PENRITH SELECTIVE HIGH SCHOOL

HSC CHEMISTY 2021

TRIAL EXAMINATION

General Instructions

- Reading time – 5 minutes

- Exam time – 3 hrs

- Board-approved calculators may be used

- Write using **blue or black** pen

- Chemistry Data Sheet is provided with this examination

- Answers written in pencil may be disqualified from review

SECTION I

Multiple Choice (20)

- Attempt Questions 1 – 20

- Allow about 30 minutes

- Provide responses on the Multiple Choice Answer Sheet

SECTION II

Free Response (80)

- Attempt Question 16 – 33

- Allow 2 hrs and 30 minutes

TOTAL: / 100

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Question 1

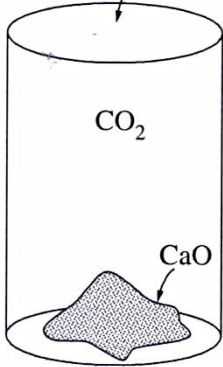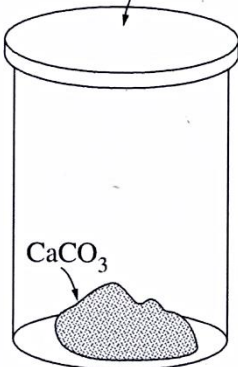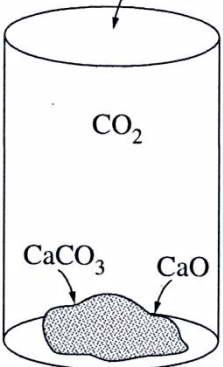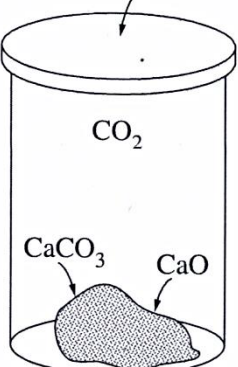The conversion of calcium carbonate to calcium oxide is a reversible reaction and will reach equilibrium under certain conditions.

In which diagram is the system most likely to have reached equilibrium?

A. no lid

CO_2

CaO

B. lid

$CaCO_3$

C. no lid

CO_2

$CaCO_3$ CaO

D. lid

CO_2

$CaCO_3$ CaO

3

Question 2

Nitrogen dioxide (a brown gas) and dinitrogen tetraoxide (a colourless gas) are both forms of oxides of nitrogen. They are in equilibrium according to the equation

$$2NO_2(g) \quad \rightleftharpoons \quad N_2O_4(g) .$$
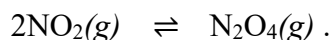
An equilibrium mixture of the two gases at room temperature is light brown but at higher temperatures the colour becomes a much deeper brown.

What conclusion can be drawn from this observation?

A.   The reverse reaction in the equation is endothermic.

B.   The forward reaction in the equation is endothermic.

C.   The brown colour is due to the strong nitrogen–oxygen bonds in NO_2.

D.   The equilibrium concentration of N_2O_4 is not dependent on temperature.

Question 3

Consider the following reaction.

$$2NOCl(g) \quad \rightleftharpoons \quad 2NO(g) + Cl_2(g)$$

What is the equilibrium expression for this reaction?

A.   [2NO] [Cl_2] / [2NOCl]

B. $[NO]^2$ [Cl_2] / $[NOCl]^2$

C.   [2NOCl] / [2NO] [Cl_2]

D. $[NOCl]^2$ / $[NO]^2$ [Cl_2]

Question 4

What will happen when sulfuric acid is added to a saturated solution of sparingly soluble calcium sulfate?

A.   Concentration of soluble calcium ions will increase over time due to the presence of H^+ ions.

B.   Concentration of soluble calcium ions will decrease over time due to the presence of H^+ ions.

C.   Concentration of soluble calcium ions will increase over time due to the presence of SO_4^{2-} ions.

D.   Concentration of soluble calcium ions will decrease over time due to the presence of SO_4^{2-} ions.

Question 5

Hydrogen gas reacts with iodine gas to form hydrogen iodide according to the following equation.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \text{at } 700 \text{ K}$$

At equilibrium, the concentrations for H_2, I_2 and HI are 0.214 mol/L, 0.214 mol/L and 1.57 mol/L respectively.

What is the value of the equilibrium constant for this reaction?

A.   0.018

B.   34.3

C.   53.8

D.   0029

Question 6

At a certain temperature, the Keq for the following reaction is 75.

$$2O_3(g) \quad \rightleftharpoons \quad 3O_2(g)$$
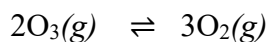
A 5 L reaction vessel contains 0.06 moles/L of O_3 and 0.30 moles/L of O_2 .

Which row of the table correctly identifies the direction of the equilibrium shift and the reason for the shift?

	Direction favoured	*Reason*
A.	Left	Q > Keq
B.	Left	Q < Keq
C.	Right	Q > Keq
D.	Right	Q < Keq

