ROSSMOYNE SENIOR HIGH SCHOOL
Science

CHEMISTRY

UNIT 1 & 2

2020

Name: _____

Teacher: _____

TIME ALLOWED FOR THIS PAPER
Reading time before commencing work: ten minutes
Working time for the paper: three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Booklet

To be provided by the candidate:
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Multiple-choice	25	25	40	/ 25	/ 25
Section Two Short answer	10	10	65	/ 83	/ 35
Section Three Extended answer	5	5	75	/ 92	/ 40
					/ 100

Instructions to candidates

1. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answer to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

4. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Multiple-choice **25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 40 minutes.

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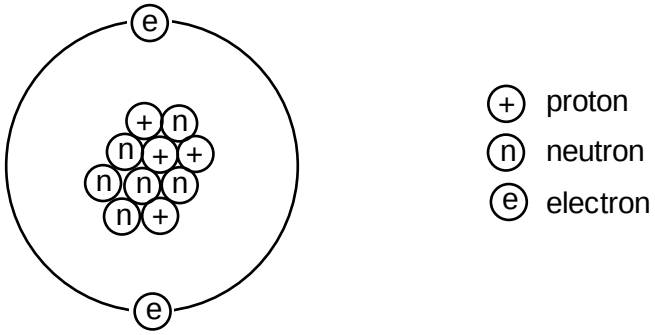
1. What is the identity of this species?



(a) A neon atom.
(b) A lithium ion.
(c) A helium atom.
(d) A beryllium ion.

2. When the volume of a gas is decreased, at constant temperature, which of the following is **true**?

(i) the pressure is increased
(ii) the average kinetic energy is increased
(iii) the frequency of collision is increased
(iv) the distance between the particles is increased

(a) (i) and (ii) only.
(b) (i) and (iii) only.
(c) (i), (ii) and (iii) only.
(d) (iii) and (iv) only.

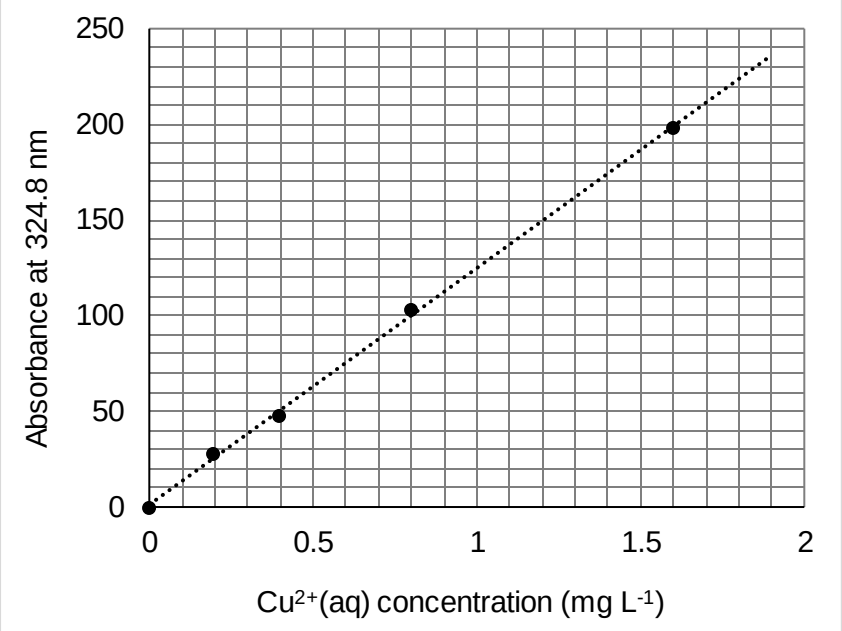
3. Which of the following would be classified as both a pure substance **and** a compound**?**

(a) Nitrogen dioxide gas
(b) Sodium chloride solution
(c) Liquid bromine
(d) Molten iron

Questions 4, 5 and 6 refer to the following information.

When copper(II) ions (Cu^{2+}) are present in water in excess amounts, this can be dangerous to human health. According to the World Health Organisation (WHO), the concentration of copper(II) ions in drinking water should not exceed 0.5 mg L^{-1}. Once levels exceed 1.3 mg L^{-1}, this can result in ill health, such as vomiting, nausea, blood cell damage and kidney failure.

Samples of groundwater were taken from various wells in Southern Ethiopia, and atomic absorption spectroscopy (AAS) was used to determine the concentration of copper(II) ions in the water. The calibration curve for copper(II) ions is shown below. The concentration of $Cu^{2+}(aq)$ is determined by recording the absorbance at a wavelength of 324.8 nm.



The absorbance reading of a particular water sample was found to be 43.

4. The concentration of copper(II) ions in this water sample would be closest to

(a) 0.29 mg L^{-1}
(b) 0.33 mg L^{-1}
(c) 0.71 mg L^{-1}
(d) 1.42 mg L^{-1}

5. Based on the results of this water sample, which of the following conclusions could be drawn?

(a) No copper(II) ions are present in the water.
(b) Copper(II) ions are not present in dangerously high concentrations.
(c) The concentration of copper(II) ions is above WHO recommended levels.
(d) The concentration of copper(II) ions is likely to cause health problems.

6. Which of the following would **not** increase the reliability and validity of the results?

(a) Collecting and testing multiple water samples from each location.
(b) Collecting and testing water samples from varying water depths.
(c) Testing the absorbance of each water sample multiple times.
(d) Collecting the copper(II) ion absorbance readings at different wavelengths.

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Questions 7 and 8 refer to allotropes of carbon.

The three common allotropes of carbon are diamond, graphite and the group of substances referred to as the fullerenes.

7. Which allotrope of carbon satisfies the following three (3) criteria?

1. Conductor of electricity
2. Classified as a nanomaterial
3. Covalent molecular structure

(a) Diamond
(b) Graphite
(c) Buckminsterfullerene (buckyball)
(d) Carbon nanotube

Another allotrope of carbon is nanodiamond. This can be formed naturally from graphite, with the application of extreme heat and pressure.

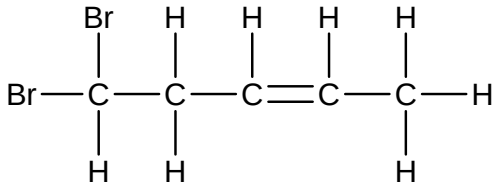
Nanodiamonds have been found to be much harder and denser than bulk diamond, and they have a higher resistance to wear. The diameter of nanodiamonds is often between 5 and 20 nanometres.

8. Which of the following characteristics could **not** be used to distinguish nanodiamond from bulk diamond?

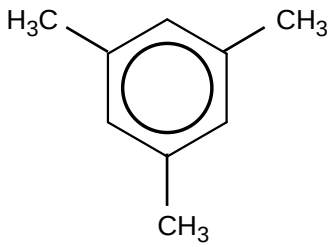
(a) Chemical composition
(b) Size
(c) Hardness
(d) Density

9. In which of the following, does the IUPAC name correctly match the molecule shown?

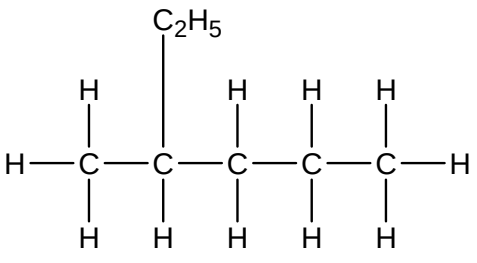
(a) 1,1-dibromopent-3-ene



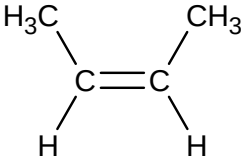
(b) 2,4,6-trimethylbenzene



(c) 3-methylhexane



(d) 1,2-dimethylethene



Questions 10, 11 and 12 refer to the information provided in the table below.

Consider the following five (5) substances and their corresponding boiling points.

	H_2S	NH_3	CH_2O	CO_2	SO_3
Boiling point (°C)	-60.2	-33.3	-19.0	-78.5	44.9

10. The Lewis structure of NH_3 has

	single covalent bonds	**double covalent bonds**	**non-bonding electron pairs**
(a)	2	0	2
(b)	2	2	1
(c)	3	0	1
(d)	3	1	2

11. Which 2 compounds have the same molecular shape?

(a) CH_2O and NH_3
(b) NH_3 and SO_3
(c) H_2S and CO_2
(d) SO_3 and CH_2O

12. Which substance would have the highest vapour pressure at 50 °C?

(a) H_2S
(b) CH_2O
(c) CO_2
(d) SO_3

13. Bromoethene, C_2H_3Br, reacts with oxygen as shown in the equation below.

$$2\ C_2H_3Br(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2H_2O(g) + 2\ HBr(g)$$

How many moles of carbon dioxide are produced when 3.0 moles of C_2H_3Br is mixed with 3.0 moles of O_2?

