

**Section I - 20 marks**

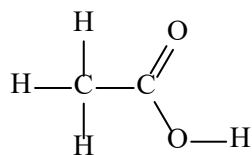
**Attempt Questions 1–20 Allow about 35 minutes for this part.**

Use the multiple-choice answer sheet provided in the bundle for Questions 1–20.

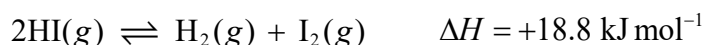
- 1 A student was given a solution containing an unknown soluble salt. They dipped a clean metal loop into the solution and place it in a blue Bunsen burner flame. The flame went blue-green.

Which metal ion could the solution contain?

- A. barium
  - B. calcium
  - C. copper
  - D. magnesium
- 2 To which homologous series does this substance belong?



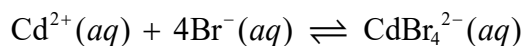
- A. alcohols
  - B. aldehydes
  - C. carboxylic acids
  - D. ketones
- 3 Hydrogen iodide gas decomposes according to the equation:



Identify the change to the system that will decrease the equilibrium concentration of iodine.

- A. Adding a catalyst.
- B. Decreasing the volume.
- C. Increasing the temperature.
- D. Decreasing the temperature.

- 4 An aqueous equilibrium between bromide and cadmium ions is shown below:



Identify the correct equilibrium expression for this reaction.

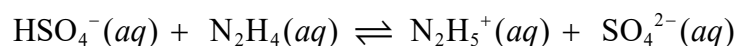
A.  $K_{\text{eq}} = \frac{[\text{CdBr}_4^{2-}]}{[\text{Cd}^{2+}][\text{Br}^{-}]}$

B.  $K_{\text{eq}} = \frac{[\text{CdBr}_4^{2-}]}{[\text{Cd}^{2+}][\text{Br}^{-}]^4}$

C.  $K_{\text{eq}} = \frac{[\text{Cd}^{2+}][\text{Br}^{-}]^4}{[\text{CdBr}_4^{2-}]}$

D.  $K_{\text{eq}} = \frac{[\text{CdBr}_4^{2-}]}{[\text{Cd}^{2+}][4\text{Br}^{-}]}$

- 5 The following reaction occurs in aqueous solution. Identify the acid reactant and its conjugate base.



	<i>Acid reactant</i>	<i>Conjugate base</i>
A.	$\text{HSO}_4^{-}(\text{aq})$	$\text{SO}_4^{2-}(\text{aq})$
B.	$\text{HSO}_4^{-}(\text{aq})$	$\text{N}_2\text{H}_5^{+}(\text{aq})$
C.	$\text{N}_2\text{H}_4(\text{aq})$	$\text{SO}_4^{2-}(\text{aq})$
D.	$\text{N}_2\text{H}_4(\text{aq})$	$\text{N}_2\text{H}_5^{+}(\text{aq})$

- 6 Which  $K_{\text{eq}}$  value indicates a reaction where the products are most favoured?

A.  $K_{\text{eq}} = 13.5$

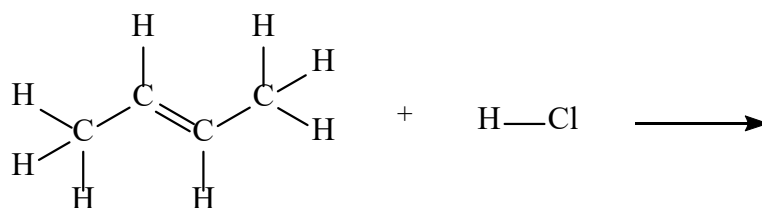
B.  $K_{\text{eq}} = 0.29$

C.  $K_{\text{eq}} = 6.1 \times 10^{-4}$

D.  $K_{\text{eq}} = 9.8 \times 10^{-12}$

- 7 Identify the tertiary alcohol.
- A. 3,3-dimethylbutan-1-ol
  - B. 3,3-dimethylbutan-2-ol
  - C. 2,3-dimethylbutan-1-ol
  - D. 2,3-dimethylbutan-2-ol

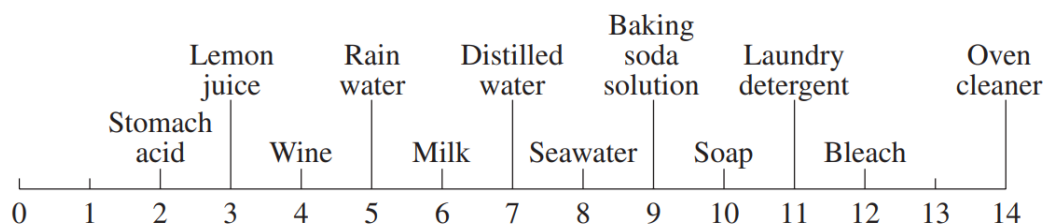
- 8 This question refers to the reaction below:



The systematic IUPAC name for the product of the above chemical reaction is:

- A. 1-chlorobutane
  - B. 2-chlorobutane
  - C. 3-chlorobutane
  - D. 4-chlorobutane
- 9 Which statement is correct for a  $0.10 \text{ mol L}^{-1}$  solution of the weak acid, hypochlorous acid ( $\text{HOCl}$ )?
- A.  $[\text{HOCl}] = [\text{H}_3\text{O}^+]$
  - B.  $[\text{HOCl}] > [\text{H}_3\text{O}^+]$
  - C.  $[\text{HOCl}] < [\text{H}_3\text{O}^+]$
  - D.  $[\text{HOCl}] = 0.10 \text{ mol L}^{-1}$

- 10 Based on the pH values of the common substances shown below, which statement is correct?



