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HL SECTION A 07s

4. (a) Propane and oxygen react according to the following equation.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Calculate the volume of carbon dioxide and water vapour produced and the volume of oxygen remaining, when 20.0 dm^3 of propane reacts with 120.0 dm^3 of oxygen. All gas volumes are measured at the same temperature and pressure. *[3]*

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(b) State and explain what would happen to the pressure of a given mass of gas when its absolute temperature and volume are both doubled. *[3]*

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(c) (i) Crocetin consists of the elements carbon, hydrogen and oxygen. Determine the empirical formula of crocetin, if 1.00 g of crocetin forms 2.68 g of carbon dioxide and 0.657 g of water when it undergoes complete combustion. *[6]*

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(ii) Determine the molecular formula of crocetin given that 0.300 mole of crocetin has a mass of 98.5 g. *[2]*

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HL SECTION A 06w

1. (a) An organic compound **A** contains 62.0 % by mass of carbon, 24.1 % by mass of nitrogen, the remainder being hydrogen.

(i) Determine the percentage by mass of hydrogen and the empirical formula of **A**. *[3]*

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(ii) Define the term *relative molecular mass*. *[2]*

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(iii) The relative molecular mass of **A** is 116. Determine the molecular formula of **A**. *[1]*

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HL SECTION A 06w

2. Methylamine can be manufactured by the following reaction.

$$CH_3OH(g) + NH_3(g) \rightarrow CH_3NH_2(g) + H_2O(g)$$

(d) In the manufacturing process 2000 kg of each reactant are mixed together.

(i) Identify the limiting reactant, showing your working. *[2]*

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(ii) Calculate the maximum mass, in kg, of methylamine that can be obtained from this mixture of reactants. *[2]*

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HL SECTION A 06s

3. The reaction below represents the reduction of iron ore to produce iron.

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$

A mixture of 30 kg of Fe_2O_3 and 5.0 kg of C was heated until no further reaction occurred. Calculate the maximum mass of iron that can be obtained from these masses of reactants. *[5]*

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HL SECTION A 05s

2. The percentage composition by mass of a hydrocarbon is C = 85.6 % and H = 14.4 %.

(a) Calculate the empirical formula of the hydrocarbon. *[2]*

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(b) A 1.00 g sample of the hydrocarbon at a temperature of 273 K and a pressure of 1.01×10^{5} Pa (1.00 atm) has a volume of 0.399 dm^{3}.

(i) Calculate the molar mass of the hydrocarbon. *[2]*

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(ii) Deduce the molecular formula of the hydrocarbon. *[1]*

HL SECTION A 04w

1. 27.82 g of hydrated sodium carbonate crystals, $Na_2CO_3 . xH_2O$, was dissolved in water and made up to 1.000 dm^3. 25.00 cm^3 of this solution was neutralized by 48.80 cm^3 of hydrochloric acid of concentration $0.1000 \text{ mol dm}^{-3}$.

(a) Write an equation for the reaction between sodium carbonate and hydrochloric acid. *[2]*

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(b) Calculate the molar concentration of the sodium carbonate solution neutralized by the hydrochloric acid. *[3]*

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(c) Determine the mass of sodium carbonate neutralized by the hydrochloric acid and hence the mass of sodium carbonate present in the 1.000 dm^3 of solution. *[3]*

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(d) Calculate the mass of water in the hydrated crystals and hence find the value of x. *[4]*

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2. 100 cm^3 of ethene, C_2H_4, is burned in 400 cm^3 of oxygen, producing carbon dioxide and some liquid water. Some oxygen remains unreacted.

(a) Write the equation for the complete combustion of ethene. [2]

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(b) Calculate the volume of carbon dioxide produced and the volume of oxygen remaining. [2]

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HL SECTION A 04s

3. (a) Write an equation for the formation of zinc iodide from zinc and iodine. [1]

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(b) 100.0 g of zinc is allowed to react with 100.0 g of iodine producing zinc iodide. Calculate the amount (in moles) of zinc and iodine, and hence determine which reactant is in excess. [3]

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(c) Calculate the mass of zinc iodide that will be produced. [1]

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HL SECTION A 03w

2. (a) Aqueous XO_4^{3-} ions form a precipitate with aqueous silver ions, Ag^+. Write a balanced equation for the reaction, including state symbols. *[2]*

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(b) When 41.18 cm^3 of a solution of aqueous silver ions with a concentration of 0.2040 mol dm^{-3} is added to a solution of XO_4^{3-} ions, 1.172 g of the precipitate is formed.

