Year 11 Semester Two Examination, 2015

MARKING KEY

CHEMISTRY

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, do not erase or use correction fluid, and shade your new answer. 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 correctly represents the electron configuration of a sulfur atom in its ground (lowest energy) state?

    (a) 2,6,6,2
    (b) 2,8,6
    (c) 2,14
    (d) 2,6

2. Which of the pairs of elements below will form polar covalent bonds?

    (a) Oxygen and hydrogen
    (b) Sodium and chlorine
    (c) Chlorine and chlorine
    (d) Magnesium and sulfur

3. Which of the following statements best describes why the atomic radius of atoms decreases across period 2 of the periodic table from lithium to neon?

    (a) The number of neutrons in the nucleus of the atoms decreases.
    (b) The number of protons in the nucleus of the atoms increases.
    (c) The number of valance electrons increases.
    (d) The number of energy levels decreases.

4. In an atomic absorption spectrum, the black lines in the spectrum are caused by

    (a) electrons gaining energy as they leave the atom.
    (b) electrons releasing energy as they move from one energy level to another.
    (c) electrons reflecting light at a particular wavelength.
    (d) electrons being promoted from a lower energy level to a higher energy level.

5. Which of the following describes the processes occurring in a mass spectrometer in the correct order from first to last?

    (a) vaporisation   acceleration deflection   ionisation   detection
    (b) ionisation vaporisation acceleration deflection   detection
    (c) vaporisation   ionisation   acceleration deflection   detection
    (d) acceleration   Ionisation   deflection   vaporisation detection

6. Which of the following species is **not** planar?

   (a) H_2CO
   (b) CO_3^{2-}
   (c) PH_3
   (d) $BeCl_3$

7. Which of the following contains polar-covalent bonds but is a non-polar molecule?

   (a) CO_2
   (b) Cl_2
   (c) H_2O
   (d) HCN

8. Nanoparticles are particles that have a size between 1 – 100 nm. (where 1 nm (nanometre) = 1×10^{-9} m). Which of the statements below best explains why nanoparticles have properties different from substances that contain larger particles?

   (a) Nanoparticles are always electrically charged.
   (b) Nanoparticles have a larger surface/volume ration than larger particles.
   (c) Nanoparticles are smaller than atoms or molecules.
   (d) Nanoparticles contain electrons in excited states which makes them more reactive.

9. Crude oil is separated into usable fractions, such as petrol, diesel and lubrication oil in an oil refinery. The crude oil is heated, the vapour produced rises up a tower, cools and condenses at different points in the tower.

   This separation technique relies on the fact that the fractions of the crude oil have different

   (a) solubilities.
   (b) reactivity's.
   (c) densities.
   (d) boiling points.

10. Which of the following substances exhibits hydrogen bonding?

    (a) HF
    (b) H_2S
    (c) H_2
    (d) CH_4

11. Which of the following substances is **not** an alkene?

    (a) $CH_3C(CH_3)C(CH_3)CH_2CH_3$
    (b) $CH_3CH(CH_3)CH(CH_3)CHCHCH_3$
    (c) $CH_3CH(CH_3)CH(CH_3)CH_2CH_3$
    (d) $CH_3CH_2C(CH_3)_2CHCH_2$

12. Which of the following would conduct an electric current?

   i   an aqueous solution of potassium bromide
   ii   liquid bromine
   iii   solid silver bromide
   iv   solid potassium

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

13. Which of the following is the correct name for this organic compound?
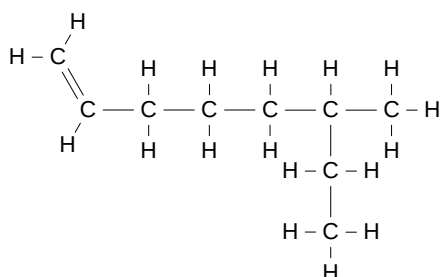
   (a) 3-methyloct-2-ene
   (b) *cis*-2-ethylhept-1-ene
   (c) 6-methyloct-1-ene
   (d) 2-ethylhept-5-ene

14. Water supplies can be contaminated by the presence of heavy metals. Which of the elements below is **not** considered a heavy metal containment?

   (a) Aluminium
   (b) Cadmium
   (c) Mercury
   (d) Lead

15. Which of the following (all at STP) will contain the most atoms?

   (a) 454 L of helium gas
   (b)   80.00 g of argon gas
   (c)   454 L of argon gas
   (d)   80.00 g of helium gas

16. Which of the following correctly lists the products of the reaction of dilute sulfuric acid and sodium hydrogencarbonate?

   (a)   sodium nitride   carbon dioxide
   (b)   carbon dioxide   water   sodium hydrogensulfate
   (c)   water   carbon dioxide   sodium sulfate
   (d)   sodium carbonate   carbon dioxide   water

17. Which of the following is the correct equation for the complete combustion of octane?

   (a) $2\ C_8H_{18}\ +\ 17\ O_2\ \rightarrow\ 16\ CO\ +\ 18\ H_2O$
   (b) $C_3H_8\ +\ 5\ O_2\ \rightarrow\ 3\ CO_2\ +\ 4\ H_2O$
   (c) $2\ C_8H_{18}\ +\ 9\ O_2\ \rightarrow\ 16\ C\ +\ 18\ H_2O$
   (d) $2\ C_8H_{18}\ +\ 25\ O_2\ \rightarrow\ 16\ CO_2\ +\ 18\ H_2O$

18. Which of the following best explains why chemical reactions speed up when the temperature is increased?

   (a)   Most reactions are endothermic so heat is always required to start a reaction.
   (b)   A higher proportion of particles will collide with sufficient energy.
   (c)   Catalysts require high temperatures to be effective.
   (d)   Higher temperature causes the activation energy of the reaction to reduce.