Question 7

Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. A change was imposed at time T and the equilibrium was re-established. The concentration of each gas is plotted against time.
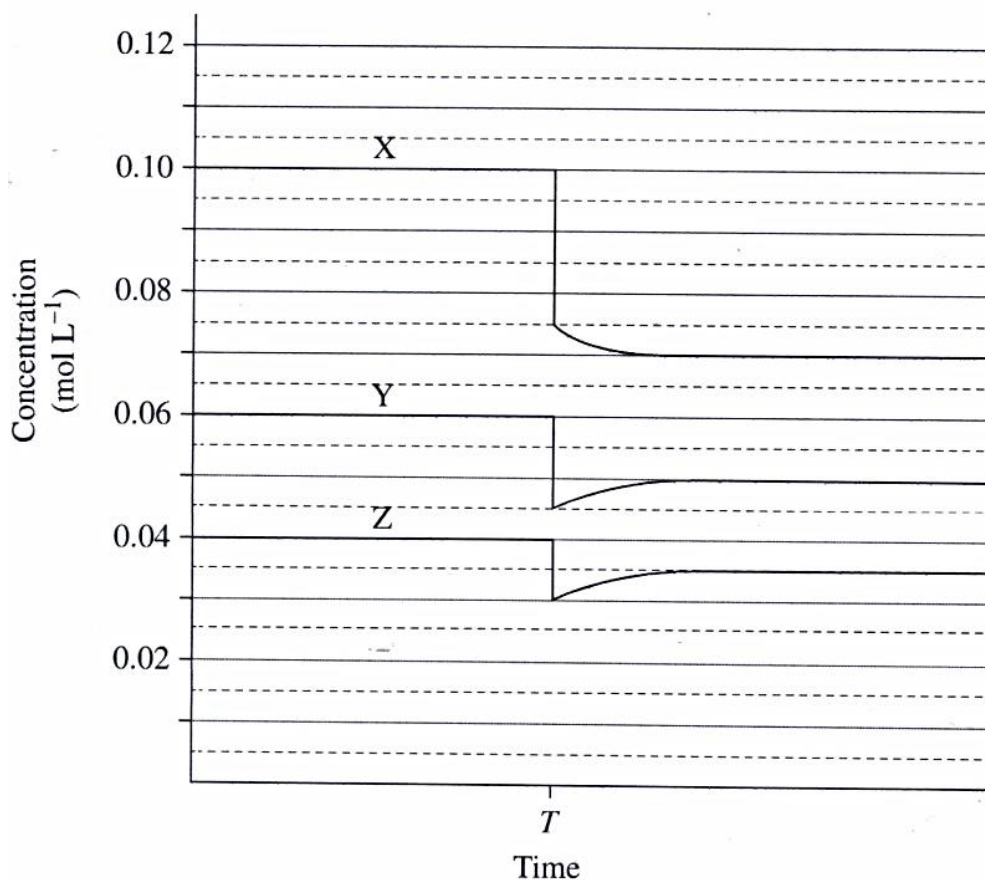
What type of change has occurred at time T?

A. Pressure change

B. Temperature change

C. Concentration change

D. Catalyst change

Question 8

Which of the following is NOT a Brønsted–Lowry reaction?

A. $NH_4^+ + NH_2^- \rightleftharpoons 2NH_3$

B. $CO_2 + OH^- \rightleftharpoons HCO_3^-$

C. $ClO_4^- + CH_3COOH \rightleftharpoons CH_3COO^- + HClO_4$

D. $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

Question 9

The graph represents the yield of an equilibrium reaction, Z, at different temperature and pressure conditions inside a reaction vessel.
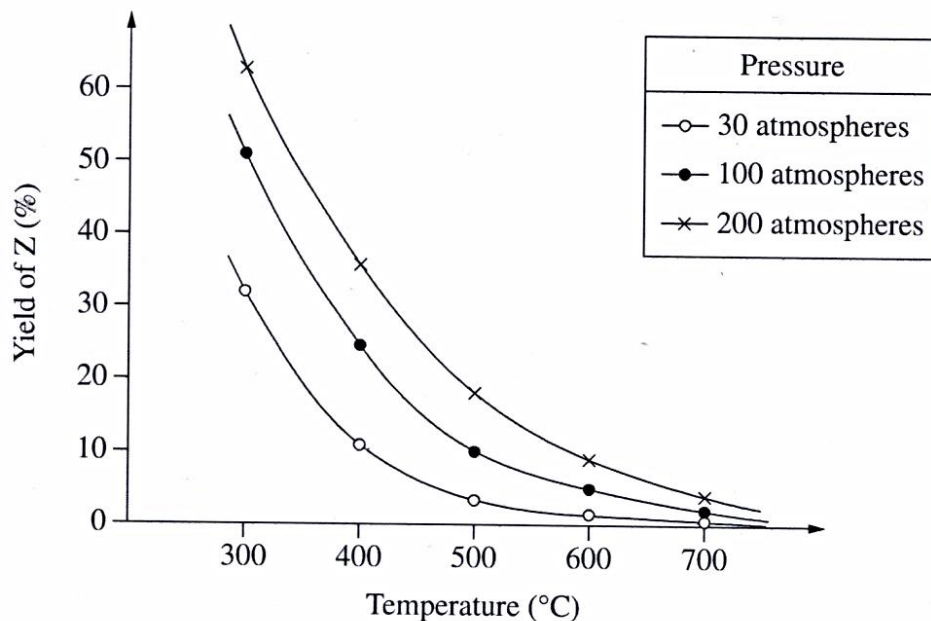
Which reaction could produce the trends shown in the graph?

A. $X(g) + Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = +100$ kJ

B. $X(g) + Y(g) \rightleftharpoons 2Z(g)$ $\Delta H = -100$ kJ

C. $4X(g) + 2Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = -100$ kJ

D. $2X(g) + 2Y(g) \rightleftharpoons Z(g)$ $\Delta H = +100$ kJ

Question 10

Which of the following is the conjugate base of the hydrogen phosphate ion (HPO_4^{-2})?

A. H_3PO_4

B. $H_2PO_4^{-1}$

C. PO_4^{-3}

D. OH^{-1}

Question 11

Equal volumes of four different acids are titrated with the same base at 25°C. Information about these acids is given in the table.

Acid	*Concentration (mol L–1)*	*pH*
HCl	0.10	1.0
H_3PO_4	0.10	1.6
CH_3COOH	0.10	2.9
HCN	0.10	5.1

Which acid requires the greatest volume of base for complete neutralisation?