(a) 2.4
(b) 3.0
(c) 3.8
(d) 6.0

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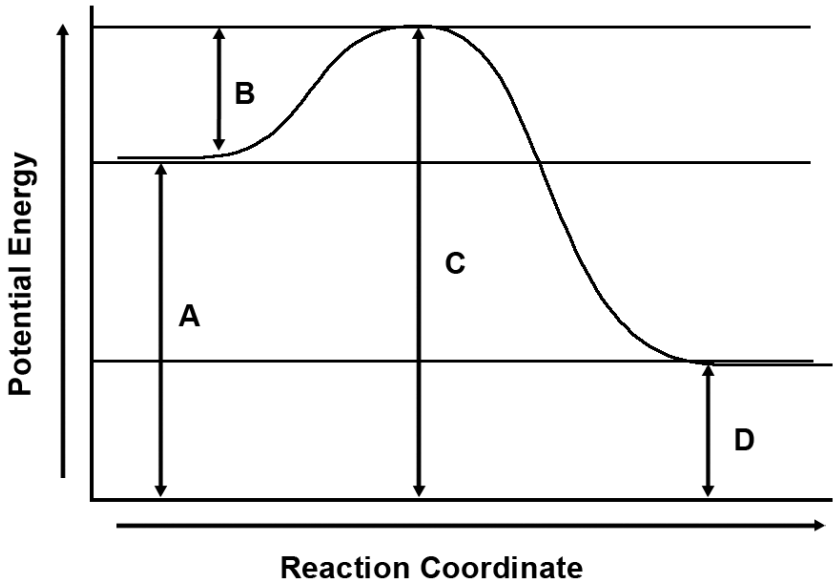
14. An unknown compound X is analysed and found to have the following properties.

- Solid at room temperature, appears as a shiny, crystalline solid.
- Enters gas phase at 184 °C at which it appears as a purple vapour.
- It does not conduct electricity in solid or aqueous state.
- When in the solid phase it feels soft.

Compound X is mostly likely

(a) metallic.
(b) ionic.
(c) covalent molecular.
(d) covalent network.

Questions 15 and 16 relate to the energy profile diagrams below.



15. Which of the following calculations will give the correct value for the change in enthalpy for the forward reaction?

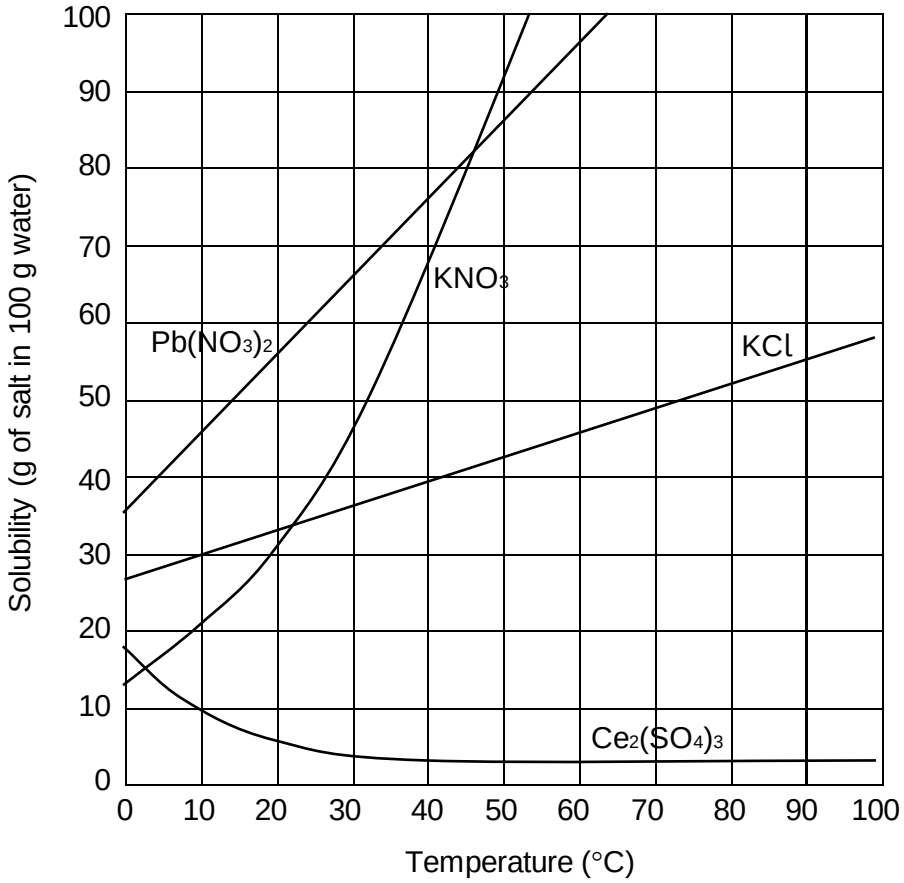
(a) C – A
(b) A – D
(c) B + A – D
(d) D – A

16. Which of the following values will change if a catalyst were added to the system?

(a) None
(b) A and B only
(c) B and C only
(d) All A, B, C and D

Questions 17, 18 and 19 refer to the following solubility graph.

Information regarding the solubilities of four (4) ionic compounds is presented in the graph below.



17. What mass of solid potassium chloride would need to be dissolved in 185 g of water at 50 °C, to produce a saturated solution?

(a) 23 g
(b) 42 g
(c) 78 g
(d) 87 g

18. A saturated solution of $Pb(NO_3)_2$ was prepared at 20 °C. This was done by dissolving 55 g of $Pb(NO_3)_2$ into 100 g of water, and stirring until all the solute was dissolved. If this solution was gently warmed to 30 °C, it would be

(a) unsaturated.
(b) saturated.
(c) super saturated.
(d) more information is required.

19. Small volumes of 0.1 mol L^{-1} $Pb(NO_3)_2(aq)$ and 0.1 mol L^{-1} $Ce_2(SO_4)_3(aq)$ were mixed. The equation for the reaction that would take place, is **best** represented by;

(a) $3\ Pb^{2+}(aq) + 3\ SO_4^{2-}(aq) \rightarrow 3\ PbSO_4(s)$
(b) $3\ Pb(NO_3)_2(aq) + Ce_2(SO_4)_3(aq) \rightarrow 3\ PbSO_4(s) + 2\ Ce(NO_3)_3(aq)$
(c) $Ce^{3+}(aq) + 3\ NO_3^-(aq) \rightarrow Ce(NO_3)_3(s)$
(d) $Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$

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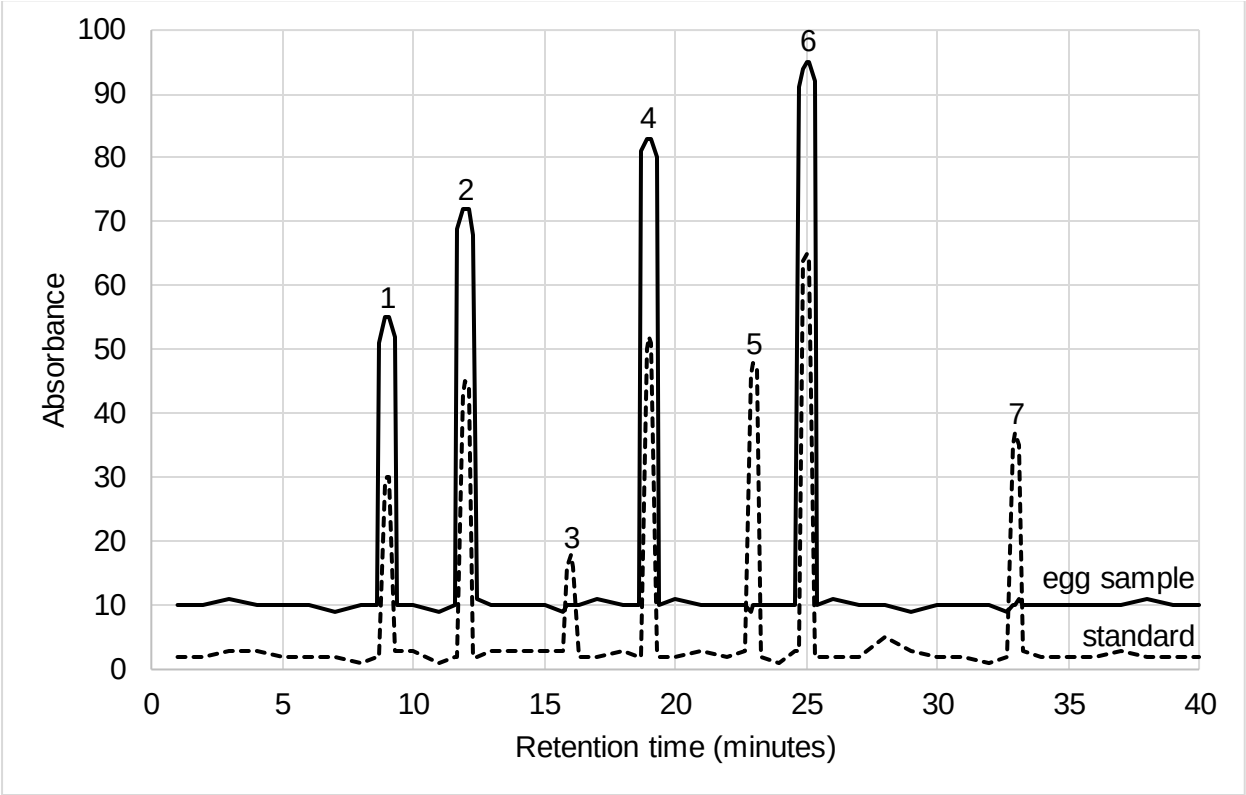
Question 20 and 21 refer to the following information.

High pressure liquid chromatography (HPLC) is often used in the analysis of food and drink. A common example, is using HPLC to determine the residual levels of drugs in food products such as milk, meat and eggs.

The HPLC chromatogram below, shows a 'standard' consisting of seven (7) drugs that are commonly used in animal farming. Reverse phase HPLC was used, which involves a non-polar stationary phase in combination with a polar mobile phase.



1	metronidazol	3	furazolidone	5	chloramphenicol	7	nicarbazin
2	sulfapyridine	4	pyrazon	6	benzothiazuron		

A sample of egg was also analysed by HPLC, under conditions identical to the standard. The results of the egg analysis are overlaid on the same chromatogram above.

