SCOTCH
COLLEGE

Semester Two Examination, 2018

Question/Answer Booklet

CHEMISTRY
Year 11

Student Name/Number:	SOLUTIONS.

Section	**Mark**
One	/50
Two	/70
Three	/60
Total	/180
	%

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

Material required/recommended for this paper

To be provided by the supervisor
Question/Answer booklet
Chemistry Data Book

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

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

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 unauthorized notes or other items of a non-personal nature in the examination room. If you have any unauthorized 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 exam
Section One: Multiple-choice	25	25	50	50	28
Section Two: Short answer	11	11	70	70	39
Section Three: Extended answer	4	4	60	60	33
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2018*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the multiple-choice answer sheet on page 9. 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.

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

3. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

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

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of question(s) that you are continuing to answer at the top of the page.

Section One: Multiple-choice

28% (50 marks)

This section has **25** questions. Answer **all** questions on the Multiple-choice Answer Sheet provided – page 9. 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: 50 minutes.

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1. Which of the following statements about subatomic particles is **false**?

   (a) Protons and neutrons have approximately the same mass. ✓ about 1 amu.
   (b) Protons and electrons have equal and opposite charge. ✓ +1 vs −1
   (c) Protons and neutrons make up most of the mass of an atom. ✓ since electrons are rather light
   (d) Protons and neutrons will be equal in number in any neutral atom. Some, but not all (eg H)

2. Two atoms, Q and R, have the electron configurations 2,2 and 2,8,8,7. Which of the following statements is **true**?

   likely ionic — group 2 - metal — group 7 - non-metal

   (a) The compound formed between Q and R is likely to have a high melting point. ✓
   (b) R is likely to conduct electricity in the liquid state. ✗ (non-metal)
   (c) Q and R are unlikely to react with other elements. ✗ (not noble gases?)
   (d) Elements Q and R would form covalent bonds with one another. ✗ ionic

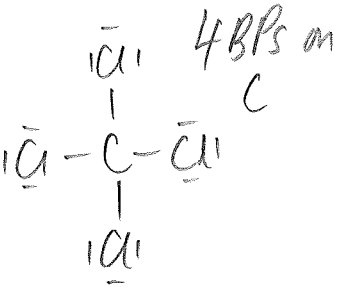
3. Which of the following solutions is likely to have the **highest** pH?

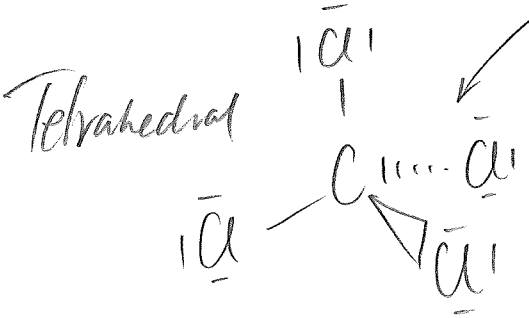
   most basic, i.e. highest $[OH^-]$ or lowest $[H^+]$

   (a) 1 mol L^{-1} NaOH(aq) Strong base
   (b) 1 mol L^{-1} NH_3(aq) weak base
   (c) 1 mol L^{-1} Na_2CO_3(aq) weak base
   (d) 1 mol L^{-1} CH_3COOH(aq) weak acid

4. Which one of the following best describes the molecular shape, polarity of bonds and the molecular polarity of a CCl_4 molecule?

	Shape	Bond polarity	Molecular polarity
(a)	tetrahedral ✓	non-polar ✗	polar
(b)	tetrahedral ✓	polar ✓	polar
(c)	pyramidal ✗	non-polar ✗	polar
(d)	tetrahedral ✓	polar ✓	non-polar ✓





Each C–Cl bond is polar, since Cl is much more electronegative than C

5. Which of the following common substances can be described as a homogenous mixture?

(a) Concrete
(b) Limestone
(c) Stainless steel
(d) Copper

6. Germanium is an element that exists as a covalent network. Which of the following statements **best** explains why germanium melts at a high temperature (938°C)?

(a) There are strong electrostatic attractions between germanium ions and delocalized electrons.
(b) There are strong electrostatic attractions between germanium atoms and shared pairs of electrons.
(c) There are strong intramolecular bonds between oppositely charged germanium ions.
(d) There are strong intermolecular forces between germanium atoms.

7. In which of the following experiments would no visible observation be made?

(a) Solid potassium nitrate is shaken with distilled water.
(b) A small piece of sodium is placed in water.
(c) Solid calcium carbonate is added to dilute hydrochloric acid.
(d) Sodium carbonate solution is mixed with ammonium nitrate solution.

8. Two solutions, A and B, have a pH of 3 and 6 respectively. Which of the following statements about the solutions must be **true**?

(i) They are both acidic.
(ii) The concentration of H^+ is higher in B than it is in A.
(iii) B is a weaker acid than A.

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

9. In which one of the following is more than one type of intermolecular force acting?

(a) $Br_2(s)$
(b) $SO_2(s)$
(c) $CH_4(s)$
(d) $CO_2(s)$

10. Which of the following lists of oxides would all produce alkaline solutions when dissolved in water?

(a) CO_2, SiO_2, CaO
(b) CaO, Na_2O, P_4O_{10}
(c) K_2O, CaO, Na_2O
(d) P_4O_{10}, SO_2, CO_2

11. Ammonia is classed as a weak electrolyte. Which of the following statements **best** explains this?

(a) Only a small proportion of ammonia molecules will be form ions in solution.
(b) The pH of ammonia solutions is quite low compared to other bases.
(c) Ammonia is not very soluble in water.
(d) Ammonia is a covalent molecule, so its solution will not have any ions.

12. Which one of these molecular chemical equations correctly shows the reaction (including state symbols) when dilute solutions of sodium hydroxide and ammonium chloride are mixed at 20°C?

