
Student Number

NORTH SYDNEY GIRLS HIGH SCHOOL

2024

Higher School Certificate

Trial Examination

Chemistry

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided
- Write your student number at the top of this booklet and on the multiple-choice answer sheet.

Total Marks – 100

Weighting – 30%

Section I 20 Marks

- Attempt Questions 1 - 20
- Allow about 35 minutes for this section.

Section II 80 Marks

- Attempt Questions 21 - 34
- Allow about 2 hours and 25 minutes for this section.

Section I

20 marks

Attempt Questions 1–20

Allow about 35 minutes for this section

Use the multiple-choice answer sheet provided for Questions 1-20. If you must use blank paper instead, clearly indicate an answer of EITHER A, B, C or D for each question from 1-20.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

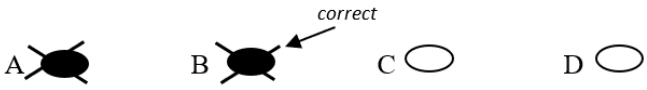
Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:



1 Which of the following is NOT an appropriate safety precaution for an experiment investigating the reaction of cyclohexene with bromine water in a school laboratory?

A. Wear safety goggles and apron.
B. Use large beakers.
C. Conduct reaction in a fume cupboard.
D. Collect reaction products in a waste bottle.

2 Which of the following rows correctly identifies the changes in entropy and enthalpy for combustion and photosynthesis?

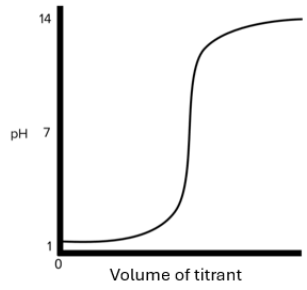
	Entropy change		Enthalpy change	
	Combustion	*Photosynthesis*	*Combustion*	*Photosynthesis*
A.	Increases	Decreases	Endothermic	Exothermic
B.	Decreases	Increases	Exothermic	Endothermic
C.	Increases	Decreases	Exothermic	Endothermic
D.	Decreases	Increases	Endothermic	Exothermic

3 Which of the following correctly matches the molecular shape around the carbon atom in each bond?

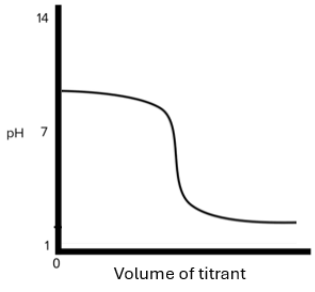
	C – C	C = C	C ≡ C
A.	Linear	Trigonal planar	Tetrahedral
B.	Tetrahedral	Trigonal planar	Linear
C.	Tetrahedral	Trigonal planar	Bent
D.	Bent	Linear	Trigonal planar

4 Which of the following titration curves shows the addition of a strong base to a weak acid?

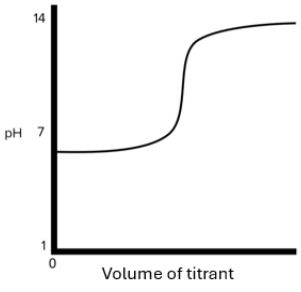
A.



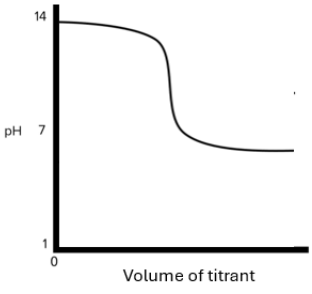
B.



C.



D.



5 The table below shows four separate tests used to identify a dilute, aqueous sample of a compound.

Test Number	Test	Observation
1	Add HNO_3 to the sample	No bubbles
2	Flame test	Apple green
3	Add Cl^-	No precipitate forms

Which compound would produce the observations shown?