- A. Rainwater has a hydrogen ion concentration half that of soap.
- B. Wine has a hydrogen ion concentration is 1 000 times greater than distilled water.
- C. Seawater has a hydrogen ion concentration is 1 000 000 times greater than stomach acid.
- D. Baking soda solution has a hydrogen ion concentration three times that of lemon juice.
- 11 A student used indicators to determine the approximate pH of a colourless solution. The indicators used are shown in the table:

<i>Indicator</i>	<i>Colour change</i>	<i>pH range</i>
Thymol blue	red to yellow	1.2 – 2.8
Methyl red	red to yellow	4.2 – 6.3
Bromothymol blue	yellow to blue	6.0 – 7.6
Phenolphthalein	colourless to pink	8.3 – 10.0

The solution gave the following results:

- yellow in thymol blue
- yellow in methyl red
- blue in bromothymol blue
- colourless in phenolphthalein

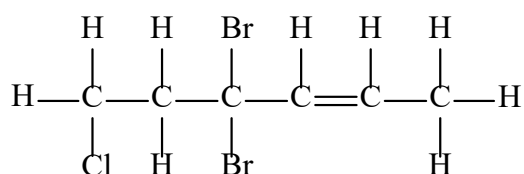
What is the pH range of the solution?

- A. 2.8 – 4.2
- B. 6.3 – 7.6
- C. 7.6 – 8.3
- D. > 8.3

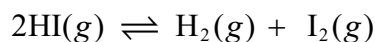
- 12 A 25.00 mL sample of 0.100 mol L<sup>-1</sup> acetic acid solution needed 22.20 mL of a NaOH solution for complete neutralisation. What volume of the same NaOH solution is needed to neutralise 25.00 mL of 0.100 mol L<sup>-1</sup> sulfuric acid solution?

A. 11.10 mL  
B. 22.20 mL  
C. 33.30 mL  
D. 44.40 mL

- 13 What is the IUPAC name of this molecule?



- A. 4,4-bromo-6-chlorohex-2-ene  
B. 3,3-bromo-1-chlorohex-5-ene  
C. 4,4-dibromo-6-chlorohex-2-ene  
D. 3,3-dibromo-1-chlorohex-5-ene
- 14 HI gas can be decomposed in a reaction vessel at 445°C. The equation for the reaction is shown below and the  $K_{eq} = 0.020$ .

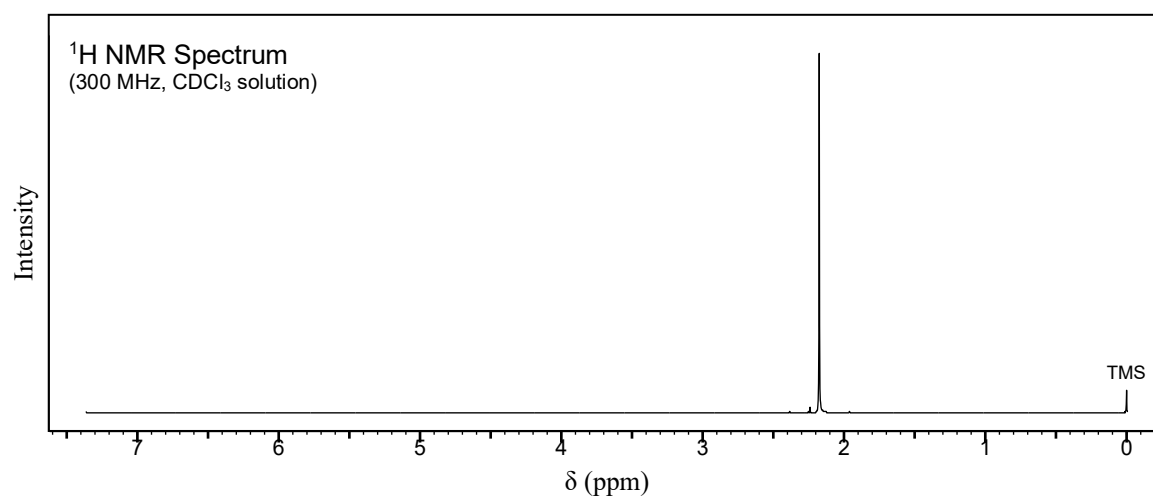


The reaction vessel was sampled and found to contain  $[\text{HI}] = 2.0 \text{ mol L}^{-1}$ ,  $[\text{H}_2] = 0.50 \text{ mol L}^{-1}$  and  $[\text{I}_2] = 0.10 \text{ mol L}^{-1}$ .

Which of the following statements concerning the reaction quotient ( $Q_{eq}$ ) is TRUE for this system?

- A.  $Q_{eq} = K_{eq}$  and the system is at equilibrium.  
B.  $Q_{eq} < K_{eq}$  and more  $\text{H}_2$  and  $\text{I}_2$  will be produced.  
C.  $Q_{eq} < K_{eq}$  and more HI will be produced.  
D.  $Q_{eq} > K_{eq}$  and more  $\text{H}_2$  and  $\text{I}_2$  will be produced.