20. Which of the following drugs was **not** present in the egg sample?

(a) Metronidazol
(b) Sulfapyridine
(c) Pyrazon
(d) Nicarbazin

21. Which of the following statements is **correct** based on the data provided?

(a) Benzothiazuron was present in the lowest concentration in the egg sample.
(b) Metronidazol is the most polar drug of those analysed.
(c) The level of drugs in this egg sample are unsafe for human consumption.
(d) Retention time would be one of the controlled variables in this analysis.

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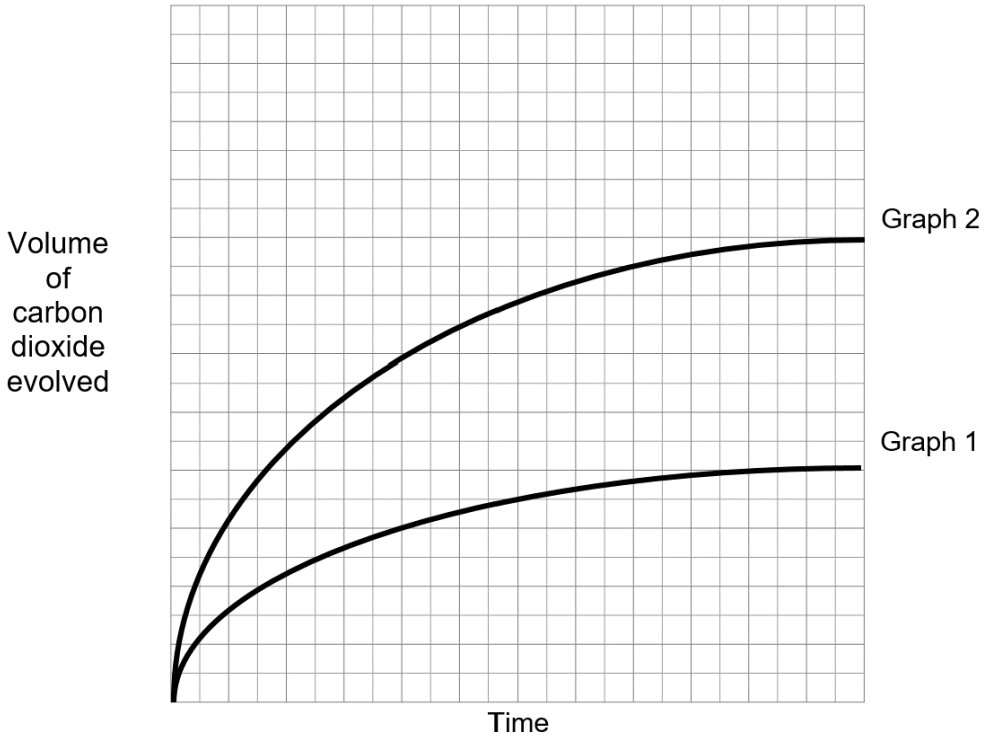
22. Which formula correctly matches the name given?

(a) Zinc hydrogenphosphate, $Zn(H_2PO_4)_2$
(b) Potassium oxalate, $K_2C_2O_4$
(c) Silver chromate, $Ag_2Cr_2O_7$
(d) Strontium nitride, $Sr(NO_2)_2$

23. The graphs below were obtained when limestone lumps reacted completely in an excess of dilute hydrochloric acid. Graph 1 was obtained when 10 g of limestone lumps were added to 100 mL of hydrochloric acid solution.



Which of the changes below could give rise to graph 2?

(a) using 200mL of the same acid solution instead of 100mL
(b) using 100mL of a more concentrated acid solution instead the dilute acid
(c) using 10g of powdered limestone instead of 10g of limestone lumps
(d) using 20g of powdered limestone instead of 10g of limestone lumps

24. Consider the chemical reaction that would occur upon mixing solid potassium hydroxide, KOH(s) and aqueous sulphuric acid H_2SO_4(aq).

When writing the chemical equation for this reaction, which of the following would be considered a spectator ion?

(a) K^+
(b) H^+
(c) SO_4^{2-}
(d) OH^-

25. A sample of powdered copper(II) sulfide was placed in a beaker and 0.5 mol L^{-1} nitric acid was then poured in. The chemicals react according to the equation below.

$$CuS(s) + 2\,HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2S(g)$$

The mass and temperature of the reaction mixture was recorded at the start (i.e. as soon as the chemicals were mixed) and then again after 5 minutes had passed (i.e. once all sign of reaction had stopped).

The results are shown in the table below.

	Initial	**After 5 minutes**
Mass (g)	128	123
Temperature (°C)	21	18

Which of the following conclusions regarding this data is **least likely** to be correct?

(a) The decrease in mass is a result of the H_2S gas being produced.
(b) The decrease in temperature is a result of the reaction being endothermic.
(c) The decrease in temperature is a result of the energy required to break the bonds being greater than the energy released when the new bonds form.
(d) The decrease in mass and temperature are a result of mass and energy not being conserved.

End of Section One

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Section Two: Short answer **35% (83 marks)**

This section has **10** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 65 minutes.

Question 26 **(12 marks)**

Consider the information given in the table below.

Name of compound	Formula	Molar mass (g mol^{-1})	Melting point (°C)
hydrogen peroxide	H_2O_2	34.016	-0.43
fluoromethane	CH_3F	34.034	-137.8
chromium(III) chloride	$CrCl_3$	158.35	1152
magnesium sulfate	$MgSO_4$	120.38	1124
dichlorine hexoxide	Cl_2O_6	166.9	3.5

(a) Explain, in terms of structure and bonding, why the melting points of magnesium sulfate and chromium(III) chloride are so high, compared to the other compounds. (4 marks)

- **$MgSO_4$ and $CrCl_3$ are ionic compounds / contain ionic bonds**	1 Mark
- **There is a strong electrostatic attraction between cations and anions**	1 Mark
- **Therefore a large amount of heat is required to disrupt the bonds in the ionic compounds (resulting in high melting points)**	1 Mark
- **The other substances are covalent molecular and have only weak intermolecular forces**	1 Mark

(b) Explain, in terms of structure and bonding, the difference between the melting points of hydrogen peroxide and fluoromethane. (4 marks)

- **Both substances have similar molecular masses and therefore similar strength dispersion forces**	1 Mark
- **CH_3F has dipole-dipole (in addition to its dispersion forces)**	1 Mark
- **H_2O_2 has dipole-dipole and hydrogen bonding (in addition to its dispersion forces)**	1 Mark
- **Therefore H_2O_2 has the stongest total intermolecular forces and highest boiling point**	1 Mark

If 100.0 g of magnesium sulfate and 100.0 g of chromium(III) chloride were placed in separate beakers and dissolved in equal volumes of distilled water;

(c) Determine, with the use of calculations, which solution would have the higher electrical conductivity. (You may assume all ions have the same conductivity.) (4 marks)

- **$n(MgSO_4)$ = m/M = 100 / 120.38 = 0.8307 mol**	1 Mark
$n(CrCl_3)$ = m/M = 100 / 158.35 = 0.6315 mol	1 Mark
- **n(total ions in $MgSO_4$) = 2 x 0.8307 = 1.6614 mol** - **n(total ions in $CrCl_3$) = 4 x 0.6315 = 2.526 mol**	1 Mark
- **Since $CrCl_3$ has the greater total number of dissociated ions (mobile charge), it will have the highest conductivity**	1 Mark

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Question 27 **(6 marks)**

The graph below shows separate trendlines (labelled A, B and C) relating to some of the physical properties displayed by the elements in period 3. The lines represent the trends in ionisation energy, atomic radius and electronegativity.

State which line corresponds to each trend. Justify your choices.

	A, B or C	
ionisation energy	C	1 Mark for all three correct
atomic radius	B	-1 if any incorrect
electronegativity	A	

- **Atomic radius decreases across a period (and line B is the only decresing trend)**	**1 Mark**
- **This is due to increased positive charge within the nucleus, pulling valence electrons closer**	**1 Mark**
- **Electronegativity increases across a period, due to the increased positive charge from the nucleus exerting a stronger pull on (a bonding pair of) electrons**	**1 Mark**
- **However there is no value given for Argon (noble gas, octet arrangement, not allocated an electronegativity value) therefore electronegativity must be line A**	**1 Mark**
- **Ionisation energy increases across a period, as the energy required to remove an electron from an atom increases, therefore line C**	**1 Mark**

Question 28 **(8 marks)**

Consider the reaction between calcium carbonate powder and **excess** 1 mol L^{-1} nitric acid.

(a) List three (3) aqueous species that would be present in the test tube upon completion of this reaction. (3 marks)

- **$Ca^{2+}(aq)$** - **$NO_3^-(aq)$** - **$H^+(aq)$ / $H_3O^+(aq)$**	1 mark each
accept also $CO_2(aq)$ and $H_2CO_3(aq)$ **(HCO_3^-, CO_3^{2-} and OH^- negligible in a solution with excess nitric acid)**	
if more than 3 species listed, mark only the first 3 answers given	

Consider two (2) test tubes; one containing 0.5 mol L^{-1} NaOH(aq) and one containing 0.5 mol L^{-1} $Ba(OH)_2(aq)$. A few drops of sulfuric acid was added to each test tube.