A. Barium nitrate
B. Copper(II) nitrate
C. Barium carbonate
D. Copper(II) acetate

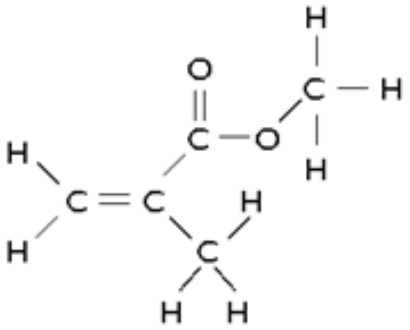
6 Hydrogen sulfide can be removed from natural gas according to the equation below.

$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(s) + 2H_2O(g) \qquad \Delta H = -145 \text{ kJ mol}^{-1}$$

Which of the following would maximise the removal of hydrogen sulfide from this system?

A. Decreasing the volume of the vessel
B. Removing some sulfur from the system
C. Increasing the temperature
D. Adding water vapour to the system

7 Methyl methacrylate is a monomer that is able to undergo polymerisation. Its structural formula is featured below.



What type of polymerisation is most likely to occur for methyl methacrylate?

A. Addition
B. Hydration
C. Condensation
D. Esterification

8 A solution was known to contain either potassium phosphate or sodium iodide. Which of the following could be used to identify the salt present in the given solution?

A. Lead(II) nitrate
B. Iron(II) carbonate
C. Copper(II) acetate
D. Magnesium hydroxide

9 At a particular temperature, iodine trichloride dissociates into iodine gas and chlorine gas according to the equation below.

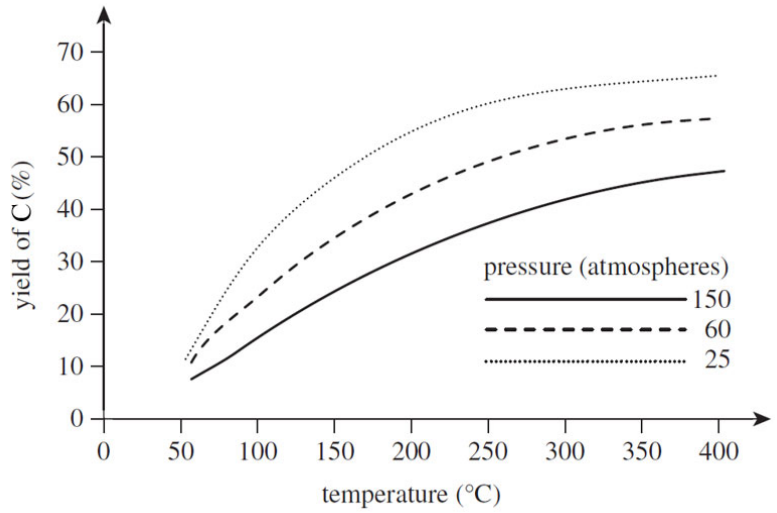
$$2ICl_3(g) \rightleftharpoons I_2(g) + 3Cl_2(g) \qquad \Delta H = 240 \text{ kJ mol}^{-1}$$

Initially, 0.60 mol of iodine trichloride was introduced into a 500 mL container and allowed to reach equilibrium. The concentration of chlorine gas at equilibrium was 0.60 mol L^{-1}.

What is the value of K_{eq} at this temperature?

A. 0.068
B. 0.15
C. 0.30
D. 0.60

10 A manufacturer carried out tests to find the yield of an equilibrium reaction at different temperatures and pressures. The graph below shows the results obtained.



Which of the following equations best matches the results shown in the graph above?

A. $A(g) + B(g) \rightleftharpoons C(g)$ $\Delta H = -500 \text{ kJ mol}^{-1}$

B. $A(g) + B(g) \rightleftharpoons C(g)$ $\Delta H = +500 \text{ kJ mol}^{-1}$

C. $A(g) + B(g) \rightleftharpoons 3C(g)$ $\Delta H = -500 \text{ kJ mol}^{-1}$

D. $A(g) + B(g) \rightleftharpoons 3C(g)$ $\Delta H = +500 \text{ kJ mol}^{-1}$

11 Which of the following compounds is most likely to have the lowest solubility in water?

A. $(CH_3)_2COHCH_2CH_3$

B. $CH_3CH_2CH_2CH_2CH_2OH$

C. CH_3OH

D. CH_3CH_2OH

12 Ascorbic acid (Vitamin C), a monoprotic acid, has the molecular formula of $C_6H_8O_6$ and a K_a value of 8×10^{-5} at 25ºC. A tablet containing 250 mg of Vitamin C was dissolved in 100 mL of water at 25ºC. What is the pH of this solution?