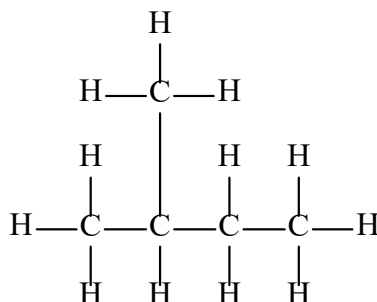
- 15 A molecule,  $\text{C}_3\text{H}_6\text{O}$  is analysed using nuclear magnetic resonance. The  $^1\text{H}$ NMR spectrum of this molecule is shown below:



What is the structural formula of this molecule?

- A.  $\begin{array}{c} \text{H} \quad \text{H} \quad \text{O}-\text{H} \\ | \quad | \quad / \\ \text{H}-\text{C}-\text{C}-\text{C} \\ | \quad | \quad \backslash \\ \text{H} \quad \text{H} \quad \text{O} \end{array}$
- B.  $\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ | \quad | \quad | \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{OH} \\ | \quad | \quad | \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
- C.  $\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\ | \quad | \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\ | \quad | \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
- D.  $\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ | \quad || \quad | \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ | \quad \quad | \\ \text{H} \quad \quad \text{H} \end{array}$

- 16 How many other structural chain isomers of the molecule shown exist?



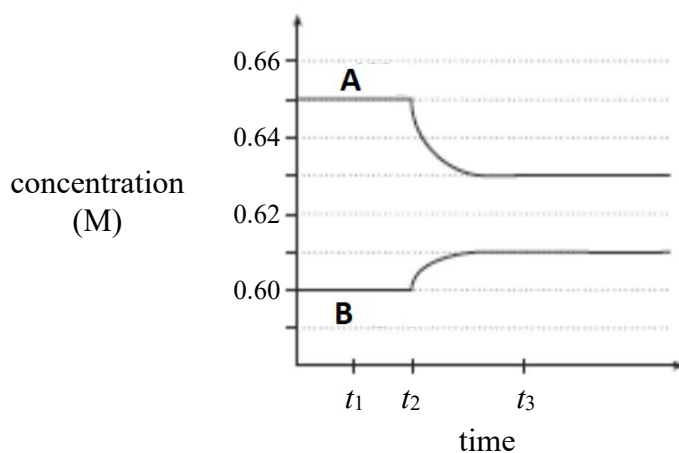
- A. 0
- B. 1
- C. 2
- D. 3

- 17 A  $0.0200 \text{ mol L}^{-1}$  solution of a monoprotic weak acid has a pH of 3.6.

What is the  $K_a$  of this acid?

- A.  $2.51 \times 10^{-4}$   
B.  $3.15 \times 10^{-6}$   
C.  $3.19 \times 10^{-6}$   
D.  $3.13 \times 10^5$
- 18 Calculate the pH of the resulting solution when 50 mL of 0.2 M HCl is added to 50 mL of 0.1 M NaOH?
- A. 1.0  
B. 1.3  
C. 2.3  
D. 7.0
- 19 Substances A and B are gases that exist in dynamic equilibrium in a sealed container.

A graph of their concentrations over time is given below:

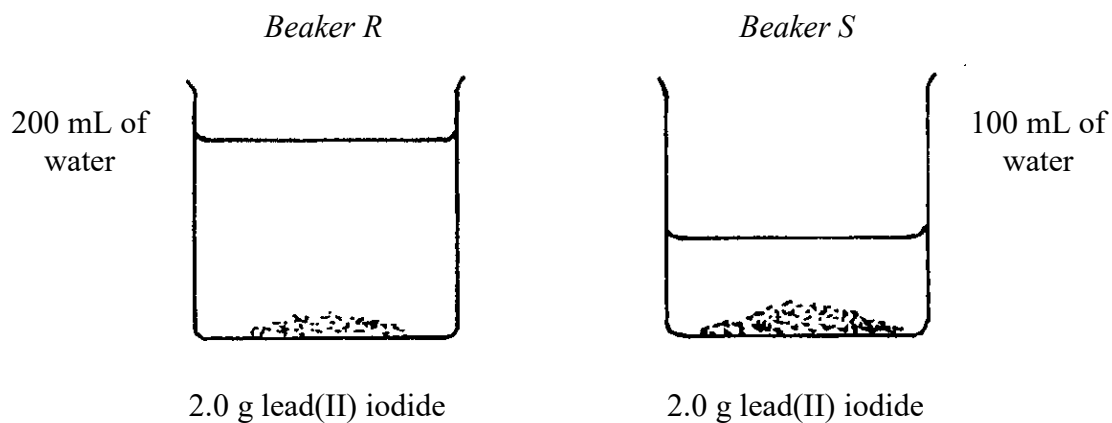


At time  $t_2$  the temperature was decreased. Which is correct?

- A.  $2A \rightleftharpoons B$   $\Delta H = \text{negative}$   
B.  $2A \rightleftharpoons B$   $\Delta H = \text{positive}$   
C.  $A \rightleftharpoons 2B$   $\Delta H = \text{negative}$   
D.  $A \rightleftharpoons 2B$   $\Delta H = \text{positive}$

- 20 Two beakers were set up each containing 2.0 g lead(II) iodide. 200 mL of water was added to Beaker R and 100 mL of water to Beaker S. The contents of both beakers was stirred for 5 minutes and then left until the undissolved solid settled as shown below.