19. An energy profile diagram for a chemical reaction is shown below.
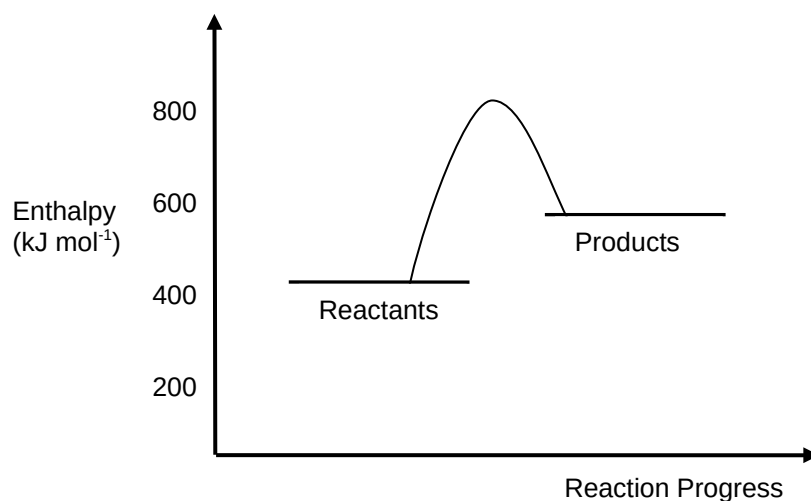
   Estimate the activation energy for this reaction.

   (a)   400 kJ mol^{-1}
   (b) 180 kJ mol^{-1}
   (c)   240 kJ mol^{-1}
   (d)   800 kJ mol^{-1}

20. A number of aerosol canisters were disposed of in a landfill facility and left out in the hot sun. As the canisters heated up, which of the statements below describe what would be happening with the gas remaining in the can?

    i The kinetic energy of all the particles in the canisters would be increasing.
    ii There would be more collisions between the particles of the gas and the inside of the container.
    iii The mass of the gas inside the container would increase.
    iv There would be more collisions between the particles of the gas and other particles in the canister.

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

21. Ethanoic (acetic) acid is the main acidic constituent in vinegar. What would be the approximate pH value for a 0.10 mol L^{-1} solution of ethanoic (acetic) acid?

    (a) 1
    (b) 5
    (c) 7
    (d) 9

22. In order to identify an unknown solution **A**, a few drops of the solution was added separately to two test tubes:

    o a test tube containing solution of dilute hydrochloric acid, and
    o a test tube containing dilute sodium hydroxide solution.

    In both test tubes there was no visible reaction.

    Which of the following could be solution **A**?

    (a) Na_2CO_3(aq)
    (b) $CuSO_4$(aq)
    (c) $BaCl_2$(aq)
    (d) $AgNO_3$(aq)

23. Which of the following processes is endothermic?

    (a) freezing of water
    (b) the combustion of methane
    (c) petrol vapour forming from liquid petrol
    (d) sodium chloride crystals forming in water

24. Approximately 80 g of solid copper sulfate is added to water in a beaker and stirred. When the mixture settles, it has become a clear blue liquid with some blue crystals at the bottom of the beaker. Which of the following statements is true?

    (a)   The clear liquid is a saturated solution.
    (b) Adding more copper sulfate crystals will make the blue colour deeper.
    (c)   The beaker contains a homogeneous mixture.
    (d) Adding more water will increase the concentration of the solution as more solid will dissolve.

25. A substance melts at 1 085 °C, it is a salmon pink colour and is a good electrical conductor in the solid and liquid state. The structure of this substance is most likely to be

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

End of Section One

Section One: Multiple-choice   SOLUTIONS

Question	Correct response
1	B
2	B
3	B
4	D
5	C
6	C
7	A
8	B
9	D
10	A
11	C
12	B
13	C
14	A
15	D
16	D
17	D
18	B
19	B
20	B
21	B
22	C
23	C
24	A
25	B

Section Two: Short answer   35% (70 Marks)

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

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

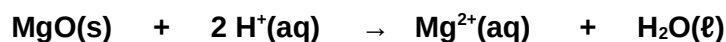## Question 26   (6 marks)

Write ionic equations, including state symbols, for any reactions that occur in the following situations.

(a)   Dilute sulfuric acid solution is added to aluminium metal.   (3 marks)

$$6\ H^+(aq)\quad +\quad 2\ A\ell(s)\quad \rightarrow\quad 2\ A\ell^{3+}(aq)\quad +\quad 3\ H_2(g)$$
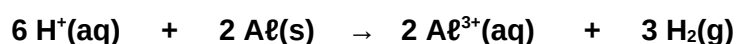
Description	Marks
Correct species	1
Equation balanced	1
Correct state symbols	1
Total	**3**

(b)   Solid magnesium oxide is added to dilute nitric acid.   (3 marks)

$$MgO(s)\quad +\quad 2\ H^+(aq)\quad \rightarrow\quad Mg^{2+}(aq)\quad +\quad H_2O(\ell)$$

Description	Marks
Correct species	1
Equation balanced	1
Correct state symbols	1
Total	**3**

Question 27 **(4 marks)**

For each of the following reactions, describe expected observations, including any