(a) $NaOH(s) + NH_4Cl(aq) \rightarrow NaCl(aq) + NH_4OH(aq)$
(b) $NaOH(aq) + NH_4Cl(aq) \rightarrow NaCl(aq) + H_2O(\ell) + NH_3(g)$
(c) $NaOH(\ell) + NH_4Cl(\ell) \rightarrow NaCl(aq) + HCl(\ell) + NH_3(\ell)$
(d) $NaOH(aq) + NH_3Cl(aq) \rightarrow NaCl(aq) + H_2O(g) + NH_3(g)$

13. In which of the following equations is water acting as an acid?

(a) $2\,K(s) + 2\,H_2O(\ell) \rightarrow 2\,KOH(aq) + H_2(g)$
(b) $NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
(c) $H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$
(d) $HCl(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq)$

14. Which of the following statements is generally true of elements in the Periodic Table?

(a) Ionization energy increases down a group
(b) atomic radii increase across a period
(c) group 1 elements become more metallic as the atomic number increases
(d) electronegativity decreases down a group

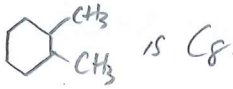
15. Which of the following reactions is endothermic?

(a) $Br_2(g) \rightarrow 2\ Br(g)$ ✓ Breaking bonds.
(b) $N_2(g) \rightarrow N_2(\ell)$ ✗ condensing
(c) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$ ✗ combustion
(d) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$ ✗ forming bonds (also neutralisation).

16. Ethanol (C_2H_5OH) has a boiling point just over 78°C. Which of the following statements is **true**? raises boiling pt. lt lower than H_2O – easier to evaporate, and higher v.p.

(a) Ethanol has stronger intermolecular forces than water. ✗ weaker
(b) Adding an impurity to ethanol would make it evaporate more quickly. ✗
(c) The vapour pressure of ethanol at 100°C would be greater than that of an aqueous solution of sodium chloride. ✓ – impure water – would have lower v.p. than water
(d) The bonds in ethanol must be weaker than those in water. ✗ not broken

17. In which of the following pairs are the two substances shown isomers of one another? 7Cs 2Cs 6Cs

(a) heptane and 3-ethylhexane ✗
(b) 1-butene and methylpropane ✗ C_4H_8 vs C_4H_{10}
(c) 1,2,3-tribromobutane and 1,1,2-tribromoprop-1-ene ✗ 4Cs vs 3Cs
(d) 1,2-dimethylcyclohexane and 1-octene ✓ C_8H_{16}  is C_8H_{16}

18. 10 g of argon gas is placed in a sealed syringe at 50°C. The temperature is lowered to 25°C, and the syringe compressed to half its original volume. Which of the following statements is **true** after the changes are made? Only AVERAGE speed falls with T (some particles may move faster)

(a) All the argon particles are moving more slowly, and the pressure inside the syringe has dropped.
(b) Some of the argon particles are moving more slowly, and the pressure inside the syringe is unchanged. ✗
(c) All the argon particles are moving more slowly and the pressure inside the syringe is unchanged. ✗
(d) Some of the argon particles are moving more slowly and the pressure inside the syringe has risen. ½ volume should DOUBLE P at constant T

But temp has not halved 323.15K → 298.15K (½ Temp) should HALVE P at constant ✓

19. Which of the following aqueous solutions contains the **greatest overall** concentration of ions?

(a) 0.25 mol L^{-1} calcium nitrate $Ca(NO_3)_2$ – 3 ions; overall conc = 3×0.25 ✗
(b) 0.50 mol L^{-1} lithium sulfate Li_2SO_4 – 3 ions; overall conc = 3×0.5 ✓
(c) 0.25 mol L^{-1} iron(III) chloride $FeCl_3$ – 4 ions; overall conc = 4×0.25 ✗
(d) 0.50 mol L^{-1} sodium chloride $NaCl$ – 2 ions; overall conc = 2×0.5 ✗

20. What mass of copper(II) chloride would need to be dissolved in 500 mL of distilled water to produce a solution with a concentration of 0.0500 mol L^{-1}?

(a) 2.47 g
(b) 3.36 g
(c) 4.95 g
(d) 6.72 g

$CaCl_2$ $M = 63.55 + 2 \times 35.45 = 134.45$

$\frac{1}{2}$ L

0.05 mol in 1 L ∴ 0.025 mol in $\frac{1}{2}$ L

$m = n \times M = 0.025 \times 134.45$

21. Which of the following pairs of substances or ions can be described as a conjugate pair according to the Brønsted-Lowry theory of acids and bases

(i) HS^- and H_2S ✓
(ii) H_2SO_4 and SO_4^{2-} × ($2H^+$)
(iii) OH^- and O^{2-} ✓
(iv) HCO_3^- and H_2CO_3 ✓

differ by 1 H^+ ion

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

22. In which of the following substances are there **no** covalent bonds present in the solid lattice?

Must be ionic or metallic

(a) SO_2 × covalent
(b) $SrSO_3$ × — ionic but SO_3^{2-} contains covalent bonds
(c) SiO_2 × covalent network
(d) SrO ✓ ionic

23. Aluminium is ductile and malleable. Which of the following statements **best** explains these properties?

ions in a metallic lattice

(a) The forces between aluminium atoms are weak, but can operate over relatively long distances.
(b) Aluminium ions are bonded in layers, with strong bonds within layers and weak forces between one layer and the next. × Sounds like graphite
(c) Aluminium ions will attract one another regardless of their orientation, and so the bonds in the metal lattice will not break when it changes shape.
(d) Delocalised electrons are able to move freely amongst the ions, meaning that metallic bonds are equally strong in all directions. ✓

Metallic bonds operate in all directions equally

no - they are all positive

24. Copper(II) sulfate pentahydrate ($CuSO_4.5H_2O$) has a solubility of 320 g L^{-1} at 20°C. A saturated solution is made by dissolving 400 g of $CuSO_4.5H_2O$ in 1 L of distilled water. The mixture is then heated to evaporate some of the water and cooled back to 20°C. Which of the following statements about the resulting mixture is **false**?

inserted "@ 20°C" ✓

(a) There would be more solid present than in the original mixture. ✓
(b) The concentration of the resulting solution would be higher than that of the original solution. ✗ Concentration determined by solubility, and T has not changed.
(c) The solution would be blue in colour. ✓ Cu^{2+} (aq)
(d) At least 80 g of solid could be recovered by filtering the mixture. ✓

25. Which of the following statements **best** explains the effect of an increase in temperature on the rate of a chemical reaction?