A.   HCl

B. H_3PO_4

C. CH_3COOH

D.   HCN

Question 12

A solution containing potassium dihydrogen phosphate and potassium hydrogen phosphate is a common laboratory buffer with a pH close to 7.

Which row of the table correctly identifies the chemistry of this buffer?

	Buffer equation	*Equilibrium shift*	
		Acid is added to the solution	*Alkali is added to the solution*
A.	$HPO_4{}^{2-} + H_2O \rightleftharpoons PO_4{}^{3-} + H_3O^+$	Right	Left
B.	$HPO_4{}^{2-} + H_2O \rightleftharpoons PO_4{}^{3-} + H_3O^+$	Left	Right
C.	$H_2PO_4{}^- + H_2O \rightleftharpoons HPO_4{}^{2-} + H_3O^+$	Right	Left
D.	$H_2PO_4{}^- + H_2O \rightleftharpoons HPO_4{}^{2-} + H_3O^+$	Left	Right

Question 13

What is the concentration of hydroxide ions in a solution with a pH of 8.53?

    A. 3.0×10^{-9} moles/L

    B.   5.5 moles/L

    C. 3.4×10^{-6} moles/L

    D. 3.0×10^{5} moles/L

Question 14

All the lead ions present in a 50.0 mL solution were precipitated by reaction with excess chloride ions. The mass of the dried precipitate was 0.595 g.

What was the concentration of lead in the original solution?

    A.   8.87 g /L

    B.   10.2 g /L

    C.   11.9 g /L

    D.   16.0 g/ L

Question 15

The formula for a compound is shown.

$$CH_3 - CH_2 - \underset{\underset{CH_3}{|}}{CH} - CH_2 - \underset{\underset{\underset{\underset{CH_3}{|}}{CH_2}}{|}}{\overset{\overset{CH_3}{|}}{C}} - CH_3$$
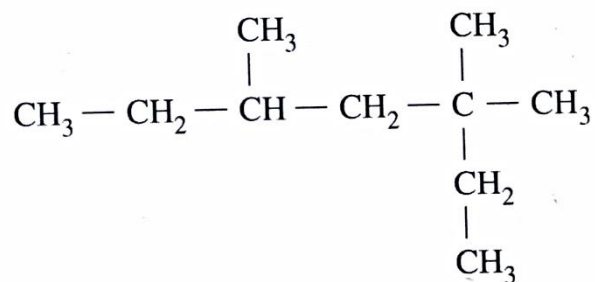
What is the name of this compound?

    A.   3,3,5-trimethylheptane

    B.   3,5,5-trimethylheptane

    C.   3,4-dimethyl-5-ethylhexane

    D.   2-ethyl-2,4-dimethylhexane

Question 16

In which of the following pairs are the substances isomers of each other?

A.   Pent-1-ene and 2-methylbut-1-ene

B.   Pentane and 2,3-dimethylbutane

C.   Pentanal and pentan-1-ol

D.   Dichloromethane and trichloromethane

Question 17

The following organic compound is shown.
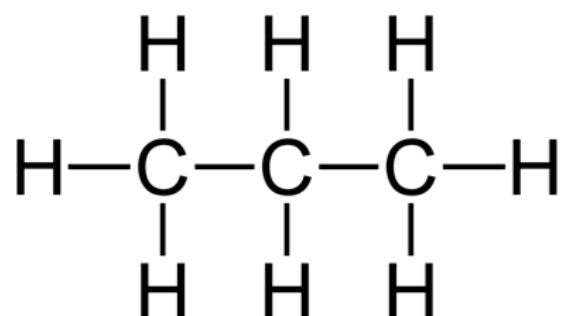
When the compound is analysed by NMR technology (C^{13} or H^1) the number of signals detected is based on the number of carbon or hydrogen environments the compound has.

The number of signals registered on a C^{13} and H^1 NMR of this compound would be

	C^{13} NMR Signals	H^1 NMR Signals
A	2	3
B	2	2
C	3	2
D	3	3

Question 18

What is the best way to identify whether a solution contains barium ions or copper ions?

A.   Add chloride ions to the solution: barium will precipitate but copper will not

B.   Add sulfate ions to the solution: barium will precipitate but copper will not

C.   Add hydroxide ions to the solution: barium will precipitate but copper will not

D.   Add phosphate ions to the solution: barium will precipitate but copper will not

Question 19

The following mass spectrograph is shown for an organic compound.
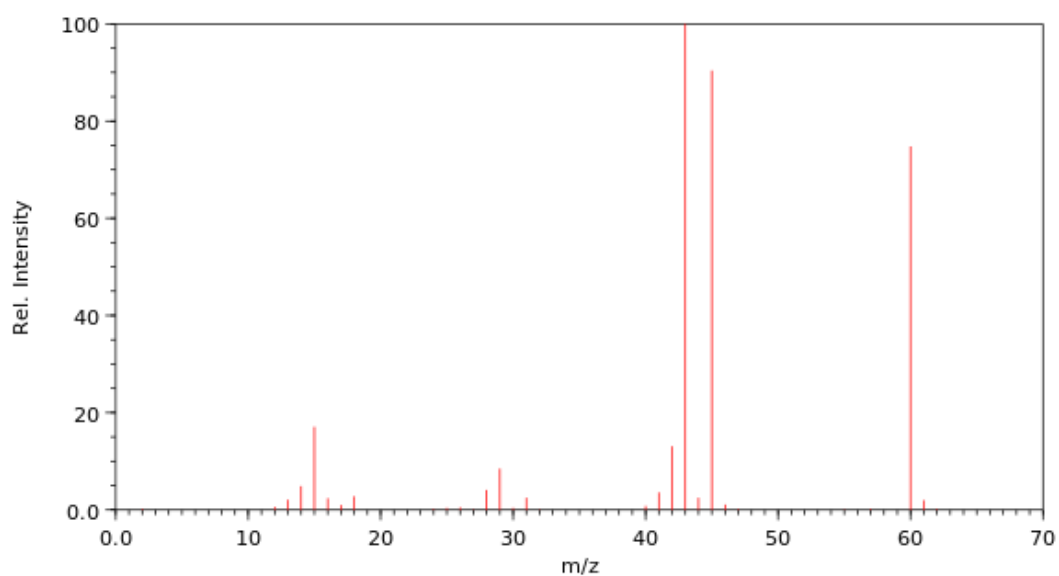
Which compound is most likely to produce this mass spectrogram?