- Colours
- Odours
- Precipitates (give the colour)
- Gases evolved (give the colour or describe as colourless)

(a) Solid copper(II) carbonate is added to dilute sulfuric acid to produce copper(II) sulfate, carbon dioxide and water. (2 marks)

Description	Marks
Green solid dissolves to form blue solution	1
Colourless odourless gas produced	1
Total	2

(b) $FeCl_2(aq)$ + $AgNO_3(aq)$ → 2 $AgCl(s)$ + $Fe(NO_3)_2(aq)$ (2 marks)

Description	Marks
White solid/precipitate	1
In pale green solution	1
Total	2

Question 28 **(4 marks)**

Classify the following 8 substances

Cu   **CuS**   **CaH₂**   **Hg**
NH₄Cl   **H₂SO₄**   **SiO₂**   **SiCl₄**

as metals, ionic compounds, covalent network substances and covalent molecular substances by completing the table below

Metals	Ionic compounds	Covalent network substances	Covalent molecular substances
Cu **Hg**	**CuS** **NH₄Cl** **CaH₂**	**SiO₂**	**O₂** **H₂SO₄** **SiCl₄**

Description	Marks
½ mark for each correct classification	0-4
Total	4

Question 29 **(8 marks)**

The maximum acceptable level of lead in Australian drinking water is 0.01 mg per litre. Dissolved lead is normally found in the in the form of Pb^{2+} ions.

(a)   State why the level of heavy metals such as lead needs to maintained at relatively low levels in drinking water. (2 marks)

Description	Marks
Lead/ heavy metals are poisonous/toxic	1
Accumulates in the body over time	1
Total	**2**

(b)   Assuming that 1.00 litre of water weighs 1.00 kg, calculate this concentration of lead in:

(i)   parts per million (ppm) (1 marks)

Description	Marks
ppm = 0.01 / 1.00 **= 0.01 ppm**	1
Total	**1**

(i)   moles per litre (mol L^{-1}) (3 marks)

Description	Marks
n(Pb) = m/M = 0.01 × 10^{-3} / 207.2 = 4.829 × 10^{-8}	1
c(Pb) = n/V = 4.829 × 10^{-8} / 1.00 = 4.829 × 10^{-8}	1
= 4.83 × 10^{-8} mol L^{-1} *(correct sig figures and units)*	1
Total	**3**

(c)   It was suggested that the lead could be removed from drinking water by a precipitation reaction.

(i)   Write the name or formula of a solution that could be added to the drinking water to remove the dissolved lead. (1 mark)

Description	Marks
Any soluble sulfate / iodide / hydroxide	1
Total	**1**

(ii)   Write an ionic equation to show the reaction that would occur with the solution suggested in Part (c) (ii) above. (1 mark)

e.g.   **$Pb^{2+}(aq)$ + $SO_4^{2-}(aq)$ → $PbSO_4(s)$**

Description	Marks
Balanced equation *(no penalty for incorrect state symbols here)*	1
Total	**1**

Question 30 (6 marks)

A student was using the neutralisation of copper(II) oxide to produce copper(II) chloride. He added an excess amount of the copper(II) oxide to 45.0 mL of 1.50 mol L^{-1} hydrochloric acid.

(a)   Calculate the maximum mass of copper(II) chloride that he could produce from this volume of acid. (3 marks)

Description	Marks
n(HCℓ) = c × V = 1.50 × 0.045 = 0.0675 mol	1
2 HCℓ + CuO → CuCℓ_2 + H$_2$O n(CuCℓ_2) = (1/2) × n(HCℓ) = (1/2) × 0.0675 mol = 0.03375 mol	1
m(CuCℓ_2) = 0.03375 × 134.45 **= 4.54 g**	1
Total	**3**

(b)   Outline a step-by-step method that he would use to produce solid crystals of the copper(II) chloride.   (3 marks)

Description	Marks
Add copper(II) oxide to acid (in a beaker) and stir (heat if required)	1
Filter the resulting solution (to remove excess CuO)	1
Evaporate the filtrate to crystallise the CuCℓ_2	1
Total	**3**

Question 31   **(6 marks)**

For each molecule listed in the table below draw the structural formula, representing **all** valence shell electron pairs as **:** or as ▬ and indicate the shape of the species by a sketch or a name.

| Species	Electron Dot Diagram (Lewis diagram)	Shape (sketch or name)
Hydrogen sulfide, H_2S		bent / V-shaped
Methane, CH_4		Tetrahedral
Ethene, C_2H_4		accept **planar** for shape or diagram:

Description	Marks
1 mark for each correct diagram / shape	0-6
Total	**6**

Question 32 **(8 marks)**

The diagram below shows the main stages of a High Performance Liquid Chromatography (HPLC) apparatus.