(a) Increasing the temperature increases the average kinetic energy of particles, meaning that the fraction of collisions exceeding the activation energy will increase. ✓
(b) Increasing the temperature causes the particles to move faster and collide with each other more often. True, but minor effect.
(c) Increasing the temperature increases the average speed of the particles, meaning there is a better chance of them colliding in the correct orientation. ✗ Won't affect which way they are oriented on average.
(d) Increasing the temperature causes the activation energy of the process to decrease, meaning a greater proportion of collisions will lead to a reaction. not affected by T.

(Since only 320g can dissolve)

24. ∘ 400g will not dissolve in 1L @ 20°C (80g will remain)
∘ Some water evaporates, so volume will be less than 1L, and LESS than 320g will dissolve @ 20°C

End of section one

so... original mixture will contain ~ 80g of solid
new mixture will contain > 80g of solid
(which can be removed by filtering)

Multi-choice answer sheet

	a)	b)	c)	d)
1				✓
2	✓			
3	✓			
4				✓
5			✓	
6		✓		
7				✓
8	✓			
9		✓		
10			✓	
11	✓			
12		✓		
13		✓		
14			✓	
15	✓			
16			✓	
17				✓
18				✓
19		✓		
20		✓		
21			✓	
22				✓
23				✓
24		✓		
25	✓			

Mark one response per question with an "X"

Section Two: Short answer **39% (70 Marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the space provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to **three significant figures and include appropriate units** where applicable.

Do not use abbreviations, such as 'nr' for 'no reaction', without first defining them.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 26 **(6 marks)**

The following question involves naming and writing formula of compounds.

(a) Complete the table below by writing the formula of each of the compounds listed. (3 marks)

Name of compound	Formula of compound
hydrogen peroxide	H_2O_2
chromium(III) bromide	$CrBr_3$
aluminium carbonate	$Al_2(CO_3)_3$

Cr^{3+} Br^- ×1 ×3

Al^{3+} CO_3^{2-} ×2 ×3

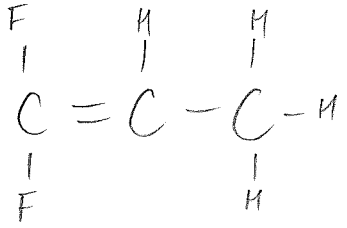
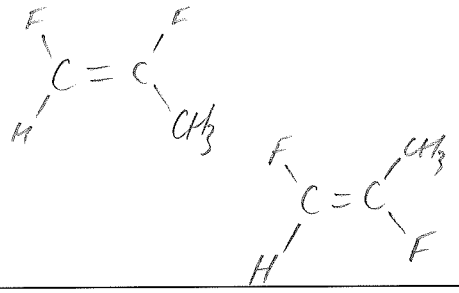
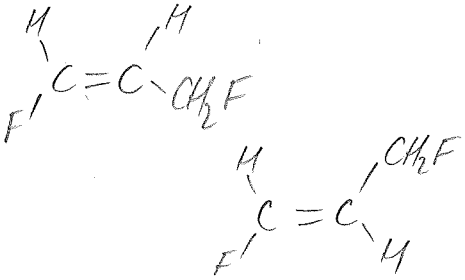
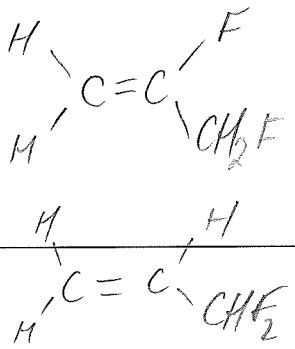
(b) Complete the table below by writing the name of each of the compounds listed. (3 marks)

Formula of compound	Name of compound
$(NH_4)_2SO_4$	Ammonium Sulfate
SF_6	Sulfur hexafluoride
$CHCl_3$	Trichloromethane.

Question 27 **(15 marks)**

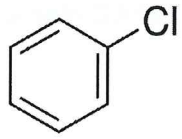
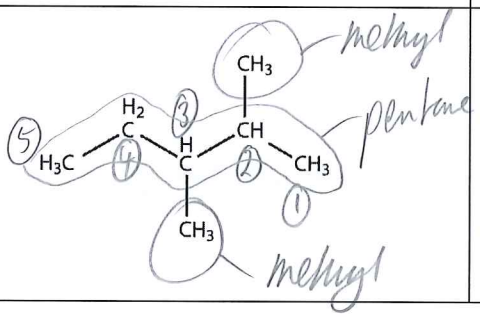
(a) Draw the full structure and give the IUPAC names of four <u>non-cyclic</u> isomers of $C_3H_4F_2$. You do not need to draw all possible isomers to gain full marks.

(8 marks)

Structure	IUPAC Name
	1,1-difluoropropene
	cis-1,2-difluoropropene trans-1,2-difluoropropene
	cis-1,3-difluoropropene trans-1,3-difluoropropene
	2,3-difluoropropene 3,3-difluoropropene.

- Allow marks if names are based on prop-1-ene / 1-propene but NOT if based on prop-2-ene / 2-propene
- Only penalise this particular error once.