A.   Methanoic Acid

B.   Ethanoic Acid

C.   Propanoic Acid

D.   Butanoic Acid

Question 20

A colorimeter was used to calculate the percentage of iron in a 0.200 gram tablet. The tablet was dissolved and oxidised, then reacted with thiosulfate according to the equation

$$Fe^{3+}(aq) + SCN^-\,(aq) \quad \rightleftharpoons \quad [FeSCN]^{2+}(aq)\,.$$

The resulting solution was made up to 200 mL with distilled water. The absorbance of the final solution was measured to be 0.6105 .

The calibration curve shows the absorbance of various concentrations of $Fe^{3+.}$
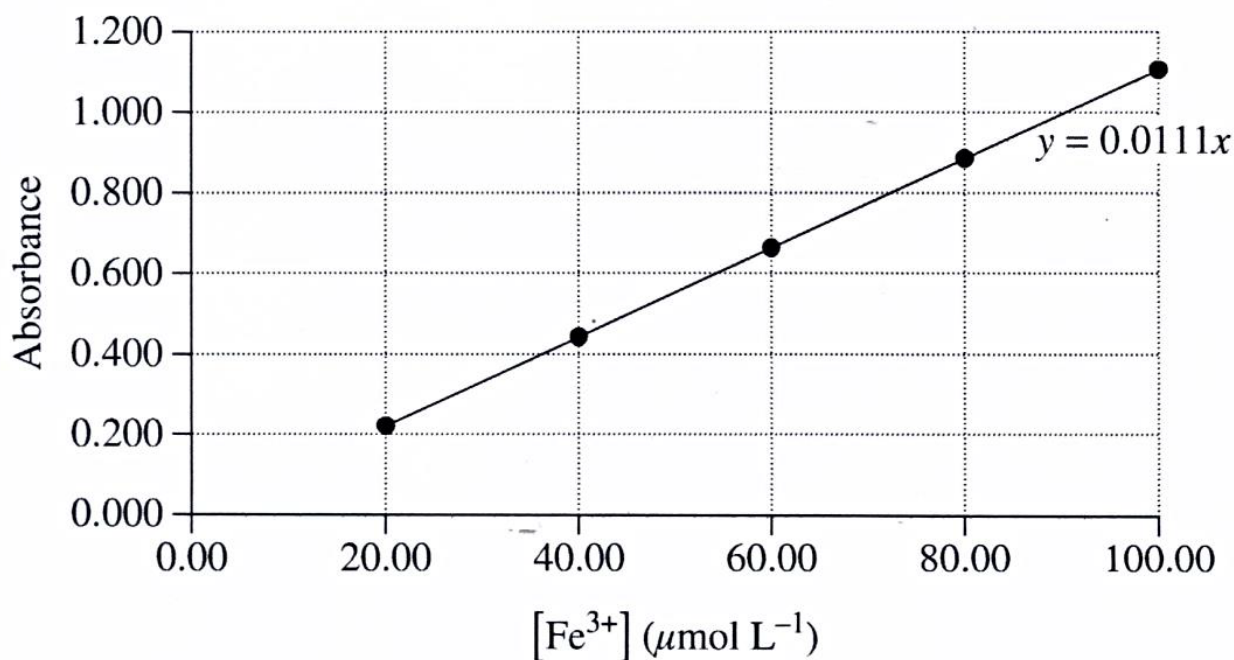
How much iron was in the tablet?

A. 1.10×10^{-5} g

B. 5.50×10^{-5} g

C. 6.14×10^{-4} g

D. 3.07×10^{-3} g

END OF SECTTION I

Question 21 (7 marks)

a) The following equation shows the dissociation of sodium hydroxide in water at 298 K.

$$NaOH(aq) \rightleftharpoons Na^+_{(aq)} + OH^-_{(aq)} \qquad \Delta H = -44.51 \text{ kJ/mol}$$

The change in entropy (ΔS) of NaOH at 298 K is +64.5 J/K mol

Explain the solubility of NaOH in water with reference to enthalpy and entropy. Support your answer with a labelled diagram. **4m**

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b) Calculate Gibbs Free Energy for the dissolution of sodium hydroxide in water at 298 K and identify if the dissolution is spontaneous or non-spontaneous. **3m**

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Question 22 (8 marks)

a) Butanoic acid is a natural product and a component of human sweat.

Calculate the value of Ka for butanoic acid if a 0.10 mol/L solution has a pH of 2.9 at 298 K. **3m**

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b) The pH of a 0.10 mol/L solution of hydrochloric acid has a pH of 1.0 at 298 K.

Explain why the butanoic acid and hydrochloric acid solutions have different pH at the same concentration. **2m**

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c) A student mixed 25mL of a 0.10 mol//L solution of hydrochloric acid with 75 mL of a 0.05 mol/L solution of potassium hydroxide.

Calculate the pH of the final mixture. **3m**

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Question 23   **(8 marks)**

The information in the table shows how the solubility of lead chloride is affected by temperature.