A. 2.97

B. 3.47

C. 3.70

D. 5.94

13 The complete combustion of propanol releases more heat per mol of fuel compared to the complete combustion of methanol. Which of the following statements best explains this phenomenon?

A. More energy is required to break the bonds in the propanol molecules.
B. More molecules of carbon dioxide are formed in the combustion of propanol.
C. More molecules of oxygen are required in the combustion of propanol.
D. The boiling point for propanol is higher.

14 The enthalpy of combustion for ethyne is -1301 kJ mol^{-1}. What is the mass of ethyne required to produce 20 MJ of heat energy when combusted?

A. 1.7 g
B. 15.4 g
C. 400 g
D. 461 g

Questions 15 and 16 refer to the equilibrium below.

$$HSO_4^-(aq) + HCO^{3-}(aq) \rightleftharpoons SO_4^{2-}(aq) + H_2CO_3(aq)$$

The equilibrium lies to the product side.

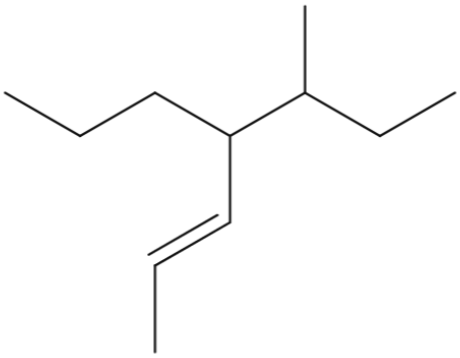
15 Which of the following species is the conjugate acid?

A. HSO_4^-
B. HCO_3^-
C. SO_4^{2-}
D. H_2CO_3

16 Which of the following species would have the highest K_a?

A. HSO_4^-
B. HCO_3^-
C. SO_4^{2-}
D. H_2CO_3

17 What is the IUPAC name of the following compound?



A. 5-methyl-4-propylhept-2-ene
B. 5-ethyl-4-propylhex-2-ene
C. 3-methyl-4-propylhept-5-ene
D. 2-ethyl-3-propylhex-4-ene

18 The table below shows the conductivity of a range of 0.01 mol L^{-1} solutions.

Solution	Conductivity (S m^2)
HBr	411
KOH	257
HCOOH	43
NH_3	11
H_3BO_3	0.14

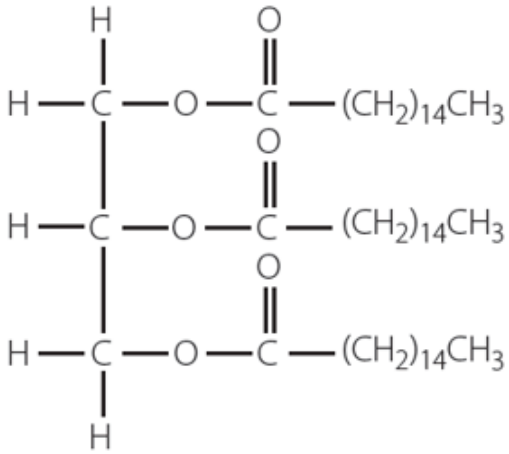
Using the table above, which of the following statements is correct?

A. KOH is a stronger acid than HCOOH.
B. H_3BO_3 has low conductivity because it is triprotic.
C. HBr has a high degree of ionisation.
D. The OH^- ions are better conductors than H_3O^+ ions.