Both beakers were maintained at 25°C and the solubility of lead(II) iodide in water at 25°C is 0.76 g L<sup>-1</sup>.



Based on this information, the ratio of the concentration of lead(II) iodide solution in beaker R to the concentration of lead(II) iodide solution in beaker S is:

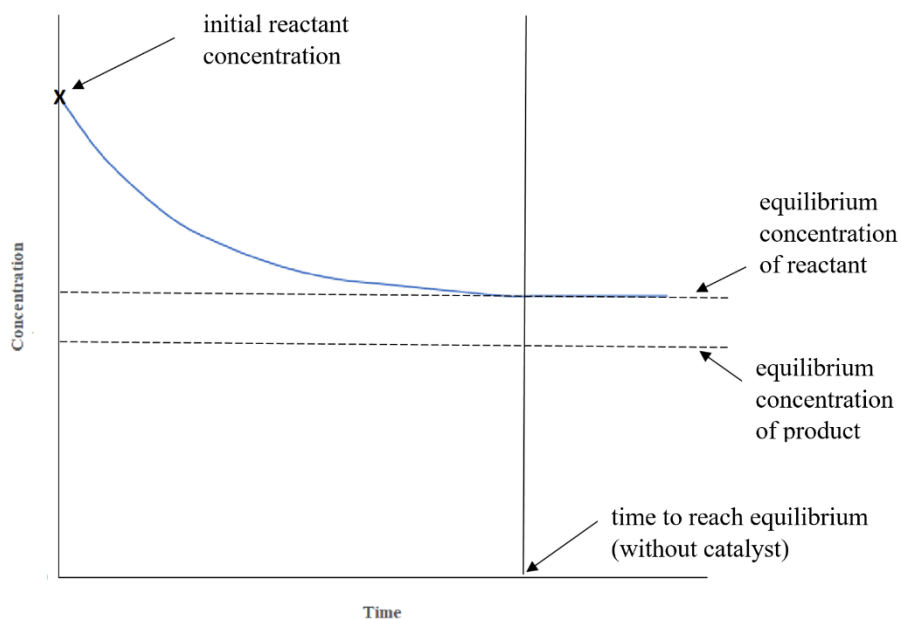
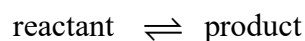
- A. 1:1
- B. 1:2
- C. 2:1
- D. 1:4



**Section II - 80 marks – answer all questions on the answer sheets provided**

**Question 21 (5 marks)**

Consider the general equilibrium system:

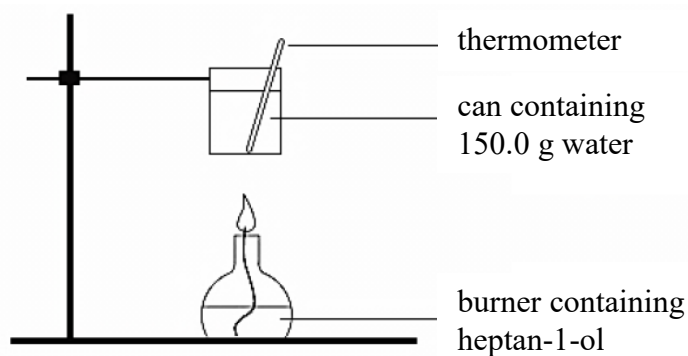


- (a) Complete the diagram above to show the product concentration as the system reaches and remains at equilibrium. The reactant concentration is given for you. Assume the initial product concentration is zero. **1**
- (b) On the same diagram, but using a dashed line, show the reactant and product concentrations as the system reaches and remains at equilibrium when a catalyst is present. Start at the initial concentrations. **1**
- (c) Account for the difference between (a) and (b) using collision theory and rate of reaction. **3**

**End of Question 21**

### Question 22 (5 marks)

150.0 g of water was heated in a calorimeter (as shown below) to measure the heat of combustion of heptan-1-ol. The initial temperature of the water was 20.0°C, the final temperature was 63.0°C and the mass of heptan-1-ol burnt was 0.750 g.



Use this information to answer the following questions.

- (a) Write a balanced chemical equation for the complete combustion of heptan-1-ol. 1
- (b) Calculate the molar enthalpy of combustion measured for heptan-1-ol. 3
- (c) Identify one experimental error that is likely to occur in this experiment. 1

**End of Question 22**

### Question 23 (4 marks)

Discuss the advantages of the Brønsted-Lowry theory of acids and bases over the Arrhenius theory. Include equations and examples in your answer. 4

**End of Question 23**

### Question 24 (6 marks)

During a practical test, Year 12 Chemistry students were given four unknown organic chemicals (**A**, **B**, **C** and **D**) and told they were, in no particular order, cyclohexane, cyclohexene, methanol and acetic acid.

The students were given the following information.

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<i>Decolourise bromine water</i>	no	yes	no	no
<i>Solubility in water</i>	yes	no	no	yes

Question 24 continued

- (a) Identify **B** and **C**. Justify your answer and include an equation with structural formula for the decolourisation of bromine water by **B**. **3**
- (b) Describe a method, including suitable safety precautions and expected results to identify **A** and **D**. **3**

**End of Question 24**

**Question 25** (4 marks)

The buffer system between the dihydrogen phosphate ion and the hydrogen phosphate ion is effective at maintaining intracellular pH in our bodies.