High Performance Liquid Chromatography
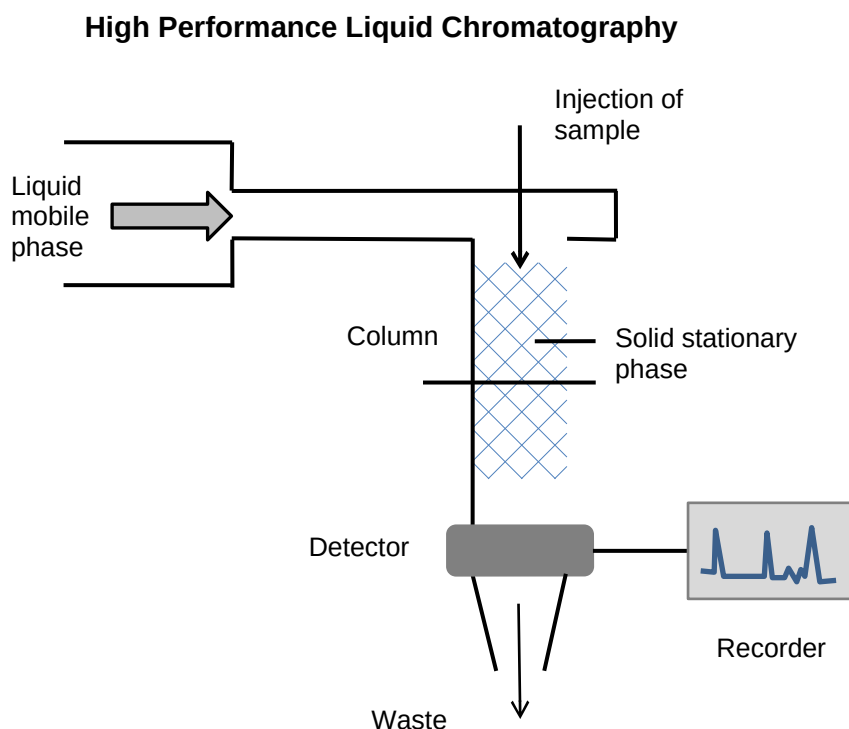
(a) Explain the role of the:

(i) liquid mobile phase (2 marks)

Description	Marks
Dissolves the components of the sample	1
Moves them through the solid stationary phase	1
Total	2

(ii) solid stationary phase (1 mark)

Description	Marks
Separate the components in the dissolved sample	1
Total	1

(b) The printout from the recorder has **absorbance** on the y (vertical) axis. Name the variable that will be on the X (horizontal) axis. (1 mark)

Description	Marks
Time / Retention time	1
Total	1

(c)   Thin Layer Chromatography (TLC) also uses a liquid mobile phase and a solid stationary phase. Complete the table to show two key differences between TLC and HPLC. (4 marks)

	TLC	**HPLC**
Description of the movement of the mobile phase.	**Upwards through the stationary phase**	**Downwards through the stationary phase**
How components of the mixture are distinguished from each other.	**Retardation factor**	**Retention time**

Description	Marks
1 mark for each correct answer	0-4
Total	**4**

Question 33 **(6 marks)**

Use your knowledge of the kinetic theory and/or intermolecular forces to explain the following situations.

(a)   The pressure inside a car tyre will increase on a hot day. (3 marks)

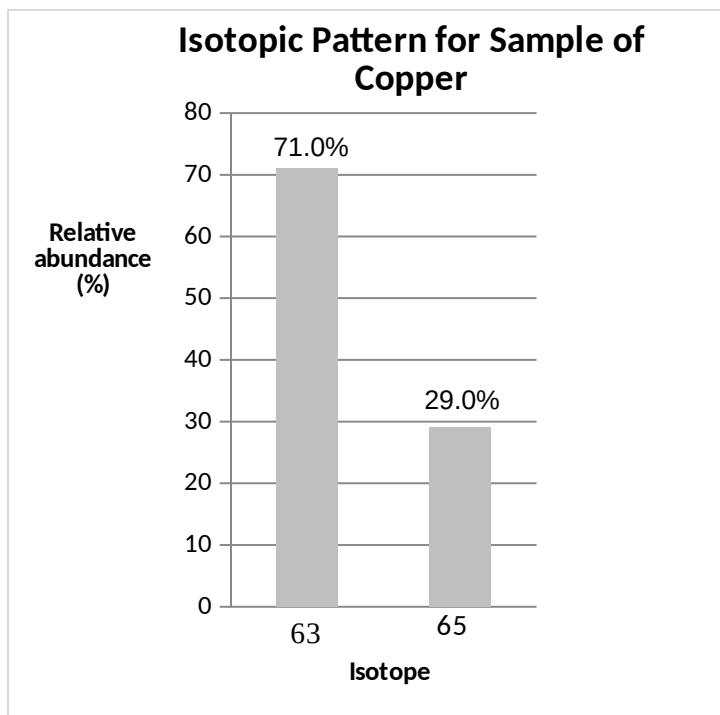| Description	Marks
Pressure is caused by collisions with the inside of the container/tyre	1
On a hot day the average kinetic energy of the particles/molecules will increase	1
Therefore more collisions resulting in higher pressure	1
Total	**3**

(b)   The vapour pressure of water reduces when the temperature reduces. (3 marks)

Description	Marks
vapour pressure is caused by particles evaporating from the liquid	1
lower temperature reduces the average kinetic energy of the water molecules	1
less particles have enough (kinetic) energy to evaporate / escape from the liquid	1
Total	**3**

Question 34 **(8 marks)**

A sample of copper was analysed using a mass spectrometer to identify the isotopic composition of the copper. In the process, copper ions with relative atomic masses of 63 and 65 where identified.

The following results were obtained.

Isotopic Pattern for Sample of Copper

Relative abundance (%)

71.0%

29.0%

Isotope: 63, 65

(a) Explain briefly how the mass spectrometer is able to separate the ions of two different isomers of copper (3 marks)

Description	Marks
The ions are deflected by a different amount	1
When passed through a magnetic field	1
Due to differences in the mass of the ions	1
Total	**3**

(b) Calculate the number of neutrons in the nucleus of a copper-65 atom.