(b) State the IUPAC name for each of the organic compounds whose structures are represented in the following table. (2 marks)

Structure	IUPAC Name
	Chlorobenzene
	2,3-dimethylpentane

(c) Explain why 2-butene is able to exist as geometric isomers, whilst 1-butene is not. (3 marks)

To exist as geometric isomers we need:

C=C ✓

Two different groups attached to each C here ✓

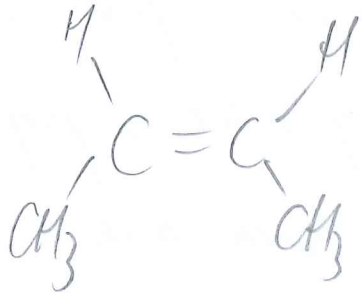
2-butene has CH_3 and H attached to each C, whilst ✓

1-butene has two H's attached to 1 of them (the 1st)

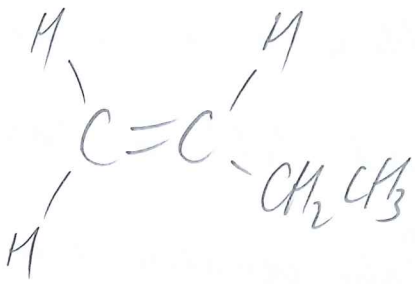
(see below)

(d) State the intermolecular force(s) in the first compound. (2 marks)

Dispersion + dipole-dipole.



but-2-ene



but-1-ene

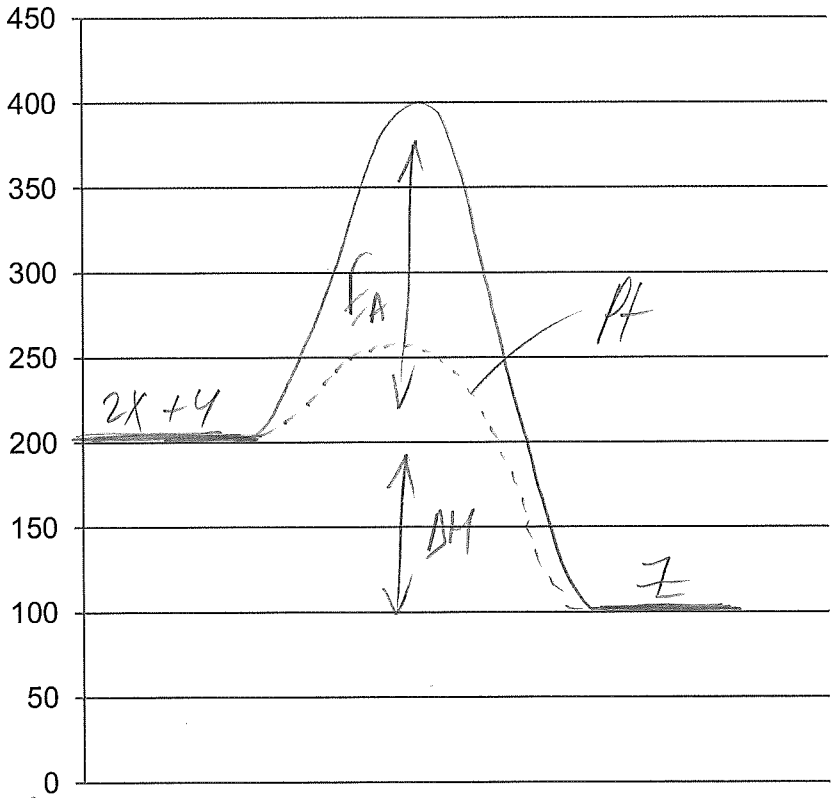
Question 28 **(9 marks)**

Two substances, X and Y, react to produce Z according to the following equation:

$$2\,X(g) + Y(g) \rightarrow Z(g) \quad \Delta H = -100\ kJ\ mol^{-1}$$

It is found that the activation energy for the reaction is 200 kJ mol^{-1}.

(a) Using the axes provided below, sketch the reaction profile for the reaction, assuming that enthalpy of the reactants is 200 kJ mol^{-1}. Ensure that you provide a title for the x and y axes in the box provided, and that you label your sketch clearly. (4 marks)



y-axis label

Enthalpy (allow Energy)

x-axis label

Reaction progress/co-ordinate

NOT time

- Exothermic Rxn shown
- E_A "hump" and ΔH drop correct size
- E_A and ΔH labelled correctly
- Axes labelled correctly

The reaction is carried out again in the presence of a fine platinum mesh. The reaction is observed to proceed much more rapidly, and the platinum is found unchanged at the end of the reaction.

(b) On the same axes as those used in part (a), add a sketch to show the effect of the platinum. Label this 'Pt'. Same ΔH, lower E_A ✓ (1 mark)

(c) Use collision theory to explain the effect that platinum has on the rate of reaction. (2 marks)

- Provides an alternative reaction pathway ✓
- With a lower E_A ✓ No marks for "lowers E_A"
- Greater proportion of particles have $\geq E_A$ ✓

Any 2.

(d) State and explain what observations would be made, regarding the rate of reaction, if the reaction were carried out again using platinum beads instead of the fine mesh. (2 marks)

Effect on rate (increase, decrease or no change)	Explanation
decrease ✓	decreased S.A. (using beads) so fewer particles exposed no collisions.

Not just "decreased S.A"

Question 29 **(3 marks)**

Complete the table below by writing the electron configuration of the atoms or ions listed.

Atom or ion	Electron configuration
A sulfur atom	2,8,6
The 2- charged ion of the element in group 16, period 3	2,8,8
An isotope of nitrogen whose nucleus contains 8 neutrons	2,5

Question 30 **(4 marks)**

Iron exists as four naturally occurring isotopes. Considering the lightest of these, ^{54}Fe:

(a) how many neutrons are there in an atom? (1 mark)

(54 − 26) = 28

(b) what is the mass number? (1 mark)

54

Carbon forms numerous oxides and ions containing oxygen, such as CO, CO_2 and CO_3^{2-}.

(c) How many protons are there in a molecule of CO_2? (1 mark)

22

(d) How many electrons are there in a carbonate ion (CO_3^{2-})? (1 mark)

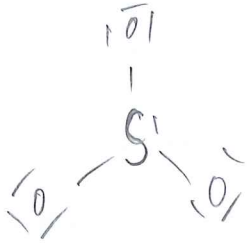
32 (24 valence electrons, but question does not ask for valence electrons)

Question 31 **(4 marks)**

For each of the species listed in the table below, draw electron dot diagrams and describe their shape.

Show all valence shell electron pairs either as : or as —

(for example, water $H:\ddot{O}:H$ or $H-\ddot{O}-H$ or $H-\bar{\underline{O}}-H$)

Species	Electron dot diagram	Shape
SO_3^{2-} 6 +2 26 e⁻s 13 pairs 3x6		Trigonal Pyramidal.
C_2H_2 2x4 2 10 e⁻s	H–C≡C–H	Linear.