A student prepared a phosphate buffer by mixing 50 mL of 0.1M  $\text{NaH}_2\text{PO}_4$  with 50 mL of 0.1 M  $\text{Na}_2\text{HPO}_4$ .

She tested the buffer and recorded the following results and conclusion:

**Results:**

	Initial pH	pH after adding a few drops of 0.1M HCl	pH after adding a few drops of 0.1M NaOH
<i>Distilled water</i>	7.0	3.0	11.0
<i>Phosphate buffer</i>	7.0	6.9	7.1

**Conclusion:**

The phosphate buffer prepared was effective in maintaining a pH of close to 7.

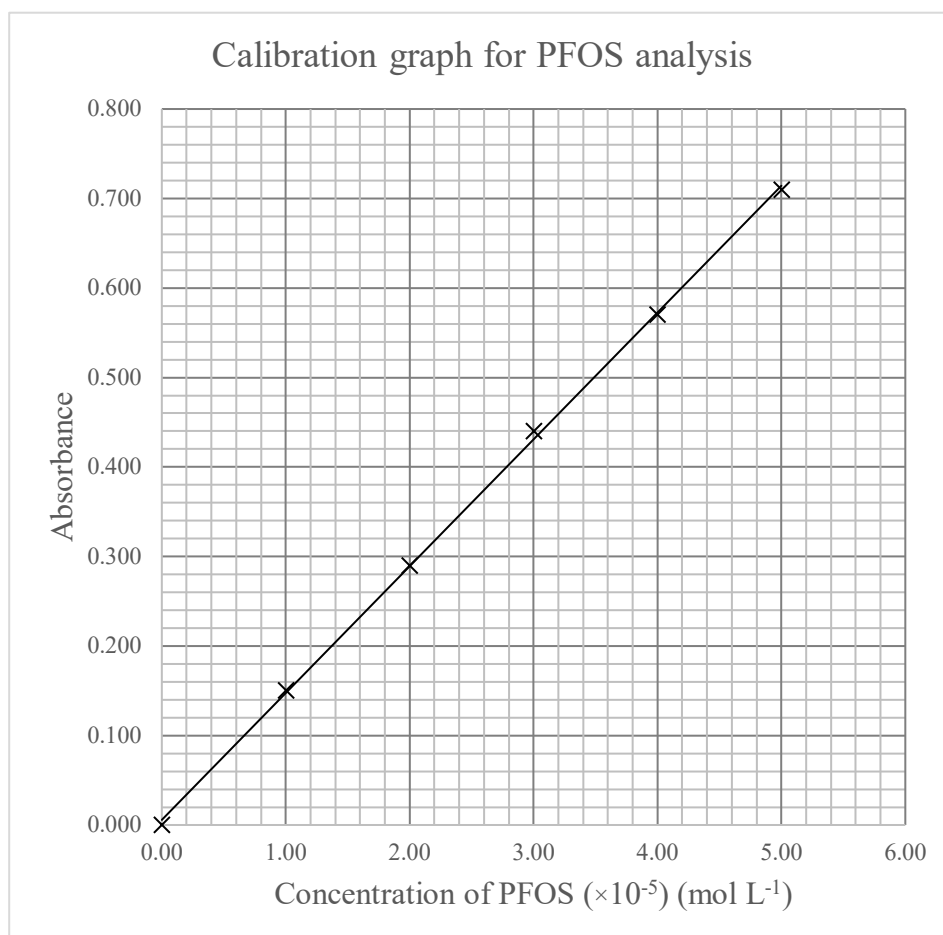
- (a) Write an equation to represent this phosphate buffer system. 1
- (b) Analyse the composition of the student's buffer AND explain using Le Châtelier's Principle why it was effective at maintaining the desired pH after the addition of a small volume of HCl. 3

**End of Question 25**

### Question 26 (6 marks)

Perfluorooctane sulfonate (PFOS) was up until recently used in fire-fighting foam. It is very stable and can persist for a long time both in the environment and in humans with detrimental effects.

The NSW EPA analyses water and soil samples near areas where PFOS has been used in large quantities. Colorimetry is used to analyse the samples as PFOS reacts with iron(III) ions in a 1:1 ratio to form a purple solution. The NSW EPA calibration graph is shown below:



To analyse soil samples, 5.00 g of soil is added to 15 mL of distilled water to dissolve the PFOS and filtered to remove particulate matter. The solution is then reacted with iron(III) ions to form a purple solution with a total volume of 50.00 mL. Exactly 10 mL of the purple solution is then pipetted into a 100 mL volumetric flask and made up to the mark with distilled water.

A soil sample was prepared using this method and the absorbance of the diluted solution was found to be **0.540**.

- (a) Use the calibration graph provided to determine the concentration of PFOS in the diluted sample. Show your working on the graph. 2
- (b) Determine the concentration of PFOS in the original soil sample in % (w/w). The molar mass of PFOS is 500.158 g/mol. 4

**End of Question 26**

**Question 27 (5 marks)**

The boiling points of some straight chain alkanes are given in the table below.