(1 mark)

Description	Marks
$65 - 29$ **= 36**	1
Total	**1**

(c) From the data above, calculate the relative atomic mass (atomic weight) of this sample of copper. (2 marks)

Description	Marks
Average = (71.0 × 63)/100 + (29.0 × 65)/100	1
= 63.6 *(no units required)*	1
Total	**2**

(d) Compare your result from (c) to the standard atomic weight given on the Chemistry Data Sheet. Suggest a reason (not including experimental error) for any difference.
(2 marks)

Description	Marks
There must be a different (compared to naturally occurring Cu) isotopic composition in this sample *(no mark for just saying it is higher)*	1
Explanation of how this has occurred, *e.g.* Due to a higher % of Cu-65 in this sample / natural Cu contains other lighter isotopes	1
Total	**2**

Question 35 (4 marks)

Complete the following table showing the structure and names of four hydrocarbons.

Structure	IUPAC Name
H – C — C — C — C – H (with H atoms above and below each carbon)	Butane
(cis structure with $C=C$ double bond)	**cis-2-pentene** *or* **cis pent-2-ene**
$CH_3 - CH_2 - CH_2 - C - CH - CH_3$ with CH_3 above central C, and CH_3, CH_3 below	**2,3,3-trimethylhexane**
or: (expanded structure) and $CH_3 - CH_2 - CH - CH_2 - CH_3$ with CH_2 and CH_3 below	ethylpentane

Description	Marks
4 correct answers (1 mark each)	4
Total	**4**

Question 36 **(10 marks)**

When magnesium burns in oxygen, a very bright white flame is produced and the white solid, magnesium oxide, is formed.

Complete the following table comparing the properties of magnesium and magnesium oxide by describing any similarities or differences, and then explaining these in terms of the bonding present in the two substances.

Marks should be awarded where labelled diagrams are used in place of the explanatory text

Description				
	Magnesium	**Marks**	**Magnesium Oxide**	**Marks**
Hardness	Malleable / ductile	1	Hard / brittle	1
Explanation	Structure comprises of positive ions surrounded by delocalised electrons / electrons free to move within structure	1	Structure exists of positive ions and negative ions attracted by electrostatic forces throughout a lattice/network or; Structure cannot be deformed without destroying many of the strong forces of attraction between the ions	1
	Structure can be deformed without destroying the forces of attraction between the ions and the electrons	1	Any disruption of the lattice/network will cause similar charged ions to be close together thus causing repulsion and the destruction of the lattice/network	1
Electrical Conductivity when molten	Conducts	1	Conducts	1
Explanation	Delocalised electrons (are free to move through the structure) carry the current	1	When molten, the (oppositely charged) ions are free to move through the liquid thus conducting the electrical current	1
	Total	**5**	**Total**	**5**
			Total	**10**

End of Section Two

Section Three: Extended answer 40% (80 Marks)

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.

Question 37 **(22 marks)**

A student carried out a series of experiments to investigate the effect of temperature on the rate of a chemical reaction. The reaction she used was dilute hydrochloric acid reacting with magnesium ribbon. She measured the rate of the reaction by measuring the time it took to produce 20 mL of hydrogen gas. The results of the experiments are shown below.

Mass of magnesium ribbon (g)	Volume of dilute HCℓ (mL)	Temperature of hydrochloric acid (°C)	Time taken to produce 20 mL of H_2 gas (s)	Rate of reaction (1/time) (s^{-1})
5.0	40	20	97	0.010
5.0	40	29	50	0.020
5.0	40	39	24	0.042
5.0	40	47	13	0.077
5.0	40	56	7	0.143

(a) For this experiment, name

(i) the independent variable. (1 mark)

Description	Marks
Temperature	1
Total	**1**

(ii) **one** controlled variable (other than volume of HCℓ and mass of Mg, and the volume of gas produced). (1 mark)

Description	Marks
State of subdivision of magnesium (ribbon)	1
Total	**1**

(b) Draw a labelled diagram of the apparatus that the student could have used to collect this data. (3 marks)

Description	Marks
Equipment allows for the mixing of magnesium and dilute acid with collection of gas (e.g. gas syringe or collection of gas over water)	1
Equipment to collect gas must be calibrated (e.g. gas syringe/measuring cylinder)	1
Diagram with a minimum of HCl, Mg and H_2 labelled	1
Total	**3**

(c) With reference to the equipment shown above, state:

(i) one possible source of **random** error in the experiment. (1 mark)

Description	Marks
Any one from: • recording the volume of the hydrogen gas • starting stopwatch when acid adding to hydrogen • scales not measuring exactly 5.0 g of magnesium each time • state of subdivision of magnesium ribbon not constant *Accept other correct suggestions*	1
Total	**1**

(ii) one possible source of **systematic** error in the experiment. (1 mark)

Description	Marks
Any one from: • escape of gas before gas is collected (resulting in recorded gas volume being lower than it should be) • the cooling of the acid during the reaction (resulting in actual temperature not being that recorded at the start of the experiment) *Accept other correct suggestions*	1
Total	**1**