(b) Describe how the subsequent observations would allow you to distinguish these two solutions. (3 marks)

- **A white precipitate would form in one test tube**	1 Mark
- **This would therefore allow identification of the $Ba(OH)_2$ solution, as $BaSO_4(s)$ is formed**	1 Mark
- **The remaining test tube with no visible change (colourless solution remaining) would be NaOH solution**	1 Mark

A piece of freshly polished aluminium metal was placed into a beaker containing 1 mol L^{-1} hydrochloric acid.

(c) Write a balanced ionic equation for the reaction that would occur. (2 marks)

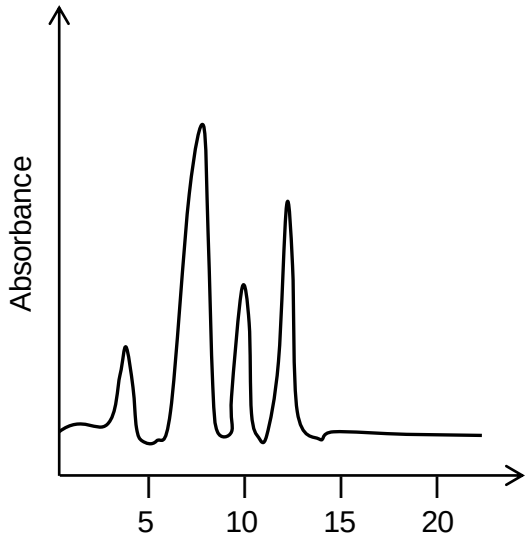
$2\ Al(s) + 6\ H^+(aq) \rightarrow 2\ Al^{3+}(aq) + 3\ H_2(g)$

(1m correct reactant and product species, 1m correct balancing)

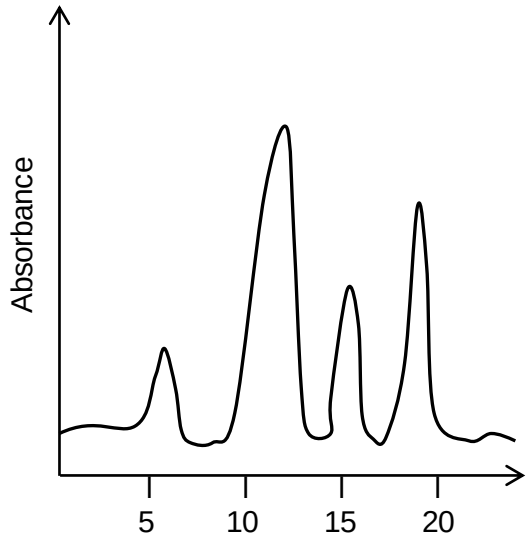
Question 29 **(8 marks)**

Consider the two (2) gas chromatograms below. Both analyses, A and B, were performed on identical gas samples. All chromatography conditions were controlled, except the temperature of the gas chromatograph oven was different in each case.

Chromatogram A



Chromatogram B



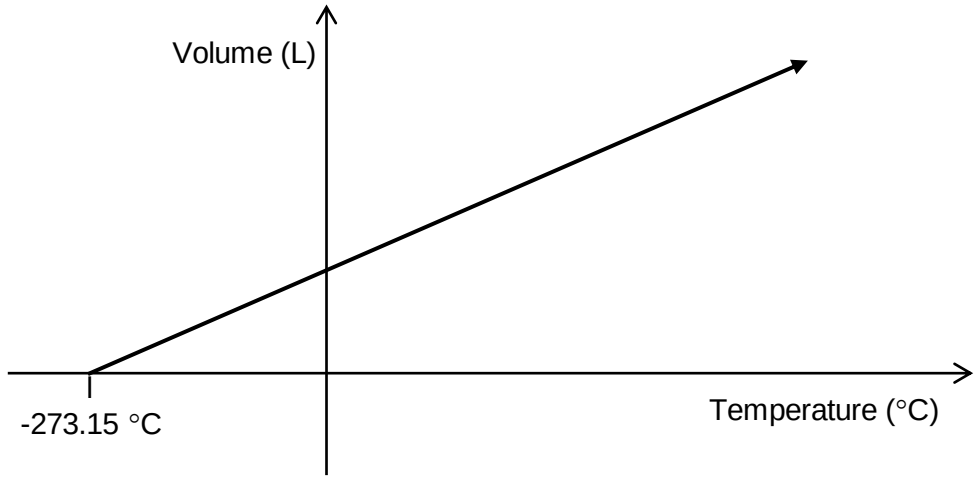
(a) Name an appropriate gas which could have been used as the mobile phase. (1 mark)

- **Any of helium, nitrogen, hydrogen, argon, Inert gas**	1 Mark

(b) Which gas chromatogram (A or B) was performed at the higher temperature? Justify your answer. (3 marks)

- **Chromatogram A**	1 Mark
- **A higher temperature means particles will have a greater average kinetic energy**	1 Mark
- **Therefore they will move through the column faster, resulting in a lower retention time**	1 Mark

When a sample of gas is cooled, the resultant effect on gas volume can be illustrated by the graph below.



(c) Why can't the sample be cooled any lower than -273.15 °C? (2 marks)

- **This temperature is absolute zero**	1 Mark
- **Sample cannot be cooled any lower because; (any one of following justifications)** • **this is the lowest temperature possible** • **all particle motion stops at this temperature** • **the volume of the gas particles would have to be negative which is impossible**	1 Mark

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An ideal gas has a theoretical volume of zero at the temperature of -273.15 °C.

(d) Explain how the behaviour of a real gas differs from this. (2 marks)

(any two of the following points) - **The particles of an ideal gas have no volume themselves, allowing the ideal gas volume to be zero** - **However the particles of a real gas do occupy volume, meaning the volume can never be zero** - **A real gas would condense and then solidify as it approaches this temperature**	2 Marks

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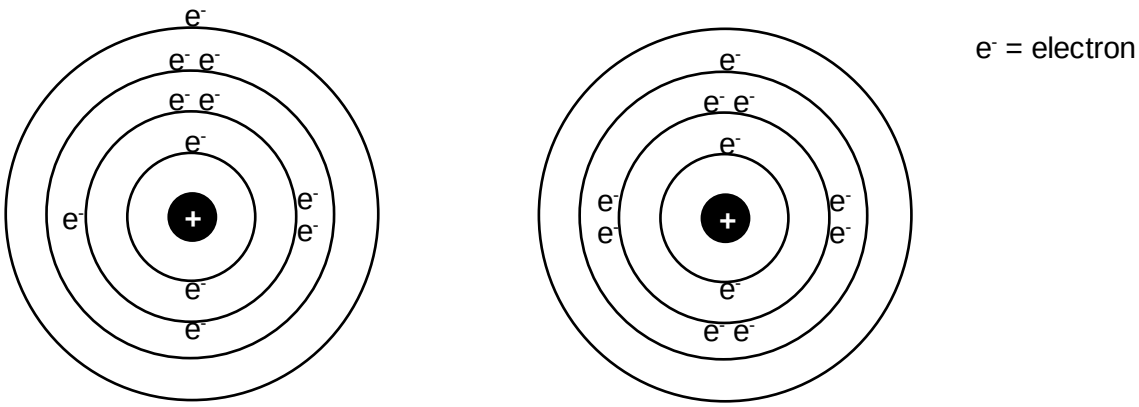
Question 30 **(7 marks)**

Consider the diagrams below, which show two (2) different representations of atoms of the same neutral element.

Configuration A **Configuration B**



(a) Which configuration (A or B) represents the element is its ground state? Justify your answer. (2 marks)

- **B**	1 Mark
- **All electrons are filling the shells from lowest to highest / inner shell to outer shell (Configuration A is 2, 6, 2, 1 whilst Configuration B is 2, 8, 1)**	1 Mark

(b) Which transition would result in the release of a characteristic colour during a flame test? Circle your choice and justify your answer.

(3 marks)

A to B OR B to A

- **(circle A to B)**	1 Mark
- **Energy is released as electrons move from higher to lower energy shells**	1 Mark
This energy can be in the form of a photon of coloured light / This energy corresponds with a particular frequency in the electromagnetic spectrum	1 Mark

(c) Which element is represented in these diagrams? (1 mark)

- **Sodium, Na**	1 Mark

(d) Write the electron configuration of the element in Group 15, that is in the same period as the element represented above. (1 mark)

- **(Phosphorus) 2, 8, 5**	1 Mark

Question 31 **(8 marks)**

Consider the information given in the table below, regarding substances A, B and C.

Substance	Conductivity as a solid	Conductivity as a liquid	Melting point (°C)
A	No	No	1895
B	Yes	Yes	812
C	No	Yes	1133

(a) Which substance (A, B or C) is likely to be covalent network? Justify your answer in terms of structure and bonding. (3 marks)

- **A**	1 Mark
- **No conductivity in the solid or liquid state indicates no mobile charge**	1 Mark
- **Very migh melting point indicates strong bonds present which would require a large amount of energy to disrupt**	1 Mark

(b) Which substance (A, B or C) is likely to be malleable? Justify your answer in terms of structure and bonding. (5 marks)

- **B**	**1 Mark**
- **Conductivity as a solid (and liquid) suggests metallic bonding is present**	**1 Mark**
- **Metallic bonding consists of non-directional bonds between delocalised electrons and positive metal ions**	**1 Mark**
- **When a force is applied the substance can change shape without disrupting / breaking the bonds**	**1 Mark**
- **Therefore metals are malleable**	**1 Mark**

Question 32 **(9 marks)**

Below is a flow diagram to show how a mixture of silver nitrate, barium nitrate, potassium nitrate and copper nitrate solutions can be separated into Ag^+, Ba^{2+}, K^+ and Cu^{2+} ions, one at a time, to form three different precipitates.