<i>Alkane</i>	<i>Formula</i>	<i>Boiling point (°C)</i>
methane	CH <sub>4</sub>	– 161
ethane	C <sub>2</sub> H <sub>6</sub>	– 89
propane	C <sub>3</sub> H <sub>8</sub>	– 42
butane	C <sub>4</sub> H <sub>10</sub>	0
pentane	C <sub>5</sub> H <sub>12</sub>	36
hexane	C <sub>6</sub> H <sub>12</sub>	69
heptane	C <sub>7</sub> H <sub>14</sub>	98

- (a) Explain the trend in the boiling points of these alkanes in terms of intermolecular forces. **2**
- (b) Ethanol has a boiling point of 78°C. Explain why ethanol has a much higher boiling point than ethane. Include a diagram in your answer. **3**

**End of Question 27**

### Question 28 (10 marks)

The maximum concentration of lead(II) ions ( $\text{Pb}^{2+}$ ) legally permitted in the aqueous wastes of a city is 1 mg/L at 25°C. Several times a month the wastewater from a certain factory is found to exceed this limit.

The factory produces two lead compounds – lead(II) hydroxide and lead(II) carbonate but it only ever produces ONE of these compounds at a time. The factory wastewater is always a saturated solution of the lead compound being produced.

- (a) Write the equilibrium expression for a saturated solution of lead(II) hydroxide. **1**
- (b) Evaluate whether lead(II) hydroxide, lead(II) carbonate, or both, will cause the factory to exceed the 1 mg/L limit at 25°C. **4**
- (c) To remove excess lead ions from their wastewater the factory added solid sodium sulfide so that the lead could be removed via precipitation followed by filtration.
- (i) Write a balanced chemical equation for this reaction. **1**
- (ii) If the factory added solid sodium sulfide to give a sulfide ion concentration in the wastewater of  $5 \times 10^{-8} \text{ mol L}^{-1}$  and the  $\text{Pb}^{2+}$  concentration was  $7 \times 10^{-6} \text{ mol L}^{-1}$ , would a precipitate of lead(II) sulfide form?  $K_{\text{sp}}(\text{PbS}) = 3.1 \times 10^{-28}$  at 25°C. **2**
- (d) Explain why this method of adding sodium sulfide is effective at lowering the  $[\text{Pb}^{2+}]$  in the wastewater. **2**

**End of question 28**

### Question 29 (7 marks)

Define what is meant by the term “biofuel” and discuss the use of biofuels against fossil fuels in the operation of motor vehicles. **7**

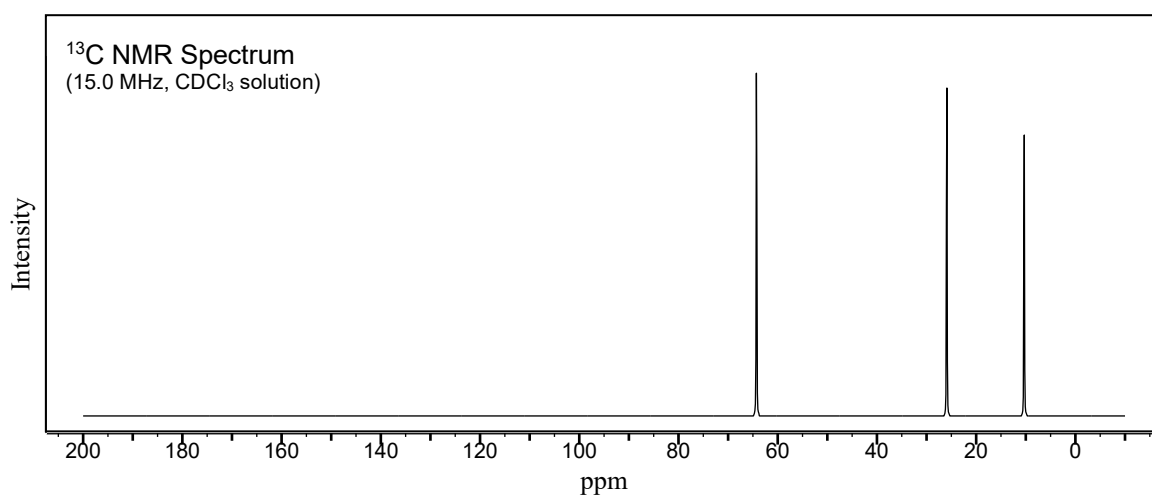
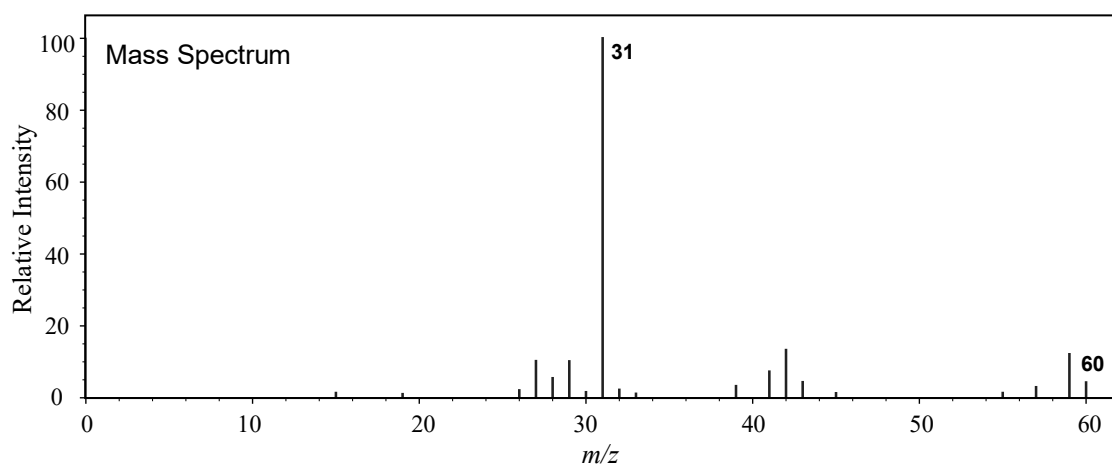
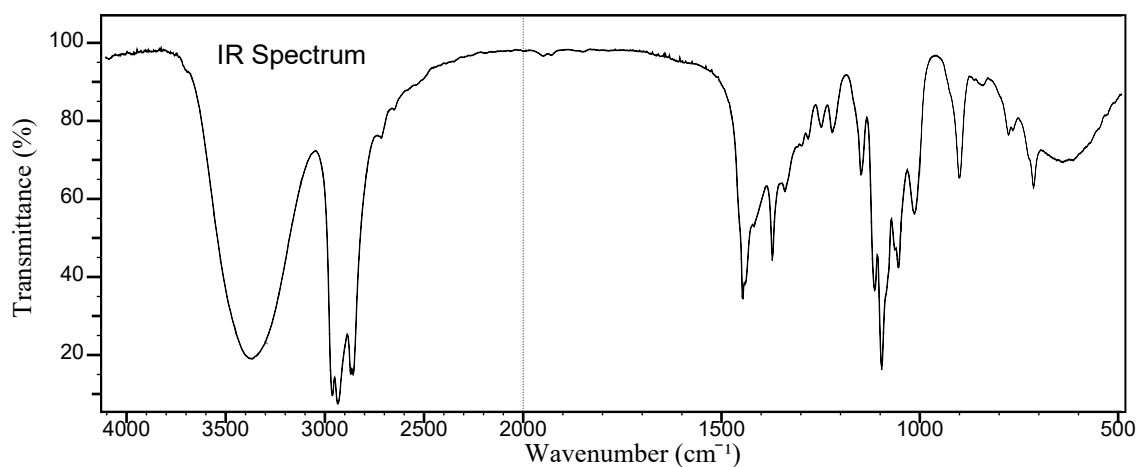
Include the following in your answer:

- Outline the synthesis of bioethanol.
- An equation to represent the synthesis of bioethanol.
- Equations to show the combustion of ethanol and octane.

**End of Question 29**

### Question 30 (10 marks)

The following spectra were obtained for an organic compound that contains only carbon, hydrogen and oxygen.



Question 30 continues on next page



### Question 30 (continued)

- (a) Use the  $^{13}\text{C}$  NMR spectrum on the previous page to identify the number of the carbon environments in the compound. 1

- (b) Using the infrared spectrum on the previous page, complete the table below for one significant absorption in the range  $4000 - 2000\text{ cm}^{-1}$ . 2

<i>Wavenumber range of absorption (<math>\text{cm}^{-1}</math>)</i>	<i>Bond responsible for absorption</i>
.....	.....

- (c) Identify the name and structure of the compound. Justify your answer with reference information from **EACH** spectrum. 5

<i>Structure</i>	
<i>Name</i>	.....

- (d) Organic chemists generally use a combination of information from different types of spectra to determine the structure of an unknown molecule. Assess the usefulness of this approach. 2

**End of Question 30**

### Question 31 (4 marks)

The following method is used to determine the mass of carbon dioxide in air:

- 50.0 L sample of air is slowly bubbled through 100.0 mL of 0.0300 M  $\text{Ba}(\text{OH})_2$  solution (carbon dioxide reacts with  $\text{Ba}(\text{OH})_2$  to form a  $\text{BaCO}_3$  precipitate and water).
- Solid  $\text{BaCO}_3$  is removed via filtration.
- Three drops of phenolphthalein is added to the filtrate turning it pink.
- The filtrate is titrated with 0.100 M HCl.

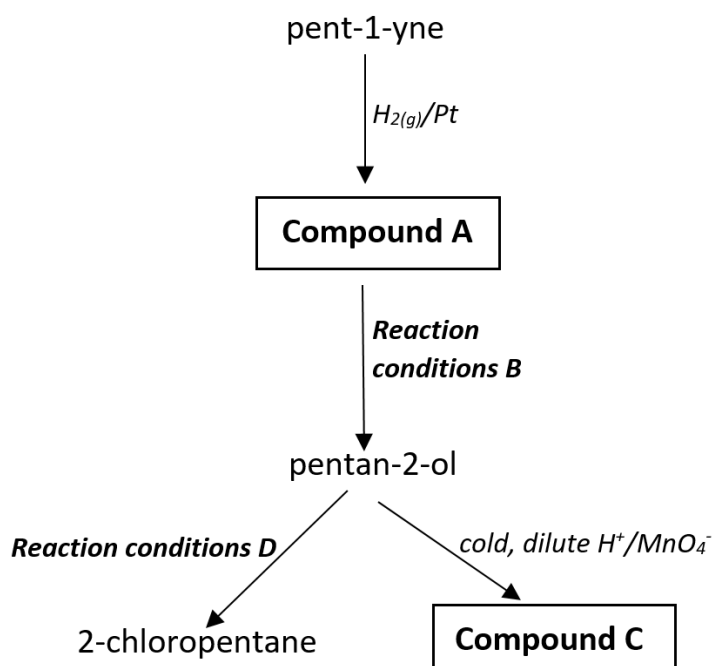
If 25.05 mL of HCl was required for the titration, calculate the mass of carbon dioxide in the 50.0 L of the air sample. 4