Question 32 **(6 marks)**

Account for the following observations.

(a) The temperature of water in a beaker is observed to fall as the water evaporates. (3 marks)

3 marks.
- Particles most likely to escape from surface are those with most K.E. average
- If some particles evaporate, K.E falls
- Temp ∝ K.E.

(or)

- Evaporation is an endothermic process
- Heat is absorbed by those particles that evaporate, causing av. K.E. to fall
- Temp ∝ K.E.

(b) Copper is an excellent conductor of electricity in the solid state, whereas solid copper chloride is an electrical insulator. (3 marks)

- When copper is solid (metallic lattice) there are delocalised electrons that can carry charge ✓
- Copper chloride is ionic, and the ions are in fixed positions in the solid state ✓
- No mobile charge carriers ∴ insulator. ✓

Question 33 **(9 marks)**

Give balanced ionic equations for any reactions which occur in the following experiments. If no reaction occurs then write 'no reaction'.

In each case describe observations such as colour changes, precipitate formation (give the colour), or gas evolution (give the colour or describe as colourless) resulting from the chemical reaction. If no visible change occurs then you should state this.

(a) A spatula full of sodium ~~sulfide~~ changed to 'oxide' is placed in a test tube of dilute nitric acid. (3 marks)

Equation $Na_2O + 2HNO_3 \rightarrow 2NaNO_3 + H_2O$ ✓ $Na_2O + 2H^+ \rightarrow 2Na^+ + H_2O$ ✓✓

Observation White solid dissolves in c/less solution, giving c/less solution

(b) Silver nitrate solution is added dropwise to a beaker of dilute hydrochloric solution. (3 marks)

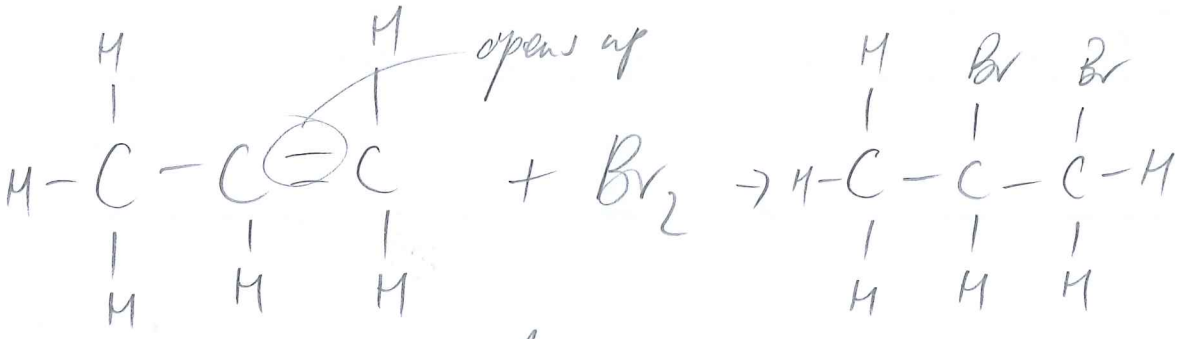
Equation $AgNO_3 + HCl \rightarrow HNO_3 + AgCl$ ✓ $Ag^+ + Cl^- \rightarrow AgCl$ ✓✓

Observation Two c/less solutions produce white ppt in c/less solution.

(c) Bromine water is added to Propene (C_3H_6). (3 marks)

Equation $C_3H_6 + Br_2 \rightarrow C_3H_6Br_2$

Observation Orange solution ($Br_{2(aq)}$) Fades to c/less



ADDITION

Question 34 **(4 marks)**

First stated by Joseph Gay-Lussac around the end of the 18th century, Gay-Lussac's law states "the pressure exerted by a gas in a sealed container is directly proportional to its temperature". In common with other laws stated around the same time, Gay-Lussac's law works well for so-called 'ideal' gases, but there are conditions under which real gases do not obey the laws particularly well.

(a) Explain why the pressure of a gas should increase as the temperature increases. (2 marks)

This is NOT a q about vapour pressure ....

$T \propto K.E.$ so the particles move faster when heated ✓

$P = F/A$ and F increases since the particles are colliding with the container walls with more force. ✓

(b) Give two reasons why the behaviour of real gases deviate from ideal gas behaviour. (2 marks)

Ideal gas (assumptions)	Real gas
○ Particles occupy no volume	○ Particles DO take up space ✓
○ Particles exert negligible forces on one another	○ Particles DO interact with one another ✓
○ Collisions are perfectly elastic	○ Energy is transferred in collisions. ✓

any 2

Question 35 **(4 marks)**

For each of the following descriptions, give the name or formula of a substance that matches the description

(a) A weak diprotic acid. H_2CO_3 / H_2SO_3 etc

(b) A substance that has ionic and covalent bonds. lots of possibilities eg Na_2CO_3

(c) An acidic oxide with two oxygens in the compound. CO_2 / SO_2 / NO_2 etc

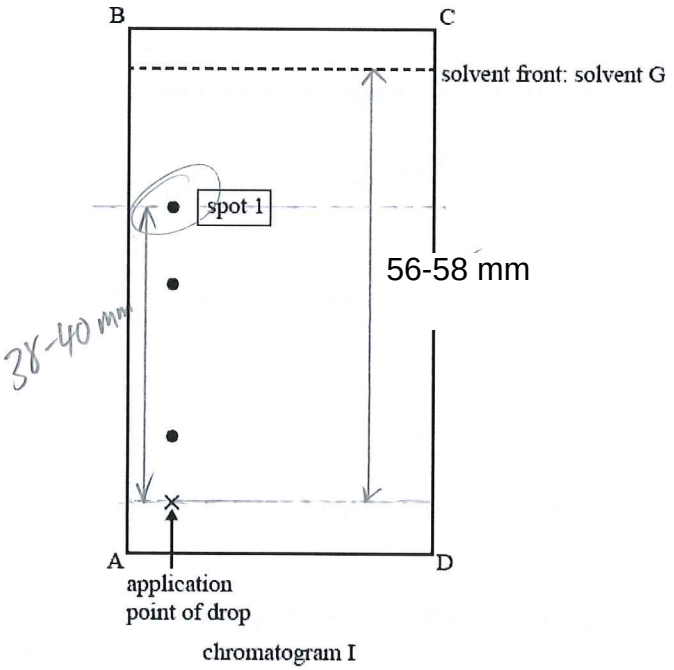
(d) A branched hydrocarbon with the formula C_4H_{10}. NOT C_4H_{10} $CH_3CH(CH_3)_2$

methyl propane.