Temperature (°C)	Solubility (g/100 g water)
0	0.25
20	0.35
40	0.55
60	0.90
80	1.75
100	3.20

a) Draw a graph to represent the solubility of lead chloride.   **3m**
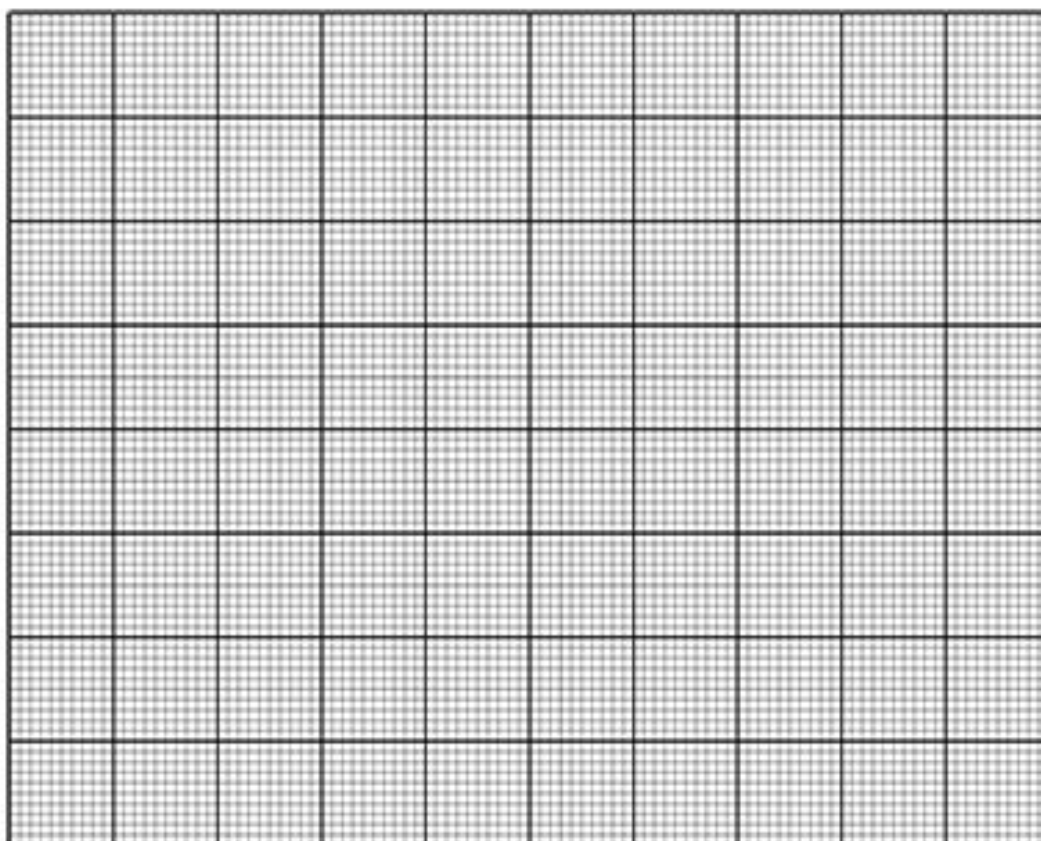
b) Use the graph to determine the mass of lead chloride that dissolves in 1 litre of water at 50°C   **1m**

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c) Calculate the solubility product (Ksp) for the dissolution of lead chloride at 50°C. Include a relevant chemical equation in your answer. **4m**

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Question 24   **(6 marks)**

The hydrogen carbonate ion (HCO_3^-) can form a buffer in water ways when carbonate ions (CO_3^{2-}) are dissolved from rocks.

a) Describe the importance of buffers in natural systems. **2m**

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b) Explain the effect of an acid and a base on the hydrogen carbonate/carbonate buffer. Use equations in your response. **4m**

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Question 25   **(7 marks)**

a) Draw structural formulae to represent a primary, secondary and tertiary alkanol with a molecular formula of $C_4H_{10}O$. Name each compound.   **3m**

Primary   *Secondary*

Tertiary

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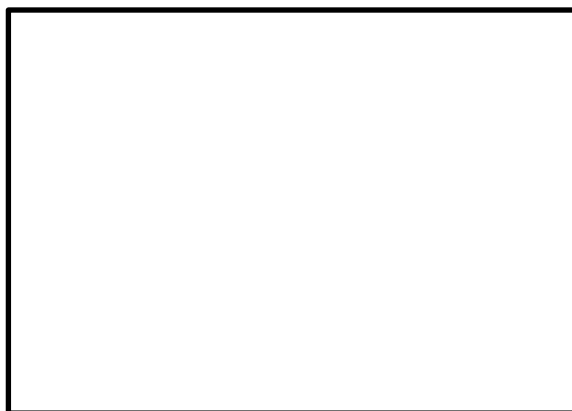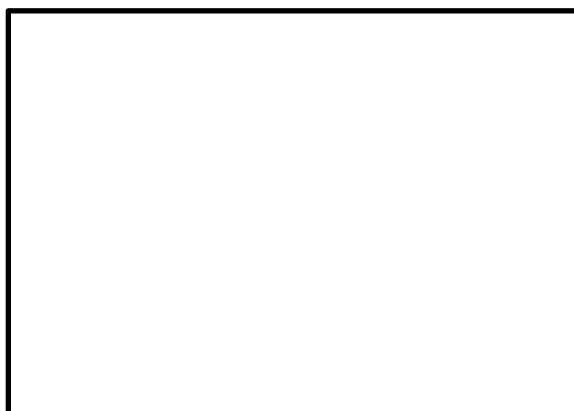
b) Explain the difference in boiling point of the THREE alkanol compounds drawn in part a). Include a relevant diagram to support your answer.   **4m**

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Question 26 (7 marks)

a) Using structural formula, give the equation for the esterification of propan-1-ol and ethanoic acid **3m**

b) Outline TWO advantages of using reflux to prepare an ester **2m**

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c) Describe the role of the catalyst (concentrated H_2SO_4) in esterification. **2m**

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Question 27 (8 marks)

The diagrams represent equipment used by students in an investigation to determine the chloride concentration in a water sample.