**End of Question 31**

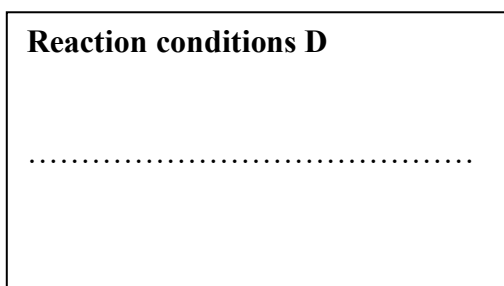
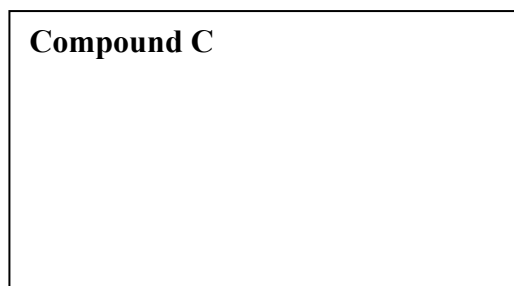
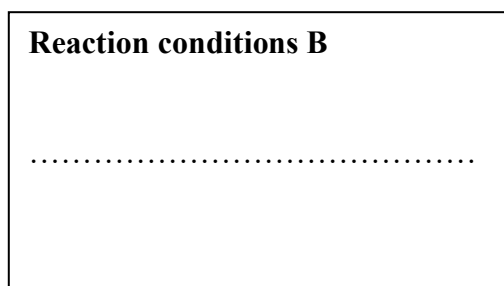
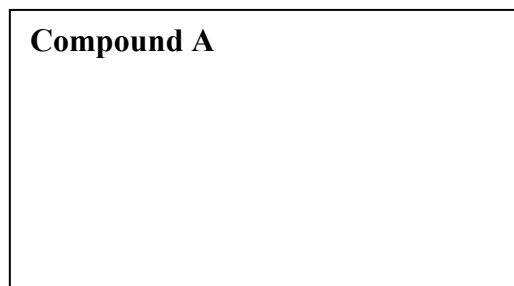
**Question 32 (4 marks)**

The diagram below shows reactions involving five different organic compounds.

4



Draw the structure of compounds A and C and identify the reaction conditions B and D in the boxes below:



**End of Question 32**

### Question 33 (10 marks)

Grey Goose vodka is an alcoholic drink from France that is made from the fermentation of potatoes and cereal grains. It has an ethanol content of 40% (v/v) which is equivalent to  $6.8 \text{ mol L}^{-1}$ .

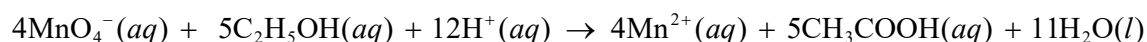


Jemima has decided to perform an experiment to find out the concentration of ethanol in Grey Goose vodka.

Below are her notes on the experiment:

#### Method:

For each titration a 20.00 mL aliquot of Grey Goose Vodka was transferred into a conical flask and titrated against a 5.02 M solution of potassium permanganate ( $\text{KMnO}_4$ ). The reaction equation is given below:



The permanganate ion ( $\text{MnO}_4^-$ ) ion was an intensely pink colour and the  $\text{Mn}^{2+}$  ion was colourless.

#### Results:

The titre volumes and observations made during the experiment are in the table below:

<i>Titration number</i>	<i>Titre (mL)</i>	<i>Observations</i>
1	23.22	Add first drop of $\text{KMnO}_4$ , contents of reaction flask turn pink immediately, then after few seconds turn colourless. Add second drop of $\text{KMnO}_4$ and contents turn pink and immediately turn colourless. Keep adding $\text{KMnO}_4$ in a slow stream, contents remain a very slight pink colour. Stop stream, contents turn colourless immediately. Bubbles are observed on the surface of the solution. $\text{KMnO}_4$ is added dropwise until colour change is persistent for ten seconds.
2	23.20	As for titration 1
3	24.01	$\text{KMnO}_4$ added as a stream initially, contents of reaction flask turn pink immediately, after a few seconds content turn colourless. Brown solid observed on bottom of flask.
4	23.21	As for titration 1
5	23.22	As for titration 1

The average of the concordant titres is 23.21 mL.

Question 33 continues on the next page

### Question 33 (continued)

- (a) Calculate the ethanol content in Grey Goose Vodka in  $\text{mol L}^{-1}$  using the titration data provided. **3**
- (b) Evaluate Jemima's experiment by addressing the following points: **7**
- evaluate the validity of the method by referring to Jemima's observations and the information below:
    - acetic acid reacts with  $\text{KMnO}_{4(\text{aq})}$  to form carbon dioxide
    - $\text{Mn}^{2+}_{(\text{aq})}$  can act as a catalyst for the reduction of  $\text{MnO}_4^{-}_{(\text{aq})}$  ions to form  $\text{MnO}_{2(\text{s})}$
    - $\text{MnO}_{2(\text{s})}$  is a brown solid
  - evaluate the reliability of the titration results AND offer an explanation for any outliers
  - evaluate the accuracy of the ethanol content calculated considering the sources of error

**End of Question 33**

**End of Paper**