19 Which of the following compounds has the lowest molar solubility in water?

A. Barium nitrate
B. Calcium hydroxide
C. Iron (III) phosphate
D. Magnesium phosphate

20 The esters of glycerol (propan-1,2,3-triol), which can be referred to as fats or oils, can be used to make soaps. This is done by reacting the ester functional groups with hydroxide ions to form glycerol and the carboxylate ions. The diagram below shows the structural formula of a particular fat used to make soap.



A student dissolved 8.0 g of sodium hydroxide in 50 mL of water and then added 10 g of the fat shown above. After the reaction mixture was heated, the soap product was extracted and found to weigh 6.45 g. The percentage yield in this process is closest to

A. 53%
B. 62%
C. 65%
D. 68%

Section II

80 marks

Attempt Questions 21 – 34. Allow about 2 hours and 25 minutes for this section.

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response. Show all relevant working in questions involving calculations. If needed, extra writing space is available on pages 30 – 32.

Question 21 (4 marks)

Complete the following table. **4**

	Polyvinyl chloride	Polytetrafluoroethene
Monomer structural formula		
Polymer structural formula		
Property	…… ……	…… ……
Use	…… ……	…… ……

Question 22 (4 marks)

A student mixed 500.0 mL of a 0.00123 mol L^{-1} solution of FeF_2 with 500.0 mL of a 0.00314 mol L^{-1} solution of KOH at 25ºC. **4**

Using calculations, determine if a precipitate will be formed from the mixture.

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Question 23 (4 marks)

a) Outline ONE advantage and ONE disadvantage of biofuels when compared to fossil fuel alternatives. **2**

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b) Outline ONE economic and ONE environmental implication of obtaining and/or using hydrocarbons. **2**

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Question 24 (6 marks)

Sodium hydroxide reacts with the weak oxalic acid according to the following equation.

$$2NaOH(aq) + H_2C_2O_4(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

a) Explain why solutions of sodium oxalate are basic. Support your answer with a relevant chemical equation. **2**

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b) A student wants to determine the concentration of a sample of oxalic acid using a standardised solution of sodium hydroxide. The student is provided with the following indicators. **2**

Indicator	*Colour Change*	*pH range over which colour changes*
Bromocresol green	yellow-blue	3.8 – 5.4
4-nitrophenol	colourless-yellow	5.7 -7.6
phenolphthalein	colourless-pink	8.3 – 10.0

Using the table above, determine the most appropriate indicator for this titration and justify your choice.

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Question 24 continues on the next page.

c) Provide chemical equations to show the amphiprotic nature of the hydrogen oxalate ion. **2**

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Question 25 (7 marks)

Benzoic acid, C_6H_5COOH, is used as a preservative in certain foods to prevent the growth of moulds. This acid has a K_a value of 6.5×10^{-5} at 25°C.

a) How many grams of benzoic acid are needed to prepare 1.0 L of a solution with a pH of 2.80 at 25°C? **4**

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b) A solution of benzoic acid and sodium benzoate was made at 25°C and was measured to have a pH of 4.48. When NaOH was added to the solution, there was little change to the pH. This was also observed when HCl was added. Using a relevant chemical equation, explain these observations. **3**

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Question 26 (3 marks)

The pH of the oceans has been maintained by the following equilibria. **3**

1. $CO_2(g) \rightleftharpoons CO_2(aq)$
2. $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3\ (aq)$
3. $H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

Since the start of the industrial age, the pH of the oceans has been decreasing. It is estimated that the pH of the ocean will fall from 8.14 to 7.90 over the next 50 years.

Using the equations provided, explain how the combustion of fossil fuels is responsible for the change in pH of the ocean.

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Question 27 (6 marks)

The equilibrium between two different coloured Co(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, has been used by ecologists in qualitative tests to determine water content in soil.