Student A used Figure 1 and shows that initially 50.0 mL of the water sample was titrated with a standardised 1.05×10^{-2} moles/L silver nitrate solution using a chromate indicator. It required 32.8 mL of silver nitrate solution to cause a colour change.

Student B used excess silver nitrate solution to precipitate the chloride ions and then filtered and dried the precipitate as shown by Figure 2.
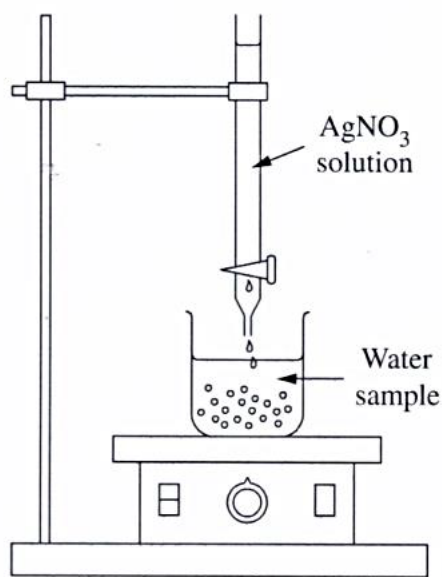
Figure 1
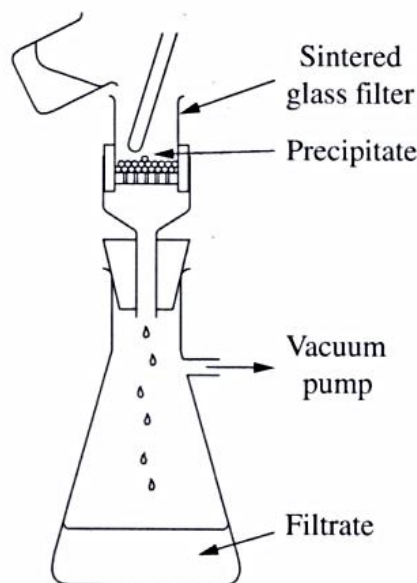
Figure 2

a) What technique is used in Figure 2 to determine the chloride concentration? **1m**

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b) Give the net ionic equation for the reaction that occurred in this investigation. **1m**

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c) Determine the mass of chloride ion in **mg** as determined by the precipitation titration technique shown in Figure 1. **3m**

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Question 27 continued

d) Discuss the validity and the accuracy of using the procedure in Figure 2 to determine the concentration of the chloride concentration of this water sample. **3m**

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Question 28 (4 marks)

The reaction of bromine gas with chlorine gas has a K value of 7.20 at 200°C.

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad K = 7.20$$

A closed vessel was filled with the two reactants, each at an initial concentration of 0.200 M, but with no initial concentration of $BrCl(g)$.

Calculate the equilibrium concentration of $BrCl(g)$ **4m**

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Question 29   **(6 marks)**

The diagram show the shapes of the different homologous series of compounds called hydrocarbons.

Tetrahedral   Planar   Linear
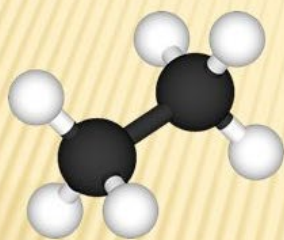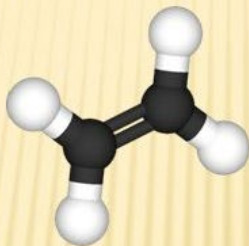
Ethane   Ethene   Ethyne
(All angles 109.5°)   (All angles 120°)   (180° bond angle)

Explain the shapes of the three types of hydrocarbon compounds shown using hybridisation and bond theory.   6m

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Question 30 (6 marks)

The flow chart shows reactions involving four different organic compounds (**A** to **D**)

$$\begin{array}{c} \mathbf{A} \\ C_5H_{10} \end{array}$$

Reacting with dilute H_2SO_4

$$\mathbf{D} \xleftarrow[\text{(strong oxidant)}]{KMnO_4/H_2SO_4} \begin{array}{c} \mathbf{B} \\ C_5H_{12}O \end{array}$$

$$\begin{array}{c} \mathbf{C} \\ C_5H_{12}O \end{array} \xrightarrow[\text{(strong oxidant)}]{KMnO_4/H_2SO_4} \begin{array}{c} \text{No} \\ \text{reaction} \end{array}$$
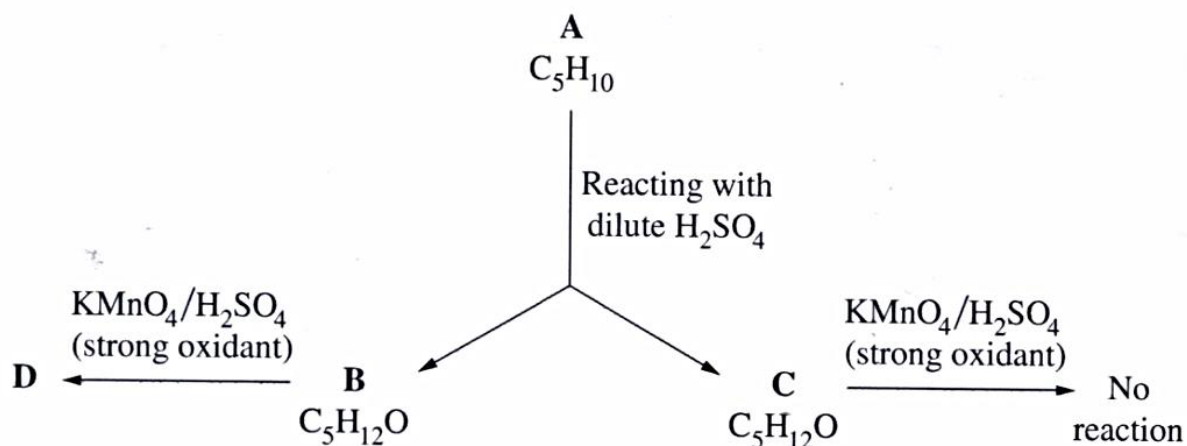
a) Identify which compound is a tertiary alcohol. **1m**