(d) On the grid below, draw a line graph showing the rate of the reaction against the temperature. (5 marks)
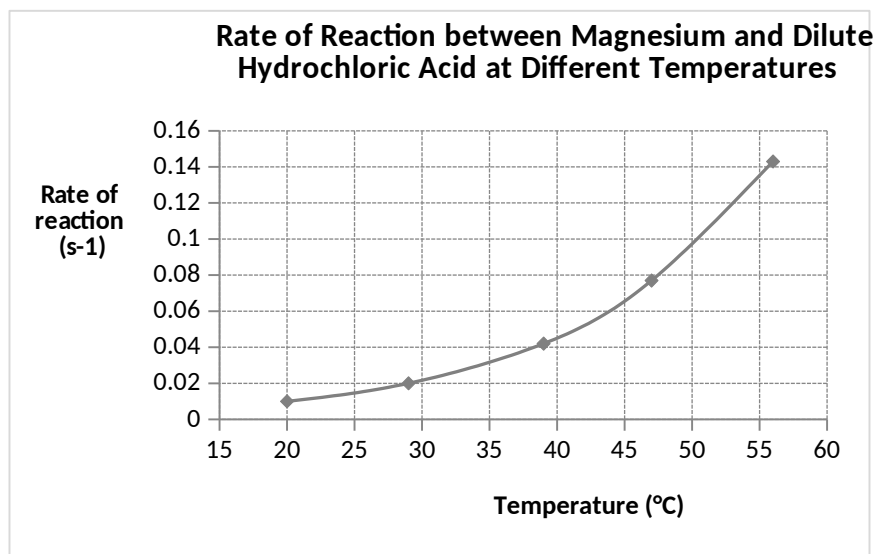
Description	Marks
Rate on y axis, temperature on x axis	1
Correct scales	1
Labels and units on both axis	1
Correct plotting of points	1
Curve drawn through points	1
Total	**5**

(e)   Use your graph to predict the **rate** of the reaction at 50 °C.   (1 mark)

Description	Marks
Between 0.09 – 0.1 (s^{-1}) *Don't penalise lack of units*	1
Total	**1**

(f)   Using the collision theory, and including an appropriate diagram, explain how temperature affects the rate of a chemical reaction.   (4 marks)

Description	Marks
Increasing temperature increases the average kinetic energy of the (reacting) particles	1
Diagram showing energy distribution of two temperatures	1
Diagram correctly labelled, including activation energy	1
Higher proportion of successful collisions / collisions with sufficient energy / collisions with greater than the activation energy / this idea shown on energy distribution diagram	1
Total	**4**

(g)   The student then carried out another experiment using the magnesium and hydrochloric acid to investigate the effect of **concentration** on the rate of the reaction. On the axis below, **sketch** the graph that she would expect to obtain.

(2 marks)

Rate of reaction

Concentration of acid
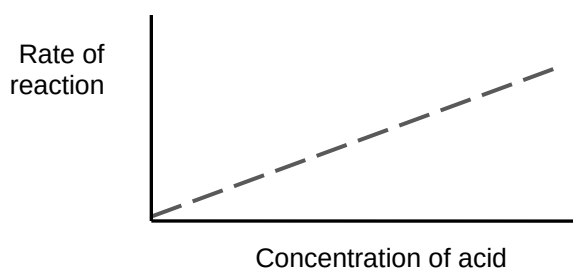
Description	Marks
Rate increases as concentration increases	1
Straight line graph	1
Total	**2**

(h)   Using collision theory, briefly explain any differences in the overall shape of the graphs in part (d) (temperature) and part (g) (concentration).   (3 marks)
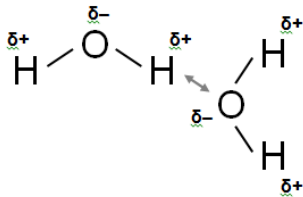
Description	Marks
Temperature has a more significant/greater effect on reaction rate	1
Because temperature increases the proportion of successful collisions	1
Concentration only increases the total number of collisions	1
Total	**3**

Question 38 **(13 marks)**

This question is about the properties of water

(a)   In cold climates, bodies of water such as ponds and lakes can freeze. The ice floats on the top of water because it is less dense than the liquid water. This allows the aquatic life in the water to survive during the colder months.

Describe, using a diagram, intermolecular bonding in solid ice and explain why the volume of the water increases (and the density reduces) when it changes from liquid water to solid ice. (5 marks)

Description	Marks
Intermolecular /secondary bonding in water is hydrogen bonding	1
Labelled diagram showing hydrogen bonding *Distribution of charge / dipoles and location of hydrogen bond required for full marks* 	1-2
Hydrogen bonding (relatively strong form of Intermolecular /secondary bonding) forms regular structure in solid ice (keeps molecules in place)	1
This regular structure less dense / more space than in the liquid water where molecules (are free to move) and pack closer	1
Total	**5**

(b) In cold climate wineries such as in Tasmania, during the winter the grape vines are sprayed with water to protect them from frost damage.

The sprayed water freezes on the vines. This process can be shown as:

$$H_2O(\ell) \quad \rightarrow \quad H_2O(s)$$
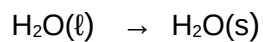
Consider the enthalpy change and by referring to intermolecular bonding explain why this process prevents the vines from freezing. (4 marks)

Description	Marks
Freezing is an exothermic process	1
Because (intermolecular/secondary) bonds are being formed (or could compare the enthalpy of the solid (lower) than the liquid (higher)	1
Therefore (heat) energy is released	1
This energy is transferred to the vines (which are the surroundings)	1
Total	**4**

(c)   Water is the most commonly used solvent, but it cannot dissolve hydrocarbons such as oil, petrol and grease.

Explain, using your knowledge of intermolecular bonding why water is **unable** to dissolve these types of substances.