(a) Using the solubility chart in the Data booklet to assist you, complete the flow chart below. (6 marks)

Correct reactant/regent used in step 1	**1 Mark**
Correct precipitate identified and thus remaining ions identified also	**1 Mark**
Correct reactant/regent used in step 2	**1 Mark**
Correct precipitate identified and thus remaining ions identified also	**1 Mark**
Correct reactant/regent used in step 3	**1 Mark**
Correct precipitate identified and thus remaining ions identified also	**1 Mark**

(b) A 20.00 mL of a of 3.85 g L^{-1} silver nitrate solution was added to an excess quantity of sodium phosphate solution. Calculate the amount, in moles, of precipitate formed. (note: The molar mass of silver nitrate is 169.87 g mol^{-1}) (3 marks)

$m(AgNO_3) = 3.85\ g\ L^{-1} \times 0.02L = 0.077g$	**1 Mark**
$n(AgNO_3) = m/M = 0.077g / 169.87\ g/mol = 0.000453\ mol$	**1 Mark**
$3Ag+ + PO_4^{3-} \rightarrow Ag_3PO_4$ **$n(Ag_3PO_4)$ formed = $1/3 \times n(AgNO_3)$** **$= 1/3 \times 0.000453\ mol = 1.51 \times 10^{-4}\ mol$**	**1 Mark**

See Next Page

Question 33 **(8 marks)**

Dry ice is solid carbon dioxide. Under atmospheric pressure, it can only form at a temperature below -78.5 °C. It is used for transporting fresh meat, poultry, fish and pre-made meals. At temperatures above -78.5 °C, dry ice undergoes sublimation, which means it converts directly from a solid to a gas.

(a) State whether the process of sublimation is endothermic or exothermic. Justify your answer, including a discussion of the movement of heat between system and surroundings. (4 marks)

- **Endothermic**	1 Mark
- **Sublimation requires the disruption of intermolecular forces**	1 Mark
- **Heat must move from the the surroundings into the system**	1 Mark
- **This results in a temperature decrease / This results in a positive ΔH value**	1 Mark

(b) Write a chemical equation, including state symbols, representing the sublimation of carbon dioxide. Your equation should incorporate information regarding the associated enthalpy change. (2 marks)

$CO_2(s)$ + heat → $CO_2(g)$

(1m reactants and products, 1m heat)

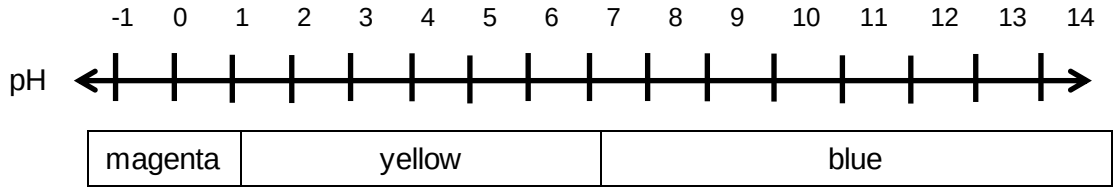
Dry ice can be purchased as small pellets or larger blocks.

(c) If a single pellet of dry ice had a mass of 1.22 g, calculate the number of carbon dioxide molecules this pellet would contain. (2 marks)

$n(CO_2)$ = m / M **= 1.22 / 44.01** **= 0.027721 mol**	1 Mark
$n(CO_2)$ = n x Av **= 0.027721 x 6.022 x 10^{23}** **= 1.669 x 10^{22}** **= 1.67 x 10^{22} (3 SF)**	1 Mark

Question 34 **(10 marks)**

The indicator 'bromothymol blue' has the formula $C_{27}H_{28}Br_2O_5S$. The diagram below illustrates the different colours exhibited by bromothymol blue at various pH levels.



(a) State the type of bonding (metallic, ionic or covalent) present in bromothymol blue. Justify your answer. (2 marks)

- **Covalent**	1 Mark
- **All non-metal elements in the chemical formula**	1 Mark

(b) Calculate the percentage by mass of carbon in bromothymol blue. (2 marks)

% C = $\frac{27 \times 12.01}{624.364} \times 100$ **= $\frac{324.27}{624.364} \times 100$**	1 Mark
= 51.94 %	1 Mark

(c) Explain why, when a few drops of bromothymol blue are added, a 1 mol L^{-1} solution of HCl(aq) is magenta, but a 1 mol L^{-1} solution of $CH_3COOH(aq)$ is yellow. Support your answer with relevant chemical equations. (6 marks)

- **HCl is a strong acid whereas CH_3COOH is a weak acid** - **This means HCl is completely ionised whereas CH_3COOH is only partially ionised**	1 Mark
- **$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$**	1 Mark
- **Therefore HCl has a greater concentration of H^+ resulting in a lower pH / resulting in a pH below 1**	1 Mark
- **$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$**	1 Mark
- **Therefore CH_3COOH has a lower concentration of H^+ resulting in a higher pH / resulting in a pH above 1**	1 Mark
- **This results in HCl appearing magenta whilst CH_3COOH appears yellow**	1 Mark

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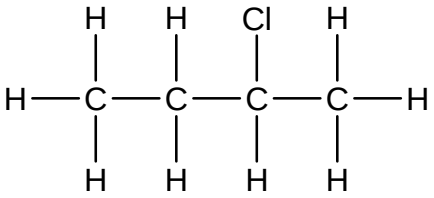
Question 35 **(7 marks)**

Consider the organic compound below.



(a) Give the IUPAC name for this compound. (1 mark)

- **2-chlorobutane**	1 Mark

(b) Name the reactants that you would mix together to produce this compound by; (4 marks)

An addition reaction.	**Hydrogen chloride**	1 Mark
	But-1-ene / But-2-ene	1 Mark
A substitution reaction.	**Chlorine**	1 Mark
	Butane	1 Mark

(c) Which of the reaction types in part (b) would require the presence of a catalyst? Name the catalyst. (2 marks)

- **Substitution reaction**	1 Mark
- **UV light**	1 Mark

End of Section Two

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Section Three: Extended answer **40% (92 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

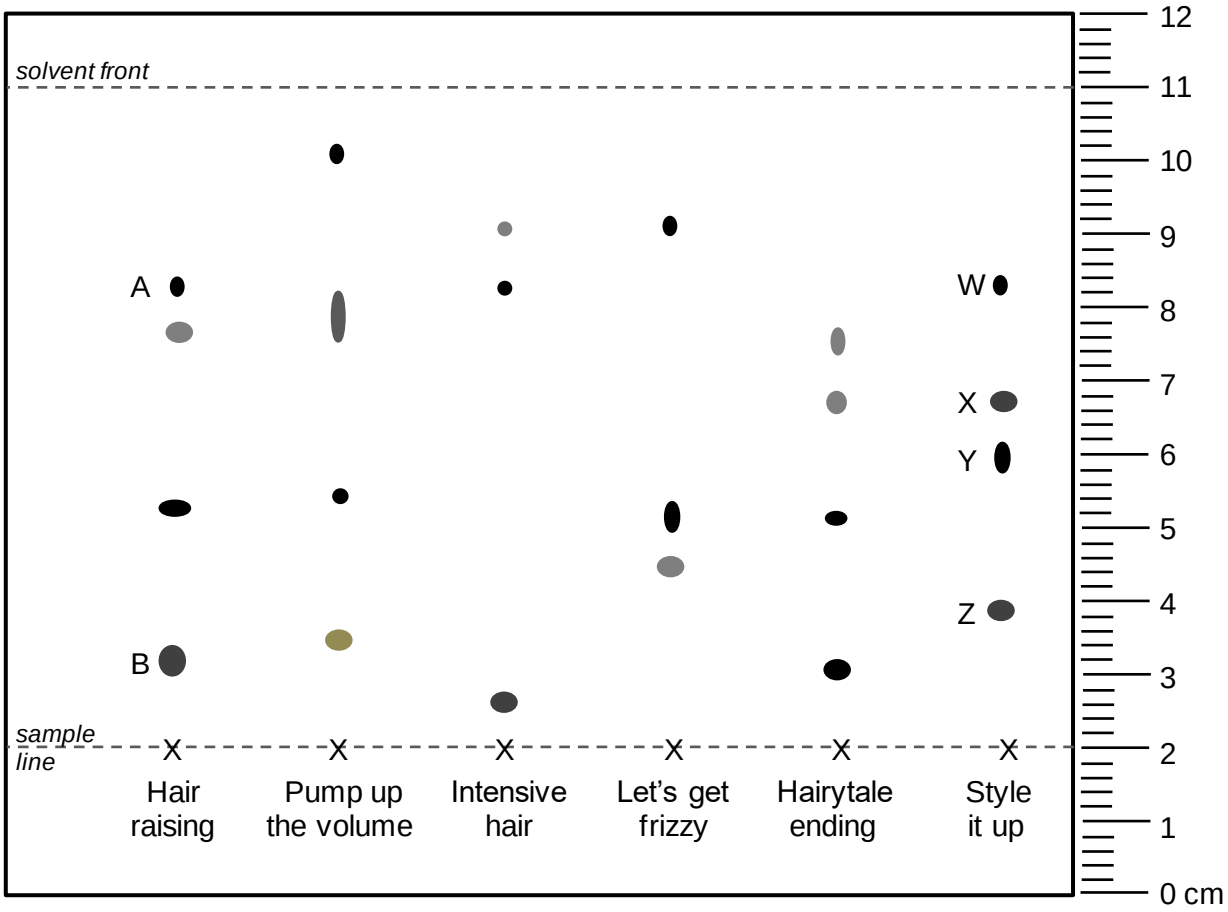
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 75 minutes.