(i) Calculate the amount (in moles) of Ag^+ ions used in the reaction. *[1]*

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(ii) Calculate the amount (in moles) of the precipitate formed. *[1]*

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(iii) Calculate the molar mass of the precipitate. *[2]*

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(iv) Determine the relative atomic mass of X and identify the element. *[2]*

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HL SECTION A 02w

5. An element X reacts with oxygen to form the oxide X_2O_3.

(a) Write a balanced equation for the reaction. *[1]*

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(b) If 2.199 g of the oxide was obtained from 1.239 g of X, calculate the relative atomic mass of X and identify the element. *[5]*

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(c) Nitrogen also forms an oxide on reaction with oxygen. This oxide contains 25.9 % of nitrogen and 74.1 % of oxygen by mass. Calculate the empirical formula of this second oxide. *[3]*

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HL SECTION A 02s

4. A student is asked to prepare some copper(II) nitrate by reacting nitric acid with copper(II) oxide.

(a) Write a balanced equation for this reaction. *[1]*

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(b) The student carries out this reaction by adding 0.0345 mol of copper(II) oxide to 36.0 cm^3 of 1.15 $mol\,dm^{-3}$ nitric acid solution. Calculate the amount (in mol) of nitric acid. *[1]*

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(c) Use the information in (a) and (b) to identify the limiting reagent and determine the amount (in mol) of copper(II) nitrate formed. *[2]*

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(d) The product of this reaction is isolated as copper(II) nitrate trihydrate. Calculate the molar mass of copper(II) nitrate trihydrate and the mass of product obtained. *[2]*

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HL SECTION A 01w

2. Indigo is a blue dye which contains only carbon, nitrogen, hydrogen and oxygen.

(a) 2.036 g of indigo was completely oxidised to produce 5.470 g of carbon dioxide and 0.697 g of water. Calculate:

(i) the percentage by mass of carbon in indigo; *[2]*

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(ii) the percentage by mass of hydrogen in indigo. *[2]*

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(b) If the percentage by mass of nitrogen in the indigo sample is 10.75 %, determine the empirical formula of indigo. *[3]*

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(c) If the molar mass is approximately 260 $g\,mol^{-1}$, determine the molecular formula of indigo. *[2]*

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HL SECTION A 01w

3. This question deals with gases and liquids.

(a) The mass of a gas sample is measured under certain conditions. List the variables that must be measured and show how these can be used to determine the molar mass of the gas. *[4]*

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(c) A small amount of a volatile liquid is added to a 50.0 cm^3 evacuated container. Twice the amount of the same liquid is added to a second 50.0 cm^3 evacuated container, and separately to a 100 cm^3 evacuated container. The three systems are allowed to reach equilibrium at the same temperature, and some liquid remains in each flask. Compare the pressure due to the vapour in the three containers and explain your answer. *[3]*

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HL SECTION A 01s

2. (a) An anti-cancer drug called Cisplatin has the following percentage composition by mass:

$$Pt = 65.01\ \%,\ Cl = 23.63\ \%,\ N = 9.340\ \%,\ H = 2.020\ \%.$$

Calculate the empirical formula of Cisplatin.
(Relative Atomic Masses are $Pt = 195.09$, $Cl = 35.45$, $N = 14.01$, $H = 1.01$.) *[3]*

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(b) The molecular and empirical formulas of Cisplatin are the same. Analysis of the molecule shows platinum to be the central atom, being bonded to four separate atoms; the hydrogen is bonded to nitrogen. Draw a representation of the molecule. *[1]*

(c) $16.20 \times 10^{-3}\ dm^3$ of $0.1020\ mol\,dm^{-3}$ aqueous $AgNO_3$ is added to $14.80 \times 10^{-3}\ dm^3$ of $0.1250\ mol\,dm^{-3}$ aqueous NaCl. Calculate the maximum mass (g) of AgCl which could be obtained from this reaction. (Relative Atomic Masses are $Ag = 107.87$, $Cl = 35.45$.) *[4]*

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HL B 12w

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(b) An ester which gives apples their characteristic smell contains C, H and O. When 3.00×10^{-3} g of this ester were completely combusted, 6.93×10^{-3} g of CO_2 and 2.83×10^{-3} g of H_2O were produced.

(i) Determine the empirical formula of the ester, showing your working. *[4]*

(ii) The molar mass of the ester is 116.18 g mol^{-1}. Determine its molecular formula. *[1]*

HL B 11w

9

(c) An important environmental consideration is the appropriate disposal of cleaning solvents. An environmental waste treatment company analysed a cleaning solvent, **J**, and found it to contain the elements carbon, hydrogen and chlorine only. The chemical composition of **J** was determined using different analytical chemistry techniques.

Combustion Reaction:

Combustion of 1.30 g of **J** gave 0.872 g CO_2 and 0.089 g H_2O.

Precipitation Reaction with $AgNO_3(aq)$:

0.535 g of **J** gave 1.75 g AgCl precipitate.