(allow 2-methyl propane)

Question 36 **(6 marks)**

Two analytical methods used in chemistry are Chromatography and Mass Spectroscopy.
A drop that contains a mixture of amino acids was applied to a Thin Layer Chromatography (T.L.C.) plate. The plate was placed in a solvent G and the following chromatogram obtained



chromatogram I

(a) Calculate the R_f for spot 1. (2 marks)

Distances correctly measured ✓

39/57 = 0.68 (allow answers in the range 38/58 = 0.66 to 40/56 = 0.71 for two marks, or any correct use of incorrect measurements for 1 mark)

(b) Which amino acid is attracted to the mobile phase the most (circle a dot) and explain why you chose this one? (2 marks)

Spot 1 since it travels furthest, and spends more time dissolved in the solvent ✓✓

(c) In Mass Spectroscopy what two factors will determine the amount of deflection? (2 marks)

State that

Charge on Ion

Mass of ion

Field strength (of magnet)

End of section two

Section Three: Extended answer 33% (60 marks)

This section contains **four (4)** questions. Answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression.

Final answers to calculations should be expressed to **three (3) significant figures**.

penalise only once

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 37 (25 marks)

Chlorine is an element that is found in several acids. The acids are shown in the table below.

Name and formula of acid	Strong/Weak
hydrochloric acid $HC\ell$	strong
hypochlorous acid $HOC\ell$	weak
chlorous acid $HC\ell O_2$	weak
chloric acid $HC\ell O_3$	strong
perchloric acid $HC\ell O_4$	strong

(a) The pH of a solution of perchloric acid was found to be 2. What was the concentration of the solution in g L^{-1}? (3 marks)

pH of 2 means $[H^+] = 0.01\ mol\ L^{-1}$ ✓

Strong acid, so $[acid] = [H^+]$ ✓

$m = n \times M = 0.01 \times (1.008 + 35.45 + 64) = 1.00\ g/mol$ ✓
$= 100.458$
(3sf)

Question 37 (continued)

Hypochlorous acid and hydrochloric acid are both formed when chlorine is dissolved in water.

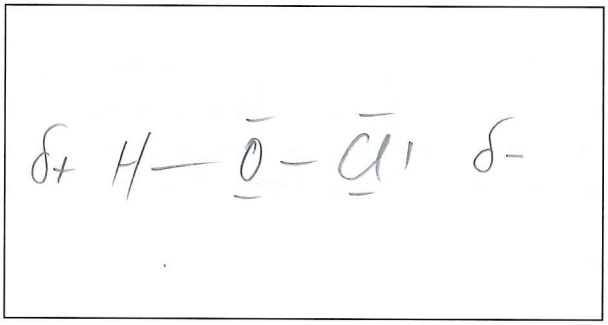
(b) Write the balanced chemical equation for this reaction. (2 marks)

$Cl_2 + H_2O \longrightarrow HOCl + HCl$ ✓✓

(reactants ✓ products ✓)

(c) Draw the structural diagram for hypochlorous acid and use vectors to show the polarity within the molecule. (2 marks)

partial charges



Allow this representation for 2 marks - the molecule should be bent, and the chlorine will be positive in relation to the oxygen, but this is not required

(d) Using appropriate equations to illustrate your answer, explain how you would expect the pH of a 0.01 mol L^{-1} solution of hypochlorous acid to compare with the pH of a 0.01 mol L^{-1} solution of hydrochloric acid. (4 marks)

$HOCl + H_2O \rightleftharpoons OCl^- + H_3O^+$ ✓

or $HOCl \rightleftharpoons OCl^- + H^+$

$HCl + H_2O \longrightarrow Cl^- + H_3O^+$ ✓

or $HCl \longrightarrow Cl^- + H^+$

Since HCl is strong, $[H^+] = 0.001\ mol\ L^{-1}$, and $pH = 3$ ✓

($pH = -\log(0.001)$)

Since HOCl is weak, $[H^+] < 0.001\ mol\ L^{-1}$, and $pH > 3$. ✓

In an experiment to investigate the reactions of hydrochloric acid with metals, a student decided to react the acid with zinc granules and measure the mass lost over a period of time.

(e) Write a balanced ionic equation to show the reaction taking place. (2 marks)