Question 36 **(11 marks)**

Analysis of various hair products such as dyes, sprays and serums can be of great benefit to forensic investigators. Since hair samples are often found at crime scenes, identification of the hair products which are coating the hair can provide valuable information to investigators.

One common and effective method used for the analysis of hair products is thin layer chromatography (TLC). The TLC plate below shows the analysis of six (6) different popular brands of hair spray.



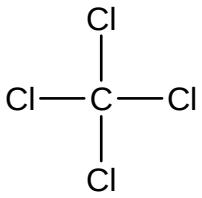
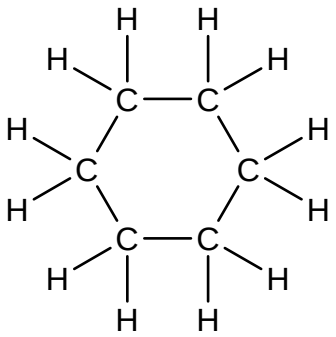
The plate, which is the stationary phase, is made of glass coated with silica. A small amount of each hair spray was spotted onto the sample line. The plate was then placed into a solution which acted as the mobile phase.

(a) Briefly describe how the technique of TLC is able to separate the various components of a sample. Your answer should make reference to the role of both the stationary and mobile phases. (4 marks)

- **Mobile phase moves upwards across stationary phase, carrying components of sample with it**	1 Mark
- **Components interact to varying degrees with stationary and mobile phases based on their polarity**	1 Mark
- **Components that adhere more strongly to the stationary phase move more slowly, whilst those dissolving to a greater degree in the mobile phase move more quickly**	1 Mark
- **Components therefore move at different rates up the plate and are thus separated**	1 Mark

For the TLC plate shown on the previous page, the scientists found that using a mobile phase composed of tetrachloromethane and cyclohexane (mixed in a 90:10 ratio) achieved optimal separation of components.

(b) Draw full structural diagrams for the two (2) substances used in the mobile phase. Your diagrams should indicate all bonds and atoms. (2 marks)

tetrachloromethane	cyclohexane
	

(c) State whether this mobile phase is polar or non-polar. Justify your answer. (2 marks)

- **Non-polar** -	1 Mark
- **Both substances are symmetrical / Both have even charge distribution / Neither substance has a net dipole**	1 Mark

A hair sample from a crime scene was analysed by TLC and found to be coated in the hairspray '**Style it up'.**

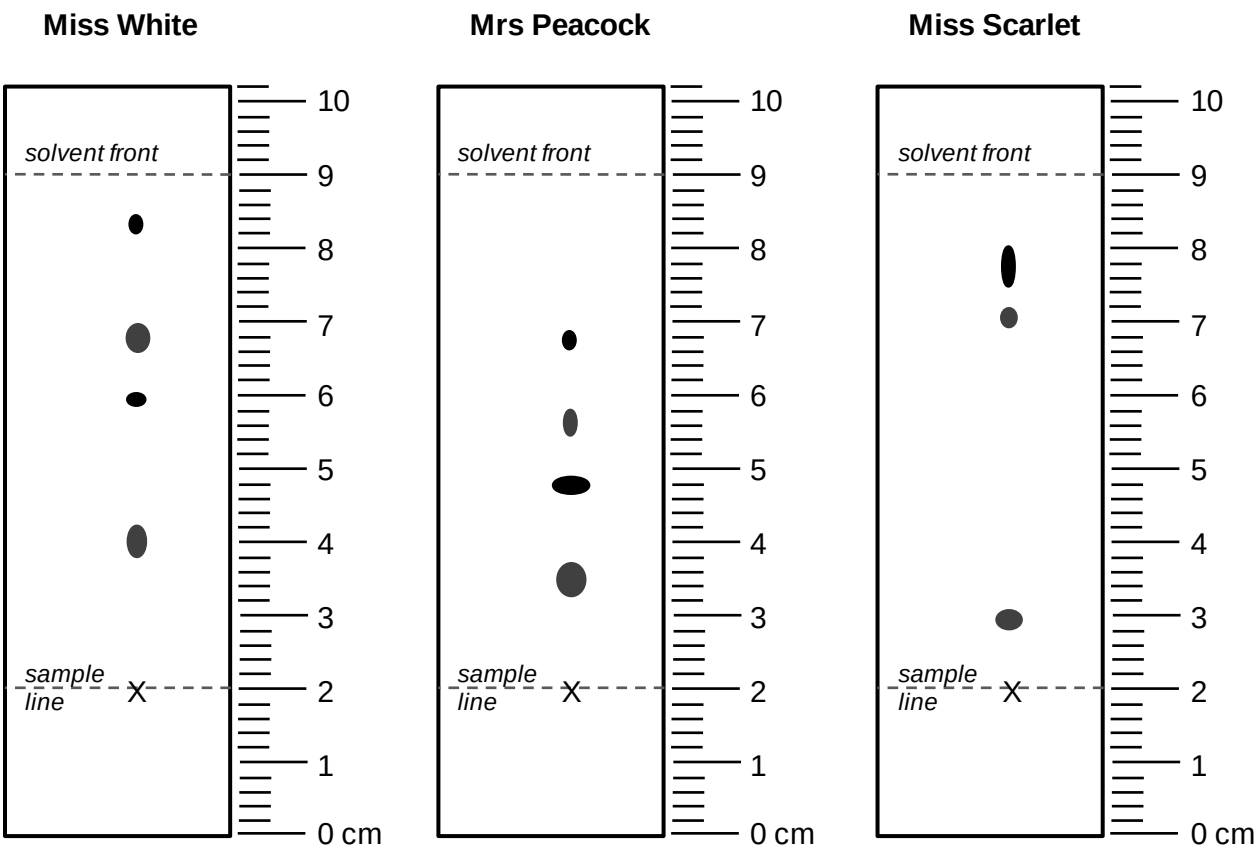
(d) Calculate the retention factor (R_f) values for each of the components (labelled W, X, Y and Z on the TLC plate) found in the hairspray **'Style it up'**. (2 marks)

$$R_f = \frac{\text{distance travelled by component}}{\text{distance travelled by solvent}}$$

	R_f
W	**6.3/9 accept between 0.68 - 0.71**
X	**4.7/9 accept between 0.51 - 0.53**
Y	**4/9 accept between 0.42 - 0.45**
Z	**1.9/9 accept between 0.20 - 0.22**
	-1 Mark for any incorrect (max 2)

Hair samples were then taken from three (3) suspects who had been arrested. The coatings on their hair samples were analysed by TLC. You may assume this analysis was performed under conditions identical to the original plate.

The results of the suspects' TLC analyses are shown below.



Based on the data provided by these TLC analyses;

(e) Which suspect is most likely to have been at the scene of the crime? (1 mark)

- **Mrs Peacock**	1 Mark

Question 37 **(19 marks)**

The silver-coloured metal molybdenum was first isolated in 1781. Molybdenum does not exist as the free metal, but is commonly found combined with sulfur, in the compound molybdenite, MoS_2.

The overall equation for the extraction of molybdenum from molybdenite is as follows.

$$2\ MoS_2(s) + 7\ O_2(g) + 6\ H_2(g) \rightarrow 2\ Mo(s) + 4\ SO_2(g) + 6\ H_2O(l)$$

A batch of $MoS_2(s)$ was placed in a reaction chamber. Oxygen and hydrogen gases were then pumped into the chamber.

The oxygen gas used in this process is extracted from air, which is comprised of 21.0% (by volume) $O_2(g)$. If 3.50×10^7 L of air, stored at **STP**, was available for this extraction process;

(a) Calculate the maximum mass of MoS_2 that would have been able to react with the available oxygen. (4 marks)

$V(O_2)$ = 21 / 100 x 3.5 x 10^7 **= 7 350 000 L** **$n(O_2)$ = V / 22.71** **= 7 350 000 / 22.71** **= 323 645.97 mol**	1 Mark
$n(MoS_2)$ = 2 / 7 x $n(O_2)$ **= 2 / 7 x 323 645.97** **= 92 470.28 mol**	1 Mark
$m(MoS_2)$ = nM **= 92 470.28 x 160.08** **= 14 802 642 g**	1 Mark
m(ore) = 14 802 642 x 100 / 57.4 **= 25 788 575 g** **= 2.58×10^7 g OR 25.8 t**	1 Mark

See Next Page

The hydrogen gas used in the extraction of molybdenum is produced by a series of reactions that can be summarised by the following equation;

$$CH_4(g) + 2\,H_2O(g) \rightarrow 4\,H_2(g) + CO_2(g)$$

(b) Calculate the volume of methane at **STP**, that would be required to produce enough $H_2(g)$ for this extraction process. (if no answer to part a use 3.4×10^5 moles of O_2)

(3 marks)

$n(H_2$ required)	**=**	**$6 / 7 \times n(O_2)$** **$6 / 7 \times 323\,645.97$** **277 410.832 mol**	1 Mark
$n(CH_4$ required)	**=**	**$1 / 4 \times n(H_2)$** **$1 / 4 \times 277\,410.832$** **69 352.708 mol**	1 Mark
$V(CH_4)$	**=**	**$22.71n$** **$22.71 \times 69\,352.708$** **1 575 000 L** **1.58×10^6 L OR 1.58 ML**	1 Mark

The $SO_2(g)$ produced during the extraction of molybdenum is a pollutant and can contribute to the formation of acid rain. Sulfur dioxide gas dissolves into the water in the atmosphere to produce sulfurous acid.