(i) Determine the percentage by mass of carbon and hydrogen in **J**, using the combustion data. *[3]*

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(ii) Determine the percentage by mass of chlorine in **J**, using the precipitation data. *[1]*

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(iii) The molar mass was determined to be 131.38 g mol^{-1}. Deduce the molecular formula of **J**. *[3]*

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HL B 11s

9e

Nitrogen monoxide may be removed from industrial emissions via a reaction with ammonia as shown by the equation below.

$$4NH_3(g) + 6NO(g) \rightarrow 5N_2(g) + 6H_2O(l)$$

(iii) 30.0 dm^3 of ammonia reacts with 30.0 dm^3 of nitrogen monoxide at 100 °C. Identify which gas is in excess and by how much and calculate the volume of nitrogen produced. *[2]*

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HL B 06w

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(a) (i) Gaseous compound = Methane

(ii) Calculate the volume that 0.0200 mol of the gaseous compound in (a)(i) would occupy at 70 °C and 1.10×10^5 Pa. *[3]*

IB HL 1 Paper 2 s99 to s13 incl W Mark Scheme

HL SECTION A 12w

1. (a) (i) *I_2(s)*: four/4 **and** *ICl(l)*: three/3; *[1]*

(ii) $n(\text{Cl}_2) = \left(\frac{2.24}{2 \times 35.45} = \right) 0.0316/3.16 \times 10^{-2}$ (mol);

Allow answers such as 3.2×10^{-2}/0.032/3.15×10^{-2}/0.0315 (mol).

$n(\text{ICl}) = 2 \times 0.0316$ / $0.0632/6.32 \times 10^{-2}$ (mol);

Allow answers such as 6.4×10^{-2}/0.064/6.3×10^{-2}/0.063 (mol).

$m(\text{ICl}) = (0.0632 \times 162.35 =)\ 10.3$ (g); *[3]*

Allow answers in range 10.2 to 10.4 (g).

Award [3] for correct final answer.

(iii) $\left(\frac{8.60}{10.3} \times 100 = \right) 83.5\%$; *[1]*

Allow answers in the range of 82.5 to 84.5%.

HL SECTION A 12w

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(c) (i) $\left(\frac{126.90}{330.71} \times 100\right) = 38.4\ \%$; *[1]*

(ii) $(25.25 - 1.05) = 24.20\ (\text{cm}^3)$; *[1]*

Accept 24.2 (cm^3) but not 24 (cm^3).

(iii) $\left(\frac{24.20 \times 5.00 \times 10^{-2}}{1000}\right) = 1.21 \times 10^{-3}/0.00121$ (mol); *[1]*

(iv) $(0.5 \times 1.21 \times 10^{-3}) = 6.05 \times 10^{-4}/0.000605$ (mol); *[1]*

Accept alternate method e.g. (0.384/126.9 × 0.2015) = 6.10×10^{-4}/0.000610 (mol).

(v) $(126.90 \times 6.05 \times 10^{-4}) = 7.68 \times 10^{-2}/0.0768$ (g); *[1]*

Accept alternate method e.g. ($6.10 \times 10^{-4} \times 126.9$) or ($0.2015 \times 0.384$) = 7.74×10^{-2}/0.00774 (g).

(vi) $\left(\frac{7.68 \times 10^{-2}}{0.2015} \times 100\right) = 38.1\ \%$; *[1]*

Answer must be given to three significant figures.

(d) ICl / iodine monochloride; *[1]*

Do not accept iodine or bromine.

HL SECTION A 11w

1

(b) (i) T: 4 **and** m: 3 **and** p: 3; *[1]*

(ii) $n = (65.0 / 65.02) = 1.00$ (mol) ; *[1]*

No penalty for using whole number atomic masses.

(iii) $n(N_2) = \left(\frac{3}{2} \times 1.00 = \right) 1.50$ (mol) ;

$T = ((25.00 + 273.15) =) 298.15$ K / $(25.00 + 273) = 298$ K ;

$p = 1.08 \times 1.01 \times 10^5$ Pa / $1.08 \times 1.01 \times 10^2$ kPa / 1.09×10^5 Pa / 1.09×10^2 kPa ;

$V = \frac{nRT}{p} = \frac{(10^3)(1.50)(8.31)(298.15/298)}{(1.08 \times 1.01 \times 10^5)} = 34.1\ (\text{dm}^3)$; *[4]*

Award [4] for correct final answer.

*Award **[3 max]** for 0.0341 (dm^3) or 22.7 (dm^3).*

*Award **[3 max]** for 34.4 (dm^3).*

*Award **[2 max]** for 22.9 (dm^3).*

*Award **[2 max]** for 0.0227 (dm^3).*

*Award **[2 max]** for 0.034 (dm^3).*

HL SECTION A 11s

5. (a) vapour pressure ethoxyethane (81×10^3 Pa) > vapour pressure benzene (16×10^3 Pa) > vapour pressure water (4×10^3 Pa);

If three correct vapour pressure values related to each substance are stated alone award M1.