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b) Draw the structural formula and name Compound A **2m**

c) Justify why compounds B and C are isomers. **2m**

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d) Compound D is formed from the oxidation of compound B. Describe the colour change that would confirm that this reaction took place. **1m**

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Question 31 (5 marks)

Shown are data from the analysis of a four carbon (C4) organic compound.

Image A. C^{13} NMR spectroscopy
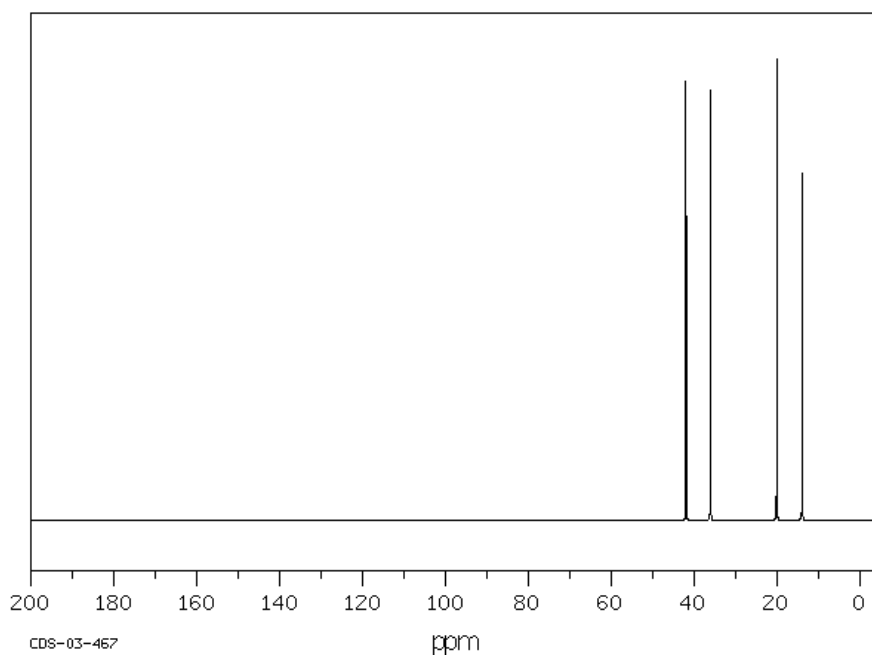
Image B. Infrared Spectrogram
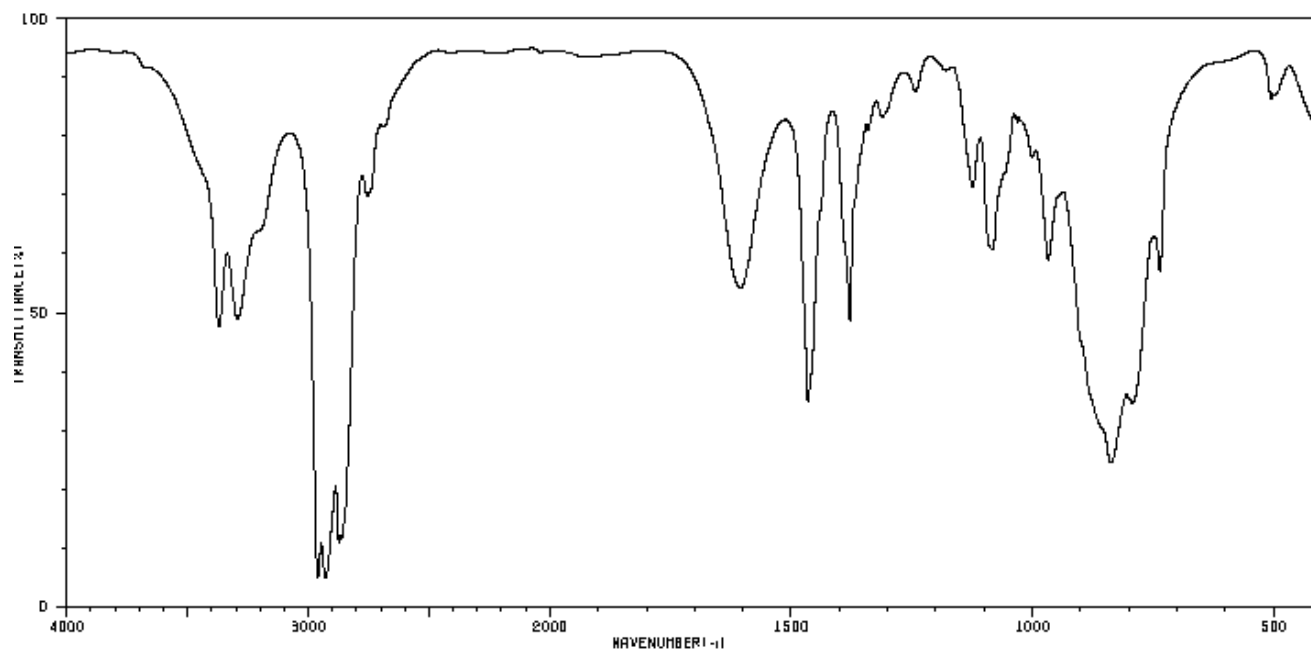
Image C. Mass Spectroscopy
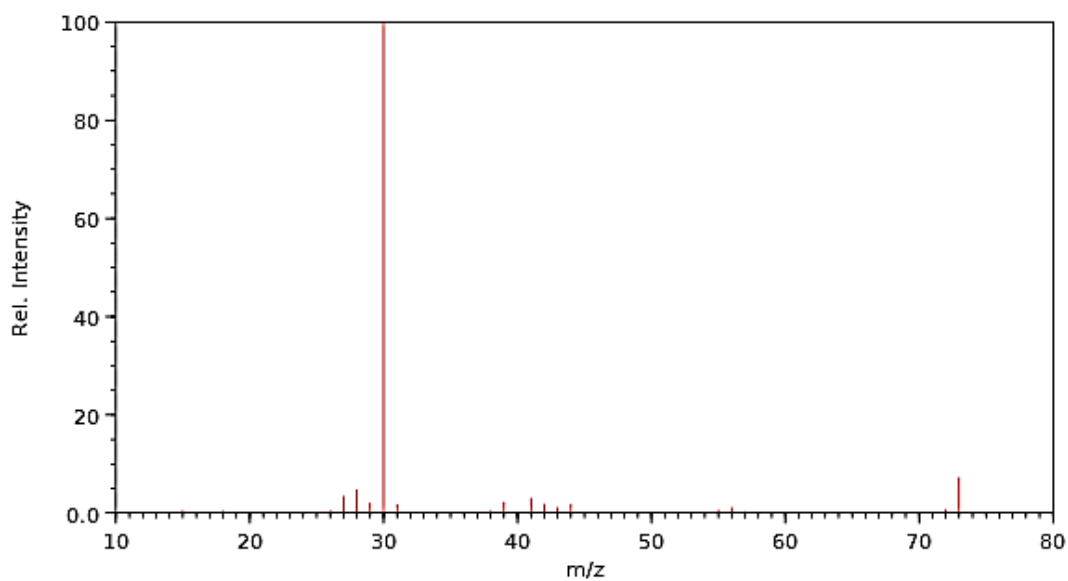
a) What functional group is inferred from the IR spectroscopy data?   **1m**