(4 marks)

Description	Marks
Water is polar solvent whereas hydrocarbons are non-polar *(must compare both)*	1
When water mixes with the hydrocarbons the intermolecular forces/bonding / secondary bonding between the water and the hydrocarbons *(recognition that new intermolecular bonds are formed)*	1
Is not strong enough to overcome the *(recognition that the new intermolecular bonds must be at least as strong as than the existing bonds in order for the solute to dissolve)*	1
Existing dispersion forces within the hydrocarbons *(must identify the intermolecular forces in hydrocarbons as dispersion forces)*	1
Total	**4**

Question 39 **(20 marks)**
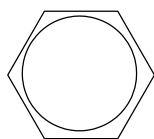
Benzene (C_6H_6) can be converted to cyclohexane (C_6H_{12})
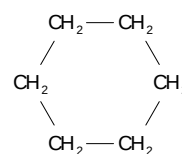
by the addition of hydrogen. The reaction can be catalysed using metallic nanoparticles.

(a) Using an appropriate diagram, explain how a catalyst can speed up the rate of the chemical reaction. (4 marks)

Description	Marks
A catalyst provides an alternative reaction pathway with a lower activation energy	1
Could also accept a fully labelled energy distribution diagram showing two positions for the activation energy, catalysed and non-catalysed	1-2
Higher proportion of successful collisions / collisions with sufficient energy / collisions with greater than the activation energy	1
Total	**4**

(b) Using collision theory, explain why the metal catalyst is more effective in the form of nanoparticles than in the bulk form (larger pieces) of the metal. (2 marks)

Description	Marks
Greater surface area in the nanoparticles	1
More chance of a collisions with the (metal) catalyst	1
Total	**2**

(c) Write a balanced chemical equation for this reaction. (1 mark)

Description	Marks
$C_6H_6 \ + \ 3\,H_2 \ \rightarrow \ C_6H_{12}$	1
Total	**1**

(d)   Calculate the mass of cyclohexane that can be produced from 750 g of benzene.

(3 marks)

Description	Marks
$n(C_6H_6) = m/M = 750 / 78.108 = 9.602$ mol	1
$n(C_6H_{12}) = (1/1) \times n(C_6H_6) = 9.602$ mol $= 0.03375$ mol	1
$m(C_6H_{12}) = m \times M = 9.602 \times 84.156$ **= 808 g**	1
Total	**3**

(e)   (i)   Calculate the mass of hydrogen that would be required for this reaction.

(2 marks)

Description	Marks
$n(H_2) = (3/1) \times n(C_6H_6) = 3 \times 9.602 = 28.806$ mol	1
$m(H_2) = m \times M = 28.806 \times 2.016$ **= 58.1 g**	1
Total	**2**

        (ii)   Calculate the volume of this amount of hydrogen gas at standard temperature and pressure (STP). (2 marks)

Description	Marks
$V = n \times 22.71 = 28.806 \times 22.71$ **= 654 L**	1
Answer to 3 sig figures and correct units *(for both answers in part (e))*	1
Total	**2**

(f) During this process, the chemical engineer was concerned that cyclohexene (C_6H_{10}) might be formed in place of the cyclohexane.

    (i) Describe a chemical test, including expected observations, that would detect the presence of cyclohexene in the products of this reaction. (2 marks)

Description	Marks
Add bromine water / aqueous bromine to the products of the reaction *or:* Add acidified potassium permanganate solution to the products of the reaction	1
If cyclohexene present, bromine water will decolourise / go from orange to colourless *or:* If cyclohexene present, potassium permanganate solution will decolourise / go from purple to colourless	1
Total	**2**

    (ii) With reference to the equation in part (c), suggest how the chemical engineer can reduce the risk of cyclohexene being formed in the reaction. (1 mark)

Description	Marks
Ensure that there is enough hydrogen present/supplied	1
Total	**1**

(g) The percentage by mass of carbon in cyclohexane is 85.8%

    (i) Calculate the percentage by mass of carbon in benzene (1 mark)

Description	Marks
$M(C_6H_6)$ = ((6 × 12.01) / 78.108) x100 = **92.3 %**	1
Total	**1**

    (ii) Use you answer to (g) (i) to suggest why aromatic substances such as benzene burn with a more smoky flame than aliphatic compounds such as cyclohexane. (2 marks)

Description	Marks
Smoke in flames is caused by (unburnt) carbon	1
Aromatic compounds have a higher percentage of carbon than aliphatic compounds (therefore more likely to have unreacted carbon after combustion) *give credit for correct chemistry in answers in other suggestions here*	1
Total	**2**

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Question 40 **(25 marks)**

When camping, a range of portable stoves can be used for cooking. Pictured below are a gas stove that burns butane, C_4H_{10}, which is stored in a pressurised container and a *Trangia* Stove, which burns methylated spirits (mainly ethanol, C_2H_5OH) as its fuel. .

Butane camp stove   Trangia stove

The properties of the two fuels are shown in the table below.

	Butane	**Ethanol**
Formula	C_4H_{10}	C_2H_5OH
Molecular weight	58.12	46.068
Boiling point	- 0.5 °C	78.4 °C
Equation for combustion	$2\ C_4H_{10} + 13\ O_2\ \rightarrow 8\ CO_2\ + 10\ H_2O$	$C_2H_5OH + 3\ O_2\ \rightarrow 2\ CO_2 + 3\ H_2O$
Enthalpy of combustion	2859 kJ mol^{-1}	1367 kJ mol^{-1}

(a)   The butane canister contains 220 g (2.20×10^2 g) of butane. Calculate the number of moles of butane in one canister. (1 mark)

Description	Marks
n(C_4H_{10}) = n / M = 220/58.12 = 3.785 **= 3.79 mol**	1
Total	1

(b)   Calculate the maximum amount of energy that could be released from this amount of butane. (2 marks)

Description	Marks
Energy = **3.785 ×** 2859 = 10 822 = **10 800 kJ** (to 3 significant figures) *or:* = **1.08 × 10^4 kJ**	1
Correct significant figures (3) and unit	1
Total	2

(c)   One canister of butane will operate the stove for 60 minutes.