Allow range of $80\text{–}85 \times 10^3$ Pa, $14\text{–}18 \times 10^3$ Pa and $3\text{–}7 \times 10^3$ Pa.

Do not award mark for comparisons of just two substances.

water has hydrogen bonding;

benzene has van der Waals'/London/dispersion forces;

ethoxyethane has dipole–dipole forces (and van der Waals'/London/dispersion) but they are weaker than benzene; *[4]*

(b) 81 °C ; *[1]*

Allow 80–82 °C.

HL SECTION A 09w

1. (a) $MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$ *[2]*

Award [2] if correctly balanced.
Award [1] for correctly placing H^+ and H_2O.
Award [1 max] for correct balanced equation but with electrons shown.
Ignore state symbols.

(b) Fe^{2+} / iron(II); *[1]*

Do not accept iron.

(c) $n = 2.152\times10^{-2}\times2.250\times10^{-2}$;

4.842×10^{-4} (mol); *[2]*

Award [1] for correct volume
Award [1] for correct calculation.

(d) 1 mol of MnO_4^- reacts with 5 mol of Fe^{2+};

$5\times4.842\times10^{-4} = 2.421\times10^{-3}$ (mol); *[2]*

(same number of moles of Fe in the iron ore)

Allow ECF from part (a) and (c) provided some mention of mole ratio is stated.

(e) $2.421\times10^{-3}\times55.85 = 0.1352\,(g)$;

$\frac{0.1352}{0.3682}\times100 = 36.72\%$; *[2]*

Allow ECF from part (d).

HL SECTION A 08s

1. (a) 1.17/233.4;

5.01×10^{-3} / 5.02×10^{-3} (mol); *[2]*

(b) 5.01×10^{-3} / 5.02×10^{-3} (mol); *[1]*

(c) 2.50×10^{-3} / 2.51×10^{-3} (mol); *[1]*

(d) (i) Iron $55.85\times2.50\times10^{-3} = 0.140\,g$;

(ii) Ammonium $18.05\times5.01\times10^{-3} = 0.0904\,g$;

(iii) Sulfate $96.06\times5.01\times10^{-3} = 0.481\,g$; *[3]*

(e) $0.982\,g - 0.711\,g = 0.271\,g\,H_2O$;

$\frac{0.271}{18.02} = 1.50\times10^{-2}$ (mol); *[2]*

(f) $\frac{0.711}{284.07} = 2.50\times10^{-3}$ (mol);

$\frac{1.50\times10^{-2}}{2.50\times10^{-3}} = 6$ (mol); *[2]*

*Award **[2]** for the correct final answer.*
Allow ECF throughout question one.

HL SECTION A 08s

5. (a) $PV = nRT$ / $P = \frac{nRT}{V}$;

$P = \frac{2.00 \times 8.31 \times 298}{1.00 \times 32.0}$ / $\frac{0.0625 \times 8.31 \times 298}{1.00}$ / $\frac{0.0625 \times 0.0821 \times 298}{1.00}$;

$P = 155$ kPa / 1.53 atm; *[3]*

*Apply –**1(U)** rule*
*Award **[3]** for final answer.*

(b) higher (because M_r is lower);
number of moles/particles/molecules is higher / more frequent collisions with the wall of the container; *[2]*

HL SECTION A 07w

1. (a) $M(BaSO_4)(= 137.34 + 32.06 + 4(16.00)) = 233.40\,(g\,mol^{-1})$;
Accept 233.4 but not 233

$n(BaSO_4)\left(= \frac{0.672\ g}{233.40\ g\ mol^{-1}}\right) = 0.00288 / 2.88 \times 10^{-3}\,(mol)$; *[2]*

ECF from M value

(b) n (alkali metal sulfate) $= 0.00288 / 2.88 \times 10^{-3}\,(mol)$; *[1]*
ECF

(c) $M = \left(\frac{m}{n} = \frac{0.502\ g}{0.00288\ mol} = \right) 174.31 / 174.3 / 174$;
ECF
units: $g\,mol^{-1}$; *[2]*

(d) $(2(A_r) + 32 + 4(16) = 174$, thus$)$ $A_r = 39$ / $A_r = \left(\frac{(174 - (32 + (4 \times 16))}{2}\right) = 39$;
Accept answer between 38.9 and 39.2
ECF
potassium / K; *[2]*
ECF from A_r value

(e) $K_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2KCl(aq)$ *[2]*
Award [1] for balanced equation and [1] for state symbols
ECF if another alkali metal arrived at in (d)
Accept net ionic equation
If no answer arrived at in (d), but correct equation given involving any alkali metal, then award [1 max]