(c) Write an equation representing this reaction. (1 mark)

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$	1 Mark

(d) State and explain the resulting effect on pH, which is caused by the dissolving of $SO_2(g)$ into rain. Use a chemical equation to support your answer. (3 marks)

- **$H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$**	1 Mark
- **The increase in H^+ concentration lowers the pH**	1 Mark
- **Since pH = -log $[H^+]$**	1 Mark

If the waste sulfur dioxide is collected, it can be converted into sulfuric acid in an industrial procedure known as the Contact process. This process can be summarised by the equation below.

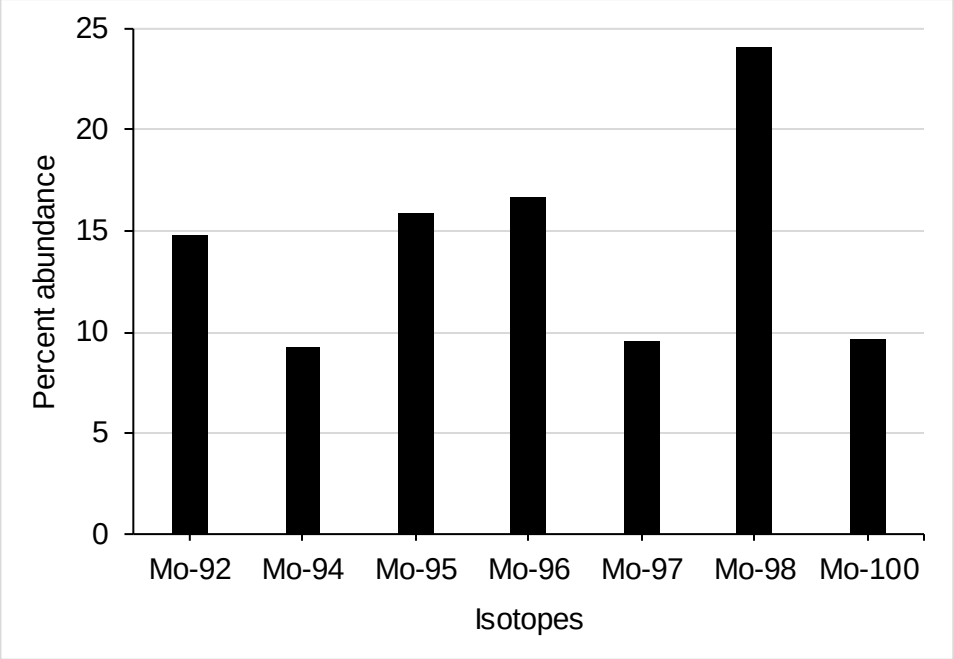
$$2\ SO_2(g) + O_2(g) + 2\ H_2O(l) \rightarrow 2\ H_2SO_4(aq)$$

This process can produce sulfuric acid with a very high concentration of 16.9 mol L^{1-}.

(e) Calculate the volume of $H_2SO_4(aq)$ that could be produced using the waste sulfur dioxide generated by the extraction of molybdenum from this batch of ore. (3 marks)

$n(SO_2)$	**= 4 / 7 x $n(O_2)$** **= 4 / 7 x 323 645.97** **= 184 940.55 mol**	1 Mark
$n(H_2SO_4)$	**= $n(SO_2)$** **= 184 940.55 mol**	1 Mark
$V(H_2SO_4)$	**= n / c** **= 184 940.55 / 16.9** **= 10 943.23 L** **= 1.09×10^4 L OR 10.9 kL**	1 Mark

A sample of pure molybdenum was analysed by mass spectrometry and the following data was obtained.



(f) Use this information, as well as that in your Data Booklet, to complete the following table about the element molybdenum. (3 marks)

Group number	**6 1 Mark**
Period number	**5 1 Mark**
Number of isotopes	**7 1 Mark**

(g) Describe, with reference to subatomic particles, the similarities and differences between the isotopes of molybdenum. (2 marks)

_____

- **All isotopes have the same number of protons (always 42)**	1 Mark
- **Each isotope has a different number of neutrons (either 50, 52-56, 58)**	1 Mark

_____

Question 38 **(23 marks)**

The Perth Desalination Plant in Kwinana supplies approximately 17% of Perth's potable (drinkable) water.

The two (2) main sources of potable water in Perth, are groundwater and seawater.

(a) Define the term 'desalination' and state which of these 2 main water sources would be processed at the desalination plant. (2 marks)

- **Removal of salt from water**	1 Mark
- **Seawater**	1 Mark

The initial stages of water treatment at the desalination plant involve the processes of filtration and desalination.

(b) Give one (1) reason that the process of filtration would be used. (1 marks)

- **Remove undissolved / insoluble solids**	1 Mark

The filtration and desalination processes produce very 'clean' water, however it is not yet suitable for drinking.

As stated previously, the plant produces 6000 m^3 of drinking water every hour.

This volume includes the following substances, which are added to the water on an **hourly basis**;

- 180 kg $CO_2(g)$
- 180 m^3 $Ca(OH)_2(aq)$
- 6 kg $Cl_2(g)$
- 30 L of 1.512 mol L^{-1} $H_2SiF_6(aq)$

(c) Calculate the volume of $CO_2(g)$ that would be required by the desalination plant each day, assuming the gas was stored at **STP**. (3 marks)

$m(CO_2)$ = 180 x 10^3 x 24 **= 4 320 000 g**	1 Mark
$n(CO_2)$ = m / M **= 4 320 000 / 44.01** **= 98 159.51 mol**	1 Mark
$V(CO_2)$ = 22.71n **= 22.71 x 98 159.51** **= 2 229 202 L** **= 2.2 x 10^6 L OR 2.2 ML**	1 Mark

The $Ca(OH)_2(aq)$ solution used, has a concentration of 1500 ppm and a density of 1.005 g mL^{-1}.
Density = mass / Volume

(d) Calculate the concentration of this $Ca(OH)_2(aq)$ solution in moles per litre. (5 marks)

1500 ppm means 1500 mg $Ca(OH)_2$ in 1 kg solution	1 Mark
Since ρ = m/V; **V(of 1 kg of solution) = m / ρ** **= 1000 / 1.005** **= 995.025 mL** **= 0.995 L**	1 Mark
$m(Ca(OH)_2$ in 1 kg of solution) = 1.5 g	1 Mark
$n(Ca(OH)_2)$ = m / M **= 1.5 / 74.096** **= 0.020244 mol**	1 Mark
$c(Ca(OH)_2)$ = n / V **= 0.020244 / 0.995** **= 0.020345 mol L^{-1}**	1 Mark

(e) State the effect on pH when the $Ca(OH)_2(aq)$ solution is added to water. Justify your answer. (3 marks)

- **The pH will increase**	1 Mark
- **$Ca(OH)_2$ is a strong base**	1 Mark
- **It will release OH^- ions into the solution (lowering the concentration of H^+ ions)**	1 Mark

(f) Give one (1) reason for the addition of $Cl_2(g)$ to the water. (1 mark)

_____

- **disinfectant**	1 Mark

The fluorosilicic acid, $H_2SiF_6(aq)$, is added as a source of fluoride, which improves dental hygiene by reducing tooth decay and preventing cavities.

(g) Calculate the final concentration of $H_2SiF_6(aq)$ in the drinking water. (3 marks)

$n(H_2SiF_6)$ = cV **= 1.512 x 30** **= 45.36 mol**	1 Mark
V(water) = 6000 x 1000 **= 6 000 000 L**	1 Mark
$c(H_2SiF_6)$ = n / V **= 45.36 / 6 000 000** **= 7.56×10^{-6} mol L^{-1}**	1 Mark

All of the fluorine present in $H_2SiF_6(aq)$ is released into the drinking water as fluoride ions (F^-). The final concentration of fluoride ions should be 0.85 mg L^{-1} ± 2.0% (i.e. an error of 2.0% is allowed).

(h) Calculate the final concentration of $F^-(aq)$ present in the drinking water. State, with justification, whether this value falls within the acceptable range of error. (5 marks)

$c(F^-) = 6 \times c(H_2SiF_6)$ **$= 6 \times 7.56 \times 10^{-6}$** **$= 4.536 \times 10^{-5}$ mol L^{-1}**	1 Mark
i.e. 4.536×10^{-5} mol in 1 L, therefore; **$m(F^-) = nM$** **$= 4.536 \times 10^{-5} \times 19.00$** **$= 8.6184 \times 10^{-4}$ g**	1 Mark
0.86184 mg	1 Mark
2% error range; **value needs to be within 0.833 – 0.867 mg L^{-1}**	1 Mark
Yes, the concentration is within the acceptable error range	1 Mark

Question 39 **(21 marks)**

Catalytic converters are devices that significantly reduce the amount of pollutants released in the exhaust gases of vehicles. Government regulations in most countries generally state that all vehicles must be fitted with catalytic converters, with the aim of improving environmental and safety outcomes.

The structure of a catalytic converter is based on a honeycomb design, which has a very large surface area. This honeycomb structure is made of a ceramic material, which is coated with a mixture of alumina and silica. The rough surface of this coating further increases the surface area available for reaction.

The catalyst, which is a mixture of finely divided precious metals, is then embedded within this structure. Platinum is the most widely used catalyst, however palladium and rhodium are also very common.

(a) Explain, in terms of the collision theory, the function of a catalyst. (3 marks)

- **A catalyst provides an alternate reaction pathway with a lower activation energy.**	1 Mark
- **Therefore a greater proportion of particles can overcome the activation energy barrier / have collision energy greater than the activation energy**	1 Mark
- **This in turn increases the reaction rate**	1 Mark

Some of the reactions catalysed by the converter are given below.