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b) Draw the structural formula for the compound. Justify your choice using data from each
   analysis.   **4m**

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Question 32 (3 marks)

There are two main types of polymers: addition polymers and condensation polymers.

Two polymers are shown

Polymer A

$$n \quad \underset{HO}{\overset{O}{C}}-R-\underset{OH}{\overset{O}{C}} + n\ H_2N-R'-NH_2 \longrightarrow \left[\overset{O}{\underset{}{C}}-R-\overset{O}{\underset{}{C}}-\underset{H}{N}-R'-\underset{H}{N} \right]_n + 2\ H_2O$$

Polymer B

$$\begin{array}{cc} H & H \\ | & | \\ C & = C \\ | & | \\ H & Cl \end{array} + \begin{array}{cc} H & H \\ | & | \\ C & = C \\ | & | \\ H & Cl \end{array} \longrightarrow \begin{array}{cccc} H & H & H & H \\ | & | & | & | \\ -C & -C & -C & -C- \\ | & | & | & | \\ H & Cl & H & Cl \end{array}$$
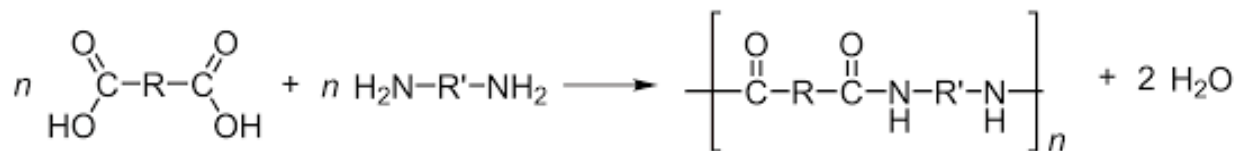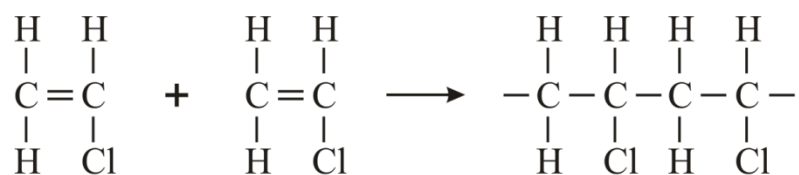
a) Which polymer is an addition polymer? **1m**

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b) Describe the difference between an addition polymer and a condensation polymer **2m**

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Question 33   **(5 marks)**

Saponification is the reaction between an ester (usually a triglyceride) and sodium hydroxide.

$$\text{Triglyceride} \ + \ 3\text{NaOH} \ \rightarrow \ 3 \text{ Fatty Acid Salt (Soap)} \ + \ \text{Glycerol}$$
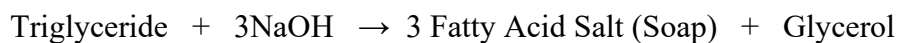
a) Describe the structure of soap.   **2m**

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b) Explain the cleaning action of soap. Include a relevant diagram   **3m**

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End of Examination Paper

SECTION II extra writing paper

If you use this paper, clearly indicate which question you are answering and also indicate that you have used this paper at the question.

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