HL SECTION A 07w

3. (a) same (average kinetic energy);
at same temperature/KE $\propto$ (absolute/Kelvin) temperature; *[2]*

(b) methane / CH_4;
$M_r(O_2) = 32, M_r(CH_4) = 16$ / $M_r(O_2) > M_r(CH_4)$ / $M_r(CH_4) < M_r(O_2)$ / because oxygen molecules are heavier than methane molecules / methane molecules are lighter than oxygen molecules / lighter methane gas has greater average velocity; *[2]*
No second mark for any reference to bigger/smaller molecules

(c) greater; *[1]*
equal masses more moles/molecules (of gas);
greater velocity;
more frequent collisions (with walls of flask); *[2 max]*

HL SECTION A 07s

4. (a) $60.0\ dm^3\ CO_2$;

$80.0\ dm^3\ H_2O$;

$20.0\ dm^3\ O_2$; *[3]*

Apply –1 (U).

(b) overall there will be no change to the pressure;
double absolute temperature and the pressure doubles;
double volume and the pressure halves;
Apply ECF if points 2 and 3 are incorrect.

OR

Use PV = nRT, Since n and R are constant;
V and T are both doubled;
P will remain unchanged;

OR

OWTTE *for mathematical interpretation*
e.g. T α P, therefore 2P;
V α 1/P, therefore ½ P;
No change to P, ½P x 2 P = P; *[3]*

(c) (i) $n(C)\left(= n(CO_2) = 2.68\ g \div 44.01\ g\ mol^{-1}\right) = 0.0609\ mol$;

$n(H)\left(= 2 \times n(H_2O) = 0.657\ g \div 18.02\ g\ mol^{-1}\right) = 0.0729\ mol$;

$m(C) = 0.0609\ mol \times 12.01\ g\ mol^{-1} = 0.731\ g$

and $m(H) = 0.0729\ mol \times 1.01\ g\ mol^{-1} = 0.0736\ g$;

$m(O) = (1.00 - 0.731 - 0.0736)g = 0.195\ g$;

n(C)	n(H)	n(O)
0.0609	0.0730	$\frac{0.195}{16.00}$
0.0609	0.0730	0.0122
$\frac{0.0609}{0.0122}$	$\frac{0.0730}{0.0122}$	$\frac{0.0122}{0.0122}$
4.99	5.98	1.00 ;

empirical formula: C_5H_6O; *[6]*

*For C_5H_6 award **[4 max]**.*

Steps used to arrive at the correct amounts (in moles) are required for full marks.

(ii) $M(\text{crocetin}) = 98.5\ g \div 0.300\ mol = 328\ (g\ mol^{-1})$;

$(\frac{328}{82.11} = 4)$

molecular formula: $C_{20}H_{24}O_4$; *[2]*

ECF from (c) (i).

HL SECTION A 06w

1. (a) (i)

C	N	H
$\frac{62.0}{12.01}/5.16$	$\frac{24.1}{14.01}/1.72$	$\frac{13.9}{1.01}/13.8$

Award [2] for above.
No penalty for use of whole number atomic masses.
If atomic numbers used then only mark for % of H can be awarded.
If H % and calculation missing, award [1], and last mark cannot be scored.
If H % calculation incorrect apply ECF.
C_3NH_8; *[3]*
Correct empirical formula scores [3].

(ii) the average mass of a molecule;
compared to $1/12$ of (the mass of) one atom of ^{12}C / compared to C–12 taken as 12;

OR

$$\frac{\text{average mass of a molecule}}{\text{mass of } 1/12 \text{ of one atom of } ^{12}C}$$ *[2]*
Award [2] for the equation above.

(iii) $C_6N_2H_{16}$; *[1]*

HL SECTION A 06w

2

(d) (i) moles of CH_3OH $(= 2000\times10^3 \div 32.05) = 6.24\times10^4$ (mol) and
moles of NH_3 $(= 2000\times10^3 \div 17.04) = 1.17\times10^5$ (mol);
Accept answers using whole-number A_r values.
Accept answers that do not include $\times10^3$.
methanol is limiting reactant; *[2]*

(ii) M_r of methylamine $= 31.07$ / 31;
mass $(= 2000\times31.07 \div 32.05) = 1940$ (kg); *[2]*
Accept answer in range 1930 to 1940.
Units not needed for mark, but penalise incorrect units and answers in g.
Correct final answer scores [2].

HL SECTION A 06s

3. $n(Fe_2O_3) = 30\times10^3 \div 159.7$ / $n(Fe_2O_3) = 188$ mol;
$n(C) = 5.0\times10^3 \div 12.01$ / $n(C) = 416$ mol;
Fe_2O_3 is the limiting reagent or implicit in calculation;
$n(Fe) = 2\times n(Fe_2O_3) = 2\times188 = 376$ mol;
$m(Fe) = 376\times55.85 = 21$ kg; *[5]*
Accept 2sf or 3sf, otherwise use –1(SF).
Correct final answers score [5].
Allow ECF.