Solutions of cobalt chloride are pink, due to the formation of the complex ion, $[Co(H_2O)_6]^{2+}$. The equilibrium equation is shown below.

$$\underbrace{CoCl_4^{2-}(aq)}_{\text{blue}} + 6H_2O(\ell) \rightleftharpoons \underbrace{Co(H_2O)_6^{2+}(aq)}_{\text{pink}} + 4Cl^-(aq)$$

a) Using Le Chatelier's Principle, explain the change in colour if drops of concentrated HCl were added to the system. **2**

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Question 27 continues on the next page.

b) In a second experiment, a solution of cobalt chloride was prepared and separated into three test tubes. One test tube was placed in a beaker of water at room temperature, while the other two were placed in a beaker of ice water and a beaker of hot water, respectively. The following observations were made. **4**

	Ice water	**Room temperature**	**Hot water**
Colour of solution	pink	purple	blue

Using your understanding of collision theory, explain the observations above.

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Question 28 (5 marks)

150.0 mL of a 0.564 mol L^{-1} barium hydroxide solution was placed in a well-insulated beaker. The temperature of the solution was 20.3ºC. Subsequently, 400 mL of a 1.25 mol L^{-1} nitric acid solution was placed in another beaker and brought to the same temperature. The two solutions were then mixed, and the final maximum temperature was recorded to be 23.7 ºC. Assume that the density of the solutions was 1.00 g mL^{-1}.

a) Calculate the molar enthalpy of neutralisation. **3**

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b) A student repeated this experiment with the same volume and concentration of barium hydroxide solution, but this time used 400 mL of 1.25 mol L^{-1} hydrochloric acid. The initial temperature of the solutions was once again 20.3ºC. **2**

Predict if the final temperature would be higher, lower or the same as the original reaction and justify your response.

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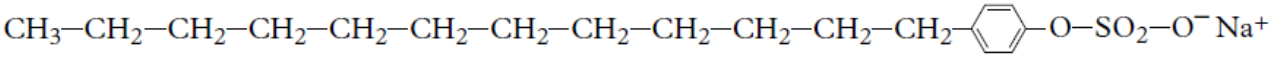
Question 29 (5 marks)

Sodium laurylbenzene sulfonate is used as a detergent in cleaning products and in pesticides. Its structure is shown below. **5**



With reference to its structure, explain the cleaning action of sodium laurylbenzene sulfonate.

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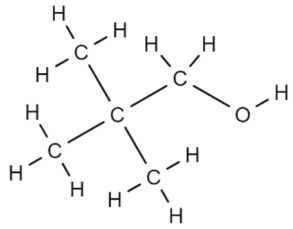
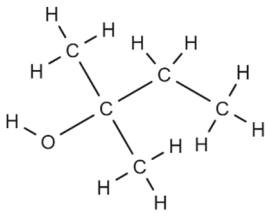
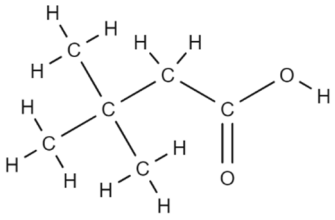
Question 30 (9 marks)

The structural formulae for Compound A, B and C are shown below.

A  B  C 

a) Describe how you could distinguish between the compounds featured above using simple reactions in a school laboratory. Include relevant reagents and observations in your response. **4**

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Question 30 continues on the next page.

b) Compounds A and B are isomers. Draw FIVE other isomers of this compound and provide their IUPAC names. **5**