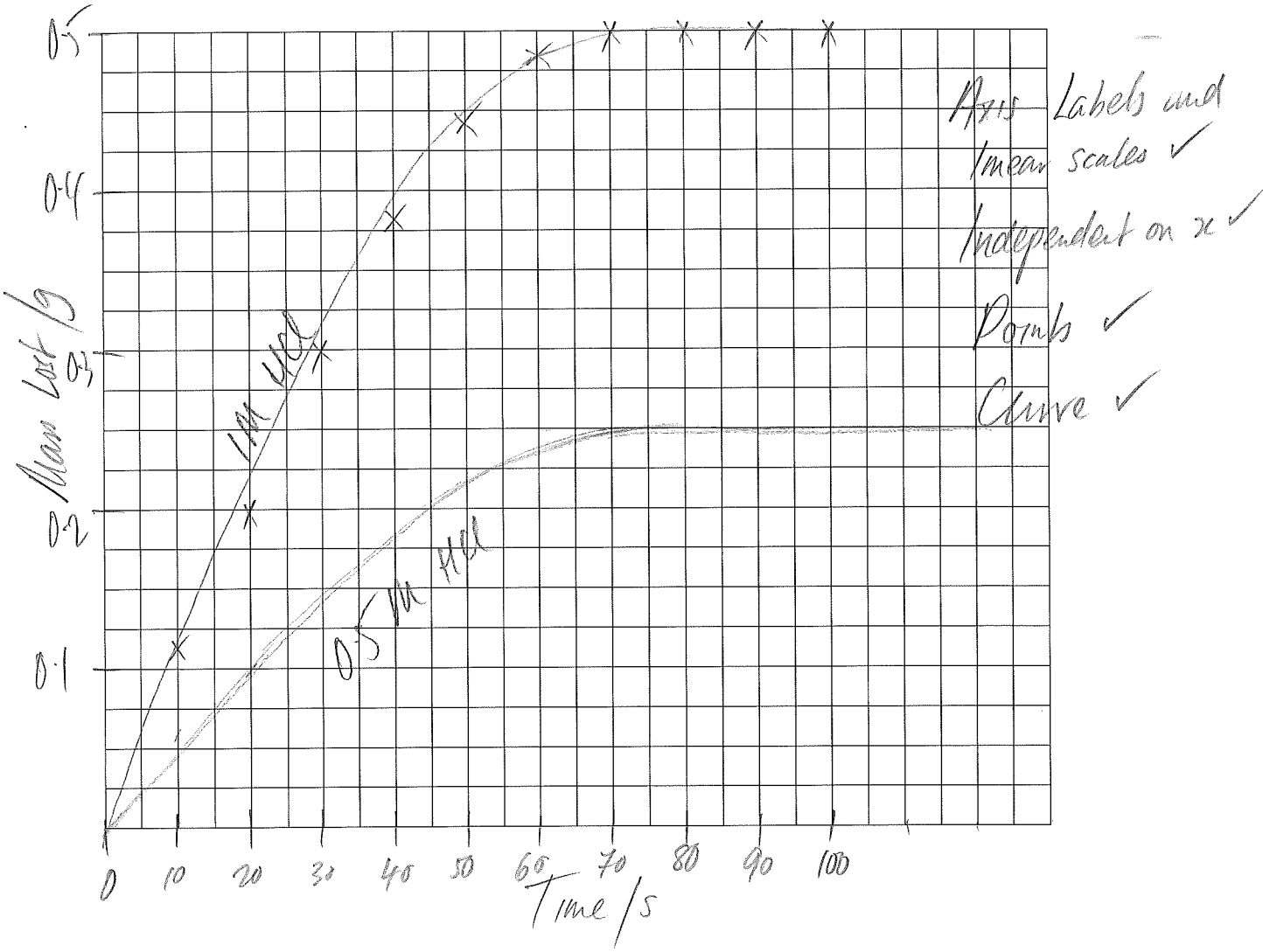
$2HCl + Zn \rightarrow ZnCl_2 + H_2$ ✓ $2H^+ + Zn \rightarrow Zn^{2+} + H_2$ ✓

In conducting the experiment, the student measured out 50 mL of 1 mol L^{-1} hydrochloric acid using a beaker, and poured this into a conical flask. She then placed the flask on a balance, together with an excess of zinc in a weighing boat. She recorded the mass, then added the zinc to the acid, and placed the weighing boat back on the balance. She then recorded the mass at intervals until it seemed the reaction had stopped. The student's results are displayed in the table below.

Time / s	0	10	20	30	40	50	60	70	80	90	100
Mass / g	90.00	89.89	89.80	89.70	89.62	89.56	89.52	89.50	89.50	89.50	89.50
Mass lost / g	0	0.11	0.20	0.30	0.38	0.44	0.48	0.50	0.50	0.50	0.50

(f) Complete the table by filling in the missing data. (1 mark)

(g) Graph the data on the graph paper below, labeling your line '1M HCℓ'. (4 marks)



Question 37 (continued)

(h) Other than by repeating the experiment, state one way in which the student might have modified her method to obtain more accurate results. (1 mark)

Used measuring cylinder rather than beaker
Placed cotton wool in flask to prevent loss of spray
Other suitable measures

(i) With reference to collision theory, explain the shape of the graph between 30 seconds and 70 seconds. (3 marks)

The rate of reaction is slowing down ✓

Reactant particle conc is falling as reactants are consumed ✓ (or fewer particles per unit volume)
Fewer collisions per second ✓

The experiment was repeated using 50 mL of 0.5 mol L^{-1} hydrochloric acid.

(j) On the same graph used in part (g), **sketch** the results you would expect using 50 mL of 0.5 mol L^{-1} hydrochloric acid. Label this line '0.5M HCℓ'. (2 marks)

½ as steep at start ✓ Reaches ½ mass lost. ✓

(k) State **one** factor that was important for the student to **control** in order to obtain valid results. (1 mark)

(Since the experiment could easily be used to measure rate...)

Temp of acid
S.A. of zinc
Not conc

Question 38 **(13 marks)**

Year 11 Chemistry students were given the task of identifying three white powders, sodium carbonate, sodium chloride and sodium nitrate.

A 2.00 g sample of each white powder was completely dissolved in 100 mL distilled water and tests carried out on separate 20.0 mL samples.

Give two **chemical tests** and **observations** that could be used to identify the powders.

The first test should enable the students to identify one of the three powders.
The second test should enable the students to identify one of the remaining two powders.

(7 marks)

Plenty of options here, for example...