HL SECTION A 05s

2. (a) mole ratio $C:H = \frac{85.6}{12.01} : \frac{14.4}{1.01} = 7.13:14.3$;

No penalty for using integer atomic masses.

empirical formula is $\underline{CH_2}$; ***[2]***

(b) (i) number of moles of gas $n = \frac{PV}{RT} = \frac{1.01 \times 10^2 \text{kPa } (.399 \text{ dm}^3)}{8.314 \frac{\text{J}}{\text{mol K}} (273 \text{ K})} = 0.178$ mol;

$$\frac{\text{mass}}{\text{mol}} = \frac{1.00\text{g}}{.017 \text{ mol}} = 56.3 \text{ (g mol}^{-1}\text{)};$$ ***[2]***

OR

molar mass is the $\frac{\text{mass of the molar volume}}{22.4 \text{ dm}^3}$ at STP;

$= \frac{1.00 \times 22.4}{0.399} = 56.1 \text{ (g mol}^{-1}\text{)}$;

Accept answers in range 56.0 to 56.3.
Accept two, three or four significant figures.
*Award **[2]** for correct final answer.*

(ii) C_4H_8; ***[1]***

No ECF.

HL SECTION A 04w

1. (a) $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$ **[2]**

Award [1] for correct products, [1] for correct balancing.
State symbols not required.
Accept correct equation with hydrated salt.
Accept ionic equation and partial neutralisation.

(b) $n(Na_2CO_3) = \frac{1}{2}n(HCl)$;

$$n(HCl) = \frac{48.80}{1000} \times 0.1000 = 0.00488 \text{ mol};$$

$$\text{concentration of } Na_2CO_3 \left(= 0.0024 \times \frac{1000}{25}\right) = 0.0976 \text{ mol dm}^{-3};$$ **[3]**

Award [3] for correct answer.
Award [3] for correct answer based on equation in (a), i.e. allow ECF from (a).
Note −1(SF) is possible.

(c) $M_r\ Na_2CO_3 = 2(22.99) + 12.01 + 3(16.00) = 105.99$;
Accept 106.

mass of Na_2CO_3 reacting with HCl (aq) $= 0.00244 \times 105.99 = 0.259$ g;
Allow ECF from (b) and M_r.

$$\text{mass of } Na_2CO_3 \text{ in } 1.000 \text{ dm}^3 = 0.259 \times \frac{1000}{25} = 10.36 \text{ g};$$ **[3]**

Note −1(U) is possible.

(d) mass of water in crystals $= (27.82 - 10.36) = 17.46$ g;
Allow ECF from (b) and (c).

$$\text{number of moles of water} = \frac{17.46}{18.02} = 0.9689;$$

Accept 0.97
mole ratio $Na_2CO_3 : H_2O = 0.0976 : 0.9689$;
$x = 10$; **[4]**

HL SECTION A 04s

2. (a) $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$; **[2]**
Award [1] for formulas and [1] for coefficients.

(b) (CO_2 produced) $= 200$ (cm^3);
(O_2 remaining) $= 100$ (cm^3); **[2]**
ECF from 2(a).

HL SECTION A 04s

3. (a) $Zn + I_2 \rightarrow ZnI_2$; *[1]*

Accept equilibrium sign.

(b) (moles of) zinc $\left(= \frac{100.0 \text{ g}}{65.37 \text{ g mol}^{-1}} \right) = 1.530$;

(moles of) iodine $\left(= \frac{100.0 \text{ g}}{253.8 \text{ g mol}^{-1}} \right) = 0.3940$;

ECF throughout.

-1 *(SF) possible.*

(reacting ratio is 1:1, therefore) zinc is in excess; *[3]*

Must be consistent with calculation above.

(c) (amount of zinc iodide = amount of iodine used $= \frac{100.0}{253.8}$ moles)

(mass of zinc iodide $= \frac{100.0}{253.8} \times (65.37 + 253.8) =$) 125.8 (g); *[1]*

Use ECF throughout.

-1 *(SF) possible.*

HL SECTION A 03w

2. (a) $3Ag^{+}(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_4(s)$; *[2]*

[1] for balanced equation and [1] for states.

(b) (i) $n_{Ag+} = cV = 0.2040 \text{ mol dm}^{-3} \times 0.04118 \text{ dm}^3$

$= 0.008401 \,/\, 8.401 \times 10^{-3}$ mol *(–1 SF)*

Unit not needed for mark. *[1]*

(ii) $n_{Ag_3XO_4} = \frac{1}{3} n_{Ag+} = \frac{1}{3} \times 0.008401$ mol *[1]*

$= 0.002800 \,/\, 2.800 \times 10^{-3}$ mol

ECF from (a) / (b) (i).