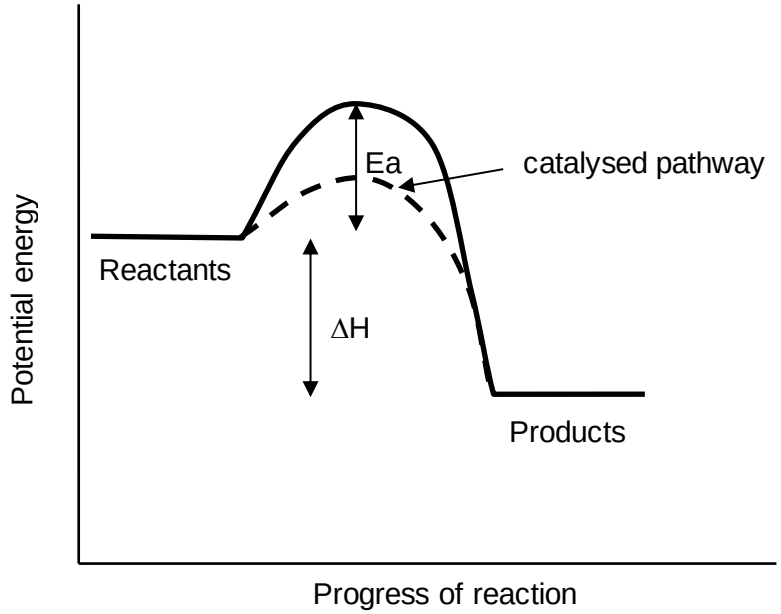
1. $2\ H_2(g) + 2\ NO(g) \rightarrow 2\ H_2O(g) + N_2(g)$ $\Delta H = -666\ kJ\ mol^{-1}$
2. $2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$ $\Delta H = -566\ kJ\ mol^{-1}$
3. $CH_4(g) + 2\ O_2(g) \rightarrow 2\ H_2O(g) + CO_2(g)$ $\Delta H = -803\ kJ\ mol^{-1}$

These reactions require a temperature of at least 425 °C to effectively convert the harmful compounds found in the exhaust gas. For this reason, the catalytic converter is located underneath the car, where the warmth from the engine provides the heat required.

(b) Explain how a high temperature increases reaction rate. (3 marks)

- **High temperature increases the average kinetic energy of particles**	1 Mark
- **This increases the frequency of collisions, and**	1 Mark
- **A greater proportion of particles can overcome the activation energy barrier / have collision energy greater than activation energy**	1 Mark

(c) Sketch **one** labelled energy profile diagram that is representative of all three (3) reactions given on the previous page. Include on your diagram, the effect of the precious metals, such as platinum, used in the converter. (5 marks)



Exothermic shape of curve	1 Mark
Reactants and products labelled	1 Mark
Ea labelled	1 Mark
ΔH labelled	1 Mark
Catalyst pathway	1 Mark

Catalytic poisoning occurs when substances such as lead, sulfur or manganese coat the inside surfaces of the converter. This significantly decreases the efficiency of the catalytic converter and allows most of the harmful exhaust gases to escape.

(d) Explain, in terms of the collision theory, the effect of catalytic poisoning on reaction rate. (3 marks)

- **Reduced surface area of catalyst available**	1 Mark
- **Therefore frequency of collision between reactants and catalyst would be decreased**	1 Mark
- **The reaction rate would thus be lower**	1 Mark

Catalytic converters function optimally when the exhaust gases passing through them are released from an engine where the oxygen to fuel ratio (oxygen : fuel) is kept slightly above stoichiometric point. For a petrol powered car, a ratio of around 14.6 : 1 is used.

The following equation is representative of the combustion reaction occurring in a petrol engine.

$$\mathbf{2}\ C_8H_{18}(l) + \mathbf{25}\ O_2(g) \rightarrow \mathbf{16}\ CO_2(g) + \mathbf{18}\ H_2O(g) + 10940\ kJ$$

(e) Balance this equation and prove that the desired ratio of 14.6 : 1 is just above the stoichiometric point for this reaction. (3 marks)

- **(balancing shown above)** -	1 Mark
- **oxygen:fuel ratio is 25:2 or 12.5:1**	1 Mark
- **Ratio of 14.6:1 is therefore just above the 12.5:1 stoichiometric point**	1 Mark

---

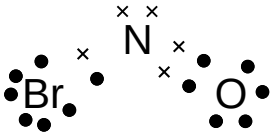
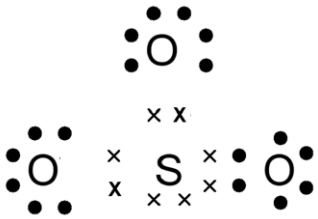
If the fuel tank of a particular vehicle carried 57.3 kg of petrol (C_8H_{18});

(f) Calculate the total amount of heat energy produced if all the petrol in the tank was combusted according to the balanced equation. Give your answer to the appropriate number of significant figures. (4 marks)

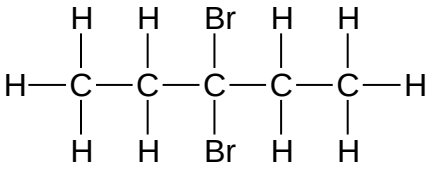
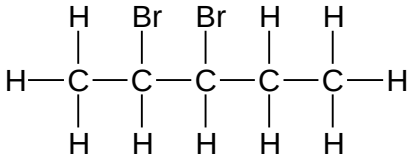
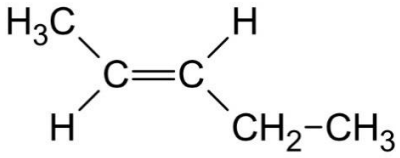
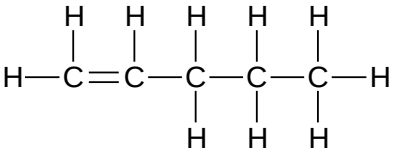
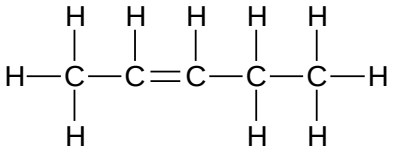
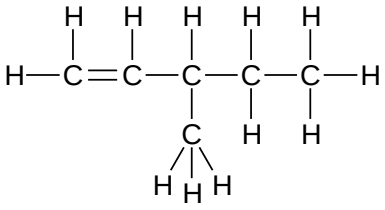
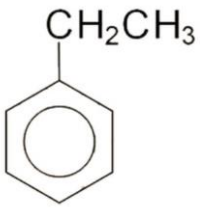
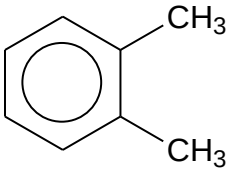
$m(C_8H_{18})$ = 57.3×10^3 **= 57 300 g**	**1 Mark**
$n(C_8H_{18})$ = m / M **= 57 300 / 114.224** **= 501.6459 mol**	**1 Mark**
Heat energy = $10940 / 2 \times n(C_8H_{18})$ **= 10940 / 2 x 501.6459** **= 2 744 003 kJ**	**1 Mark**
= 2.74×10^6 kJ (3 SF)	**1 mark**

Question 40 **(18 marks)**

Complete the table below by drawing a Lewis structure, stating the name of the shape of the molecule and identifying whether it is polar or non-polar(central **atom** will be the most electronegative) (6 marks)

Molecule	**Lewis Structure**	**Shape of Molecule**	**Polar or non–polar**
Nitrosyl bromide (NOBr)		*Bent or V–shaped*	*Polar*
Sulfur trioxide (SO_3)		*Trigonal Planar*	*Non–polar*

Complete the table below.(**Showing all bonds**) (12 Marks)

IUPAC name	Structural formula	IUPAC name and structure of one isomer of the molecule in column 1
3,3 dibromo pentane		Multiple possible answers with formula $C_5H_{10}Br_2$  2,3–dibromo pentane
Trans pent–2–ene		Multiple possible answers with formula C_5H_{10}  Pent–1–ene  Cis–pent–2–ene
4–methyl pent–1–ene	$CH_2CHCH_2CH(CH_3)_2$	Multiple possible answers with formula C_6H_{12}  3–methyl pent–1–ene
Ethyl benzene		Multiple possible answers with formula C_8H_{10}  1,2–dimethylbenzene

Description	Marks
Correct Structural formula drawn for 3,3–dibromo pentane in column 2	1
Correct IUPAC name in each box of column 1 *Namely: Trans–pent–2–ene, 4–methylpent–1–ene and Ethyl benzene* (1 mark each)	3
A structure with the same molecular formula is drawn in column 3 *Model answers provided above* (1 mark each)	4
Each isomer drawn in column 3 is correctly named *Model answers provided above* (1 mark each)	4
Total	**12**

End of questions

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Spare answer page

Question number: _____

Spare answer page

Question number: _____

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Question number: _____

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Question number: _____

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Marking Guide

Section		Questions	Marks	Your Mark	Section Total	Section as % of Exam (4SF)
1		1-25	50		/50	
2	SH	26	12		/83	
	SH	27	6			
	JV	28	8			
	MD	29	8			
	AB	30	7			
	JV	31	8			
	SH	32	9			
	SH	33	8			
	MD	34	10			
	SH	35	7			
3	AB	36	11		/92	
	BL	37	19			
	JV	38	23			
	AB	39	21			
	SF	40	18			

TOTAL