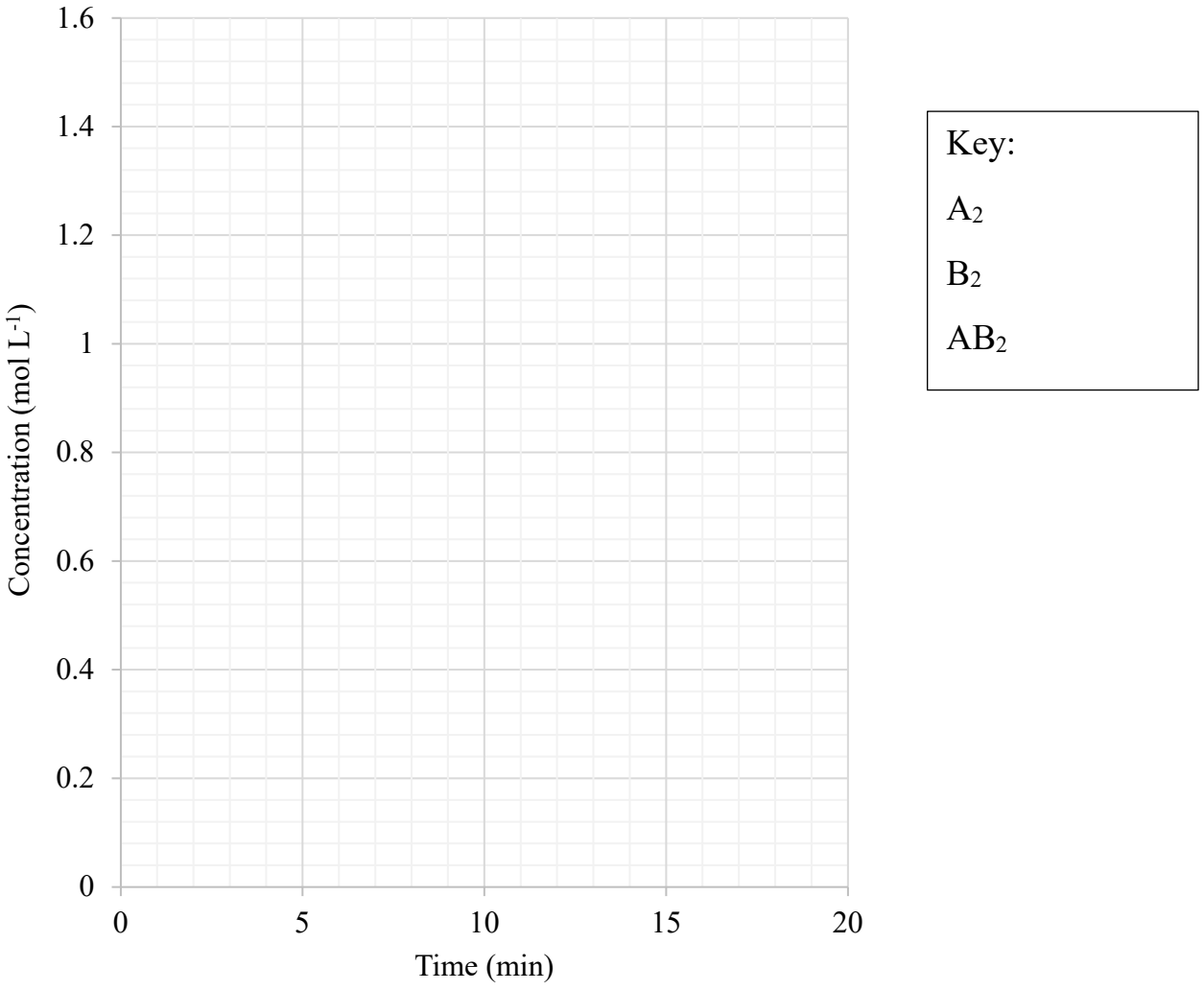
Question 31 (6 marks)

Gases A_2 and B_2 react according to the equation below.

$$A_2(g) + 2B_2(g) \rightleftharpoons 2AB_2(g) \qquad \Delta H < 0$$

A mixture of A_2 and B_2 was placed into a sealed vessel. The initial concentration of A_2 was 1.4 mol L^{-1} and the initial concentration of B_2 was 1.0 mol L^{-1}. At 5 minutes, the system had reached equilibrium where the concentration of A_2 was 1.2 mol L^{-1}. The system remained at equilibrium until at 10 minutes, the temperature of the system was reduced. At 15 minutes, the system re-established equilibrium.

a) On the graph below, complete the key and draw a trendline for each of the chemical species involved in this equilibrium to show their changes in concentrations over time. **4**



Question 31 continues on the next page.

b) Calculate the K_{eq} at 7 minutes. **2**

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Question 32 (9 marks)