(iii) 0.002800 mol weighs 1.172 g

1 mol weighs $\frac{1.172 \text{ g}}{0.002800 \text{ mol}} = 418.6 \text{ g mol}^{-1}$ *[2]*

Accept answer in range 418 to 419.

No penalty for too many sig figs.

ECF from (b)(ii) (g mol^{-1});

Do not accept g.

(iv) $(3 \times 107.87) + x + 4\,(16.0) = 418.6$ *(ECF)*

therefore, $x = 30.99$ *(accept 31.0 / 31)*;

P / phosphorus; *[2]*

HL SECTION A 02w

5. (a) $4X + 3O_2 \rightarrow 2X_2O_3 \,/\, 2X + 1\tfrac{1}{2}O_2 \rightarrow X_2O_3$ *[1]*

(b) mass of oxygen $= 2.199 - 1.239 = 0.960$ g ;

amount (mol) of oxygen $= \dfrac{0.960}{16.00} = 0.060$;

amount (mol) of X $= \tfrac{2}{3} \times 0.060 = 0.040$;

$= 30.97 \,/\, 31.0$;

$X = P$ / phosphorus; *[5]*

(c)

	N	O
mass in 100 g	25.9	74.1
amount (mol)	$\dfrac{25.9}{14.01}$	$\dfrac{74.1}{16.00}$;
mole ratio	= 1.85	= 4.63;

formula N_2O_5; *[3]*

HL SECTION A 02s

4. (a) $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ *[1]*

(b) $0.036 \text{ dm}^3 \times 1.15 \text{ mol dm}^{-3} = 0.0414 \text{ mol}$ *[1]*

(c) $\left(0.0414 \text{ mol HNO}_3 \times \dfrac{1 \text{ mol Cu(NO}_3)_2}{2 \text{ mol HNO}_3} = 0.0207 \text{ mol Cu(NO}_3)_2\right)$

$\left(0.0345 \text{ mol CuO} \times \dfrac{1 \text{ mol Cu(NO}_3)_2}{1 \text{ mol CuO}} = 0.0345 \text{ mol Cu(NO}_3)_2\right)$

HNO_3 is limiting reagent (*Must be justified, not guessed. Allow ECF.*) ***[1]***

therefore 0.0207 mol $Cu(NO_3)_2$ formed (*allow ECF*) ***[1]*** *[2]*

(d) $63.55 + 124.02 + 54.06 = 241.63 \text{ g mol}^{-1}$ ***[1]***

$241.63 \text{ g mol}^{-1} \times 0.0207 \text{ mol} = 5.00 \text{ g}$ *(allow ECF from (c) and from molar mass)****[1]*** *[2]*

HL SECTION A 01w

2. (a) (i) $M_r = 44.01$; m_C in CO_2 produced $= \frac{12.01}{44.01} \times 5.470 = 1.493$ g *[1]*

Percentage $C = \frac{1.493}{2.036} \times 100 = 73.32\,\%$ *[1]*

(ii) $m_H = \frac{2.02}{18.02} \times 0.697 = 0.0781$ g *[1]*

Percentage $H = \frac{0.0781}{2.036} \times 100 = 3.84\,\%$ *[1]*

(b) Percentage $O = 100 - 73.32 - 3.84 - 10.75 = 12.09\,\%$ *[1]*

	C	H	N	O		
amount, n =	$\frac{73.32}{12.01}$	$\frac{3.84}{1.01}$	$\frac{10.75}{14.01}$	$\frac{12.09}{16.00}$	*(ECF if % oxygen not worked out)*	
	= 6.1	3.8	0.77	0.76	(divide by 0.76)	*[1]*

$= 8:5:1:1$, thus C_8H_5NO *[1]*

(c) Empirical mass $= (8 \times 12) + (5 \times 1) + 14 + 16 = 131\ \mathrm{g\,mol^{-1}}$ *(allow for ECF)* *[1]*
This is half the M_r **OR** $M_r = 2 \times M_{emp}$; thus molecular formula is $C_{16}H_{10}N_2O_2$. *[1]*

HL SECTION A 01w

3. (a) Pressure, volume and temperature of the gas. (*Need all three for mark.*) *[1]*

$PV = nRT$ **OR** $n = \frac{PV}{RT}$ *[1]*; $n = \frac{m}{M}$ **OR** $M = \frac{m}{n}$ *[1]* *[2]*

OR $M = \frac{m}{V}\frac{RT}{P}$ (for *[2]*)

Where R is the Ideal Gas Constant *(accept gas constant, but not just constant)* $(= 8.314\ \mathrm{J\,mol^{-1}\,K^{-1}})$ *[1]*