         (i)   Calculate the volume of oxygen (in mL) required **per second**, assuming standard temperature and pressure (STP).   (4 marks)

Description	Marks
$n(O_2)_{total\ required}$ = (13/2) × $n(C_4H_{10})$ = 13/2 × 3.785 = 24.6 mol	1
$n(O_2)_{required\ per\ second}$ = 24.6/3600 = 6.83×10^{-3} mol	1
$V(O_2)_{required\ per\ second}$ = 6.83×10^{-3} × 22.71 = 0.155 L	1
= 155 mL	1
Total	**4**

         (ii)   If the oxygen is not supplied at the rate calculated in (d) part (ii), butane will undergo incomplete combustion to produce carbon monoxide, a toxic gas. Write an equation for the incomplete combustion of butane.   (1 mark)

Description	Marks
$2\ C_4H_{10} + 9\ O_2 \rightarrow 8\ CO + 10\ H_2O$	1
Total	**1**

         (iii)   The camper used the stove inside his tent with a limited supply of oxygen to the stove. Give two reasons why this is extremely dangerous.   (2 marks)

Description	Marks
Any two from: • Carbon monoxide will be produced (instead of carbon dioxide) • (Concentration of) carbon monoxide will build up in enclosed space • Carbon monoxide is odourless/colourless so would not be detected by the camper	1-2
Total	**2**

(d)   A camping magazine was producing an article about camp cooking and you have been asked to provide information to inform to this article - using your scientific knowledge to compare the two stoves.

Using the headings given below, **compare** the fuels used in the two stoves. You should include relevant diagrams, equations, and calculations to **explain** your ideas.

The information about the fuels is included again below:

	Butane	**Ethanol**
Formula	C_4H_{10}	C_2H_5OH
Molecular weight	58.12	46.068
Boiling point	- 0.5 °C	78.4 °C
Enthalpy of combustion	2859 kJ mol^{-1}	1367 kJ mol^{-1}
Equation for combustion	$2\ C_4H_{10} + 13\ O_2\ \rightarrow 8\ CO_2\ + 10\ H_2O$	$C_2H_5OH + 3\ O_2\ \rightarrow 2\ CO_2 + 3\ H_2O$

Safety (Compare how safe each fuel is to store)   (2 marks)

Description	Marks
Ethanol is safer to store/transport as it is a liquid at room temperature	1
Butane is a gas at room temperature so needs to be stored under pressure, so increased risk of explosion / ignition of vapour if exposed to a flame/spark	1
Total	**2**

Energy output (Compare the amount of energy released per 100 g of each fuel) (4 marks)

Description	Marks
Butane	
n(C_4H_{10}) = 100/58.12 = 1.72 mol Energy = 1.72 × 2859 = 4917 kJ	1
Ethanol	
n(C_2H_5OH) = 100/46.068 = 2.171 mol Energy = 2.171 × 1397 = 2967 kJ	1
Butane releases/produces more energy than ethanol	1
Some mathematical comparison, for example: • butane releases/produces 1.65 times more energy than ethanol • 100 g of ethanol only releases 60% of the energy released by 100 g of butane	1
Total	**4**

Carbon emissions (Compare the volume (at STP) of carbon dioxide released to the atmosphere for every 100 g of each fuel) (5 marks)

Description	Marks
Butane	
$n(CO_2)$ = $(8/2) \times n(C_4H_{10})$ = $(8/2) \times 1.72$ = 6.88 mol	1
$V(CO_2)$ = n × 22.71 = 6.88 × 22.71 = 156.2 L	1
Ethanol	
$n(CO_2)$ = $(2/1) \times n(C_2H_5OH)$ = $(2/1) \times 2.171$ = 4.342 mol	1
$V(CO_2)$ = n × 22.71 = 4.342 × 22.71 = 98.6 L	1
Butane releases/produces significantly more carbon dioxide per 100 g of fuel than ethanol / the ethanol produces only 63% of the carbon dioxide produced by the butane.	1
Total	**5**

Sustainability (compare the renewability of each fuel) (2 marks)

Description	Marks
Ethanol can be produced from plants / is a biofuel therefore it is renewable	1
Butane is produced from crude oil therefore it is considered to be a non-renewable fuel	1
Total	**2**

Recommendation (Overall summary and recommendation of which fuel to use) (2 marks)

Description	Marks
Summarises key findings with examples of three or more pieces of evidence. *For example:* I would suggest that **ethanol** be used because it is safer to transport, and although it produces less heat per 100 g, it is a more environmentally friendly fuel because it is renewable and produces less greenhouse gases when it is burned. *or:* I would suggest that butane be used because it produces more energy per 100g, so less would have to be carried on an expedition and the amount of carbon emissions would not be significant, especially because you would actually use less fuel. As it is a gas, it will also combust more quickly, resulting in more efficient cooking	2
Suggests best fuel with less than three pieces of evidence	1
Total	**2**