0.050 mol of ethanoic acid was reacted with 0.050 mol of ethanol in 100 mL of solution at a certain temperature. The reaction mixture was then cooled, and the excess ethanoic acid was titrated needing 34 mL of 0.50 mol L^{-1} NaOH for neutralisation.

a) Draw the structural formulae of the products formed in the reaction between ethanoic acid and ethanol. **2**

b) What reagent could be added to act as a catalyst for this reaction? **1**

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c) Identify a laboratory technique that could be used to help this reaction reach equilibrium quicker and provide another advantage of using this technique. **2**

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Question 32 continues on the next page.

d) Calculate the equilibrium constant for this reaction. **4**

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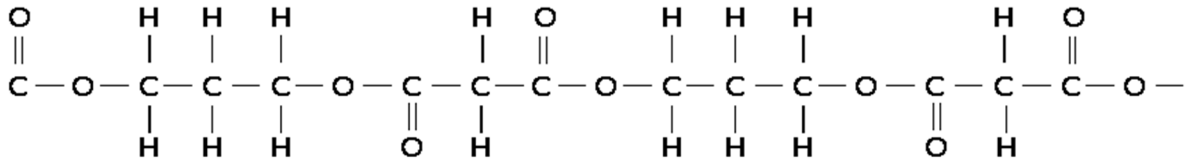
Question 33 (5 marks)

The following structural diagram shows a section of Polymer A



a) Draw the monomers for Polymer A. **2**

b) Determine the molar mass of a section of Polymer A that consists of 40 monomers. **3**

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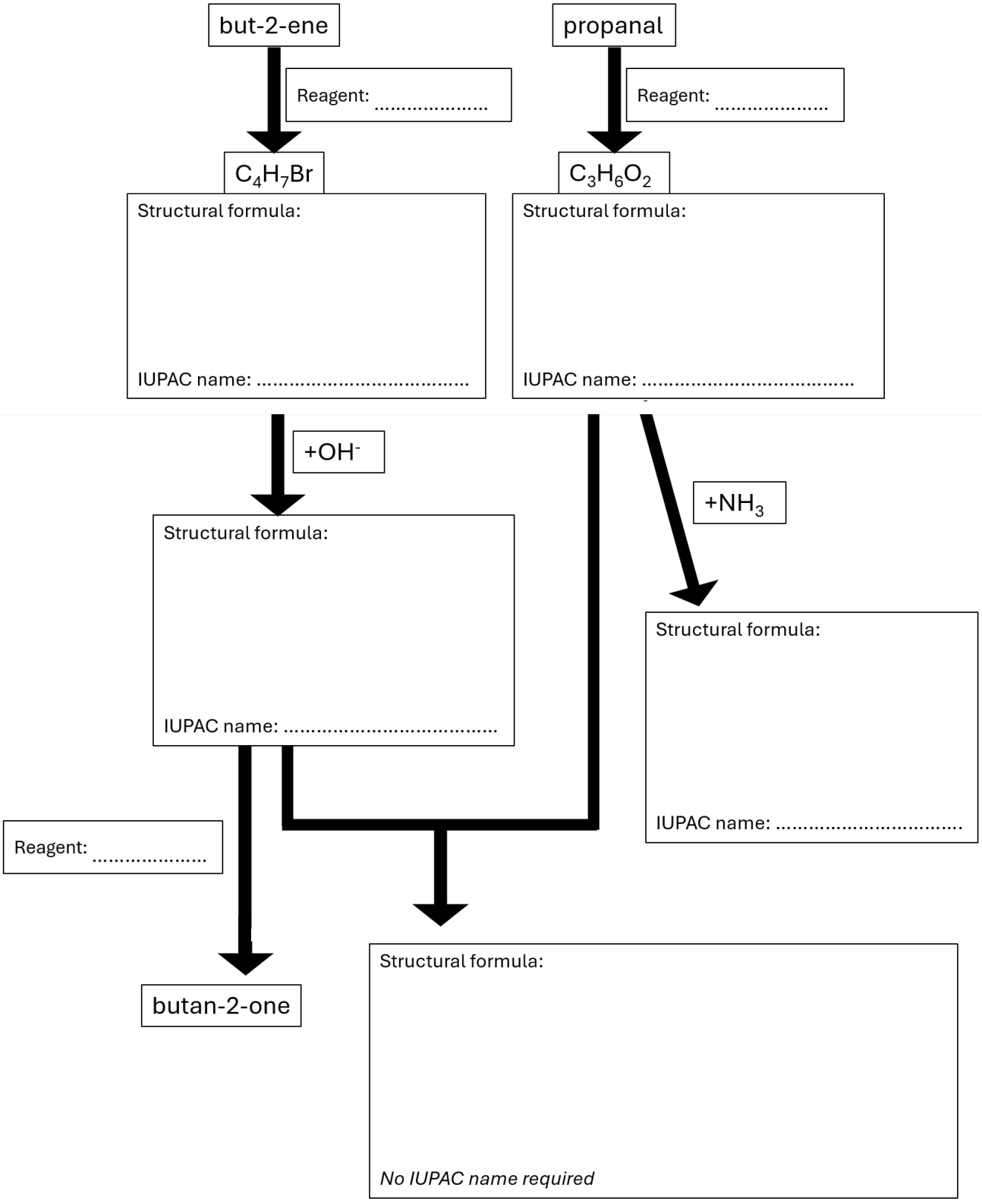
Question 34 (7 marks)