OR calculations as appropriate using molar volume $= 22.4\ \mathrm{dm^3}$

(c) Vapour pressures are all the same. *[1]*
Vapour pressure does not depend on the:
- volume of the liquid *[1]*
- volume of the container *[1]*

OR As long as there is vapour-liquid equilibrium present, and the temperature remains the same, then the vapour pressure will be the same.
correct explanations in terms of dynamic equilibrium involved should be awarded marks

HL SECTION A 01s

2. (a)

	Pt	Cl	N	H	
Divide by A_r values					*[1]*
No. of moles	0.3332	0.6666	0.667	2	*[1]*

Empirical formula $PtCl_2N_2H_6$ *[1]* *[3 max]*

(b) Accept any diagram that shows two Cl atoms attached to Pt **and** two NH_3 groups attached to Pt. (Allow ECF from (a)). *[1]*

(c) Moles of $AgNO_3 = 0.0162 \times 0.102 = 0.00165$ *[1]*
Moles of $NaCl = 0.0148 \times 0.125 = 0.00185$ *[1]*
Therefore limiting reactant is $AgNO_3$ / 0.00165 moles AgCl produced *[1]*
Mass of AgCl produced $= 0.00165 \times 143.32 = 0.236$ g (accept values in range 0.236 - 0.237 g) *[1]* *[4 max]*

If the wrong limiting reagent is used (NaCl), 0.265 g scores [3].
(N.B. Error carried forward; other routes are possible for the deduction that $AgNO_3$ is limiting / moles AgCl = moles $AgNO_3$)

HL B 12w

(b) (i) *Mass of C*: $\frac{6.93 \times 10^{-3} \times 12.01}{44.01} = 1.89 \times 10^{-3}$ /0.00189 (g) **and**

Mass of H: $\frac{2 \times 1.01 \times 2.83 \times 10^{-3}}{18.02} = 3.17 \times 10^{-4}$/0.000317 (g);

Mass of O: $3.00 \times 10^{-3} - 1.89 \times 10^{-3} - 3.17 \times 10^{-4} = 7.93 \times 10^{-4}$/0.000793 (g);

n_C: $\frac{1.89 \times 10^{-3}}{12.01} = 1.57 \times 10^{-4}$/0.000157 (mol) **and**

n_H: $\frac{3.17 \times 10^{-4}}{1.01} = 3.14 \times 10^{-4}$/0.000314 (mol) **and**

n_O: $\frac{7.93 \times 10^{-4}}{16.00} = 4.96 \times 10^{-5}$/0.0000496 (mol) ;

Empirical formula $= C_3H_6O$; *[4]*

Allow $C_{19}H_{38}O_6$.
Award [4] for correct final answer if alternative working is used.
*Award **[1 max]** for C_3H_6O/$C_{19}H_{38}O_6$ without working.*

(ii) $C_6H_{12}O_2$; *[1]*

HL B 11w

9

(c) (i) $\left(\left(\frac{2\times1.01}{18.02}\right)(0.089)=\right)1.0\times10^{-2}$ g H **and** $\left(\left(\frac{12.01}{44.01}\right)(0.872)=\right)2.38\times10^{-1}$ g C ;

$\left(\left(\frac{0.238}{1.30}\right)(100)=\right)18.3\%$ C ;

$\left(\frac{1.0\times10^{-2}}{1.30}\right)(100)=0.77\%$ H ; *[3]*

Award [3] for correct final answer of 18.3 % C and 0.77 % H without working.
Allow whole numbers for molar masses.

(ii) $\left((1.75)\left(\frac{35.45}{143.32}\right)=\right)0.433$ g (Cl) **and** $\left(\left(\frac{0.433}{0.535}\right)(100)=\right)80.9\%$ (Cl) ; *[1]*

Allow whole numbers for molar masses.

(iii) $\left(\frac{18.3}{12.01}\right)=1.52$ mol C **and** $\left(\frac{0.77}{1.01}\right)=0.76$ mol H **and** $\left(\frac{80.9}{35.45}\right)=2.28$ mol Cl ;

Allow whole numbers for atomic masses.

Empirical formula $= C_2HCl_3$;

Award [2] for correct empirical formula without working.

$M_r=(24.02+1.01+106.35)=131.38$, so molecular formula is C_2HCl_3 ; *[3]*

Award [3] for correct final answer without working.
Allow whole numbers for atomic masses.

HL B 11s

9e

(iii) NH_3/ammonia (in excess by) **and** 10 (dm^3);
25.0 (dm^3); *[2]*

HL B 06w

7a

(ii) $T(=70+273)=343$ K ;

$V=nRT\div P$ / $V=0.0200\times8.31\times343\div1.10\times10^5$;

$=5.18\times10^{-4}\,m^3$ / $0.518\,dm^3$ / $518\,cm^3$; *[3]*

Correct final answer with unit scores [3].
Apply ECF for incorrect value of temperature.