Test 1	Observations
Add $HCl_{(aq)}$	Sodium Carbonate White solid dissolves, Bubbles of clear gas Sodium chloride White solid dissolves → clear solution Sodium Nitrate White solid dissolves → clear solution.
Test 2	**Observations (remaining two powders)**
Add $AgNO_{3(aq)}$	Powder 1 Sodium Chloride No visible reaction (since white solid dissolves and white ppt forms) Powder 2 Sodium Nitrate White solid dissolves

Students must mention STATE of reactants in tests, since these will determine observations.
If no state given/implied, give no marks for obs (mark can be given for test)

b) Calculate the number of moles of sodium carbonate in the 20.0 mL sample. (2 marks)

$n(Na_2CO_3)$ in 2.00g $= m/M = 2/(22.99\times2 + 12.01 + 48) = 2/105.99 = 0.0189$ mol ✓

but this was in 100ml ✓

$\therefore$ in 20ml we have $\frac{20}{100} \times$ ans $= 3.77 \times 10^{-3}$ mol (3sf)

c) Calculate the concentration of the sodium carbonate in the 100 mL sample. (1 mark)

$c = n/v = 0.0189/0.100 = 0.189$ mol L^{-1} ✓

Sodium chloride solution can be made by reacting sodium hydroxide and hydrochloric acid.

d) Calculate the minimum volume of 2.00 mol L^{-1} hydrochloric acid required to produce 2.00 g of sodium chloride. (3 marks)

$HCl + NaOH \rightarrow NaCl + H_2O$

$\therefore n(HCl) = n(NaCl)$ ✓

$n(NaCl) = 2/(22.99+35.45) = 0.0342$ mol ✓

$V = n/c = 0.0342/2 = 17.1$ ml (3sf) ✓

Question 39 **(10 marks)**

As the human race seeks to reduce its reliance on fossil fuels, the importance of discovering alternative fuels, and new ways of producing fuels, becomes ever more important. Methanol (CH_3OH) is one such alternative fuel, and plays a number of important roles in replacing fossil fuels: it can be mixed with petrol; it can be converted into diesel; and it can be used in the production of biodiesel.

Methanol can be made from carbon monoxide and hydrogen. Currently, the most commonly used method of producing the carbon monoxide and hydrogen is called steam reforming, and involves the reaction of methane (from natural gas) and steam according to the following equation:

$$2\ CH_4(g) + 3\ H_2O(g) \rightarrow CO(g) + CO_2(g) + 7H_2(g)$$

The carbon monoxide and hydrogen then react to produce methanol according to the following equation:

$$CO(g) + 2\ H_2(g) \rightarrow CH_3OH(g)$$

10 kg of carbon monoxide are mixed with 10,000 L of hydrogen gas at STP.

(a) Find the limiting reactant. (using the second equation) (3 marks)

$n(CO) = \frac{10,000}{(12.01+16)} = 357$ mol ✓

$n(H_2) = V/22.71 = 10,000/22.71 = 440$ mol ✓ } 3sf

357 mol of CO requires 2×357 mol $= 714$ mol ✓

But we only have 440 mol $\therefore H_2$ is L.R ✓

(b) What is the maximum mass of methanol that can be formed? (3 marks)

$n(\text{methanol}) = 1/2\ n(H_2) = 220$ mol ✓

$m(\text{methanol}) = n \times M = 220 \times \frac{(12.01 + 4 \times 1.008 + 16)}{32.042}$

$= 7050$ g ✓

or 7.05 kg (3sf)

(c) How many moles of unreacted gas remain at the end of the reaction? (2 marks)

$n(CO)$ consumed $= \frac{1}{2} n(H_2) = 220$ mol ✓

$\therefore n(CO)$ remaining $= 357 - 220 = 137$ mol ✓

Although the heat produced by the reactions, described on the previous page, can be used to generate the electricity needed for the process, more sustainable methods of production are sought. A team of researchers at the University of Texas have developed a new method of producing methanol that involves using copper(II) oxide nanowires coated in copper(I) oxide and submerged in a solution containing carbon dioxide. When subjected to sunlight, the carbon dioxide is converted to methanol whilst avoiding the excess energy input.

(d) By considering the reactions outlined above, give two ways in which this new method of production may help the environment. (2 marks)

No fossil fuels used to provide energy
∴ Less greenhouse gas emissions
Copper oxides can be reused, so less waste generated
No other raw materials (like H_2) required

any 2 sensible reasons.

Question 40 **(12 marks)**

Although petrol is made up predominantly of alkanes with between seven and eleven carbon atoms, these are often combined with additives to improve performance.

An additive used to prevent knocking (an effect caused by uncontrolled combustion in the cylinders of a combustion engine) was analysed by burning it in excess oxygen and collecting the gases formed. The additive contained carbon, hydrogen and oxygen, and it was found that a ~~12.24~~ 12.99 g sample of the anti-knocking additive produced 31.16 g of carbon dioxide and ~~7.98~~ 6.37 g of water upon combustion.

(a) Find the empirical formula of the anti-knocking additive. Show clear working.

(7 marks)

$n(C) = n(CO_2) = \frac{31.16}{44.01} = 0.708$ mol

$n(H) = 2 \times n(H_2O) = 6.37/18.016 = 0.707$ mol ✓

$m(C) = 0.708 \times 12.01 = 8.50$ g

$m(H) = 0.707 \times 1.008 = 0.713$ g ✓

$m(O) = 12.99 - 8.50 - 0.713 = 3.78$ g ✓

$n(O) = 3.78\text{ g}/16 = 0.236$ mol ✓

C	H	O
0.708	0.707	0.236
3	3	1

✓

C_3H_3O ✓

9.69

Subsequent analysis of the anti-knocking additive involved taking another ~~6.08~~ g sample and heating it in the absence of oxygen to vaporise it. It was found that the vapours occupied 2.00 L at STP.

(b) Find the molecular formula of the anti-knocking additive. Show clear working.

(3 marks)

$n = 2/22.71 = 0.0881$ mol

$M = m/n = 9.69/0.0881 \simeq 110$ ✓

"M" of E.F. $= 3\times12.01 + 3\times1.008 + 16 = 55.054$

$\therefore MF = \frac{110}{55.054} \times EF$ ✓

$= 2 \times E.F. \Rightarrow C_6H_6O_2$

(c) The melting point of the additive is 78 C^0. Relate this value to its possible ~~Van der Waals~~ intermolecular forces

(2 mark)

Relatively high melting point, so must have relatively strong IMFs ✓

Perhaps H-bonds (since it contains O and H) ✓

Bonus question: What colour is the All Blacks rugby jumper? Green + Gold?

End of paper

Spare answer page

Question number: _____

Spare answer page

Question number: _____