Fill in the blanks in the following flow chart. **7**



End of Exam

Extra writing space:

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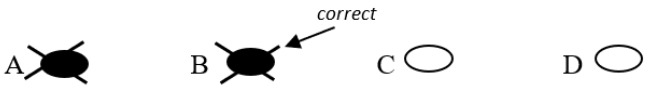

1 Which of the following is NOT an appropriate safety precaution for an experiment investigating the reaction of cyclohexene with bromine water in a school laboratory?

A. Wear safety goggles and apron.
B. Use large beakers.
C. Conduct reaction in a fume cupboard.
D. Collect reaction products in a waste bottle.

2 Which of the following rows correctly identifies the changes in entropy and enthalpy for combustion and photosynthesis?

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C.	Increases	Decreases	Exothermic	Endothermic
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3 Which of the following correctly matches the molecular shape around the carbon atom in each bond?

	C – C	C = C	C ≡ C
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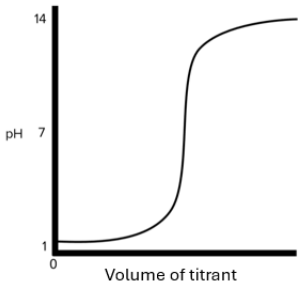
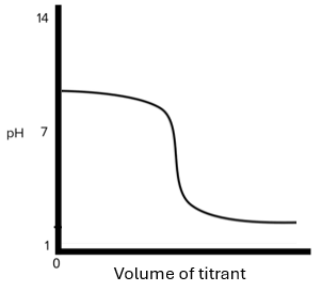
B.	Tetrahedral	Trigonal planar	Linear
C.	Tetrahedral	Trigonal planar	Bent
D.	Bent	Linear	Trigonal planar

4 Which of the following titration curves shows the addition of a strong base to a weak acid?

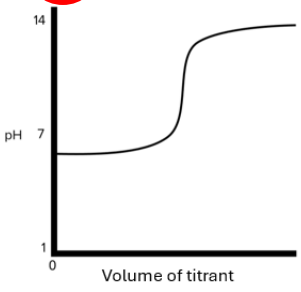
A.



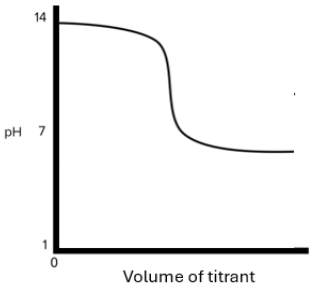
B.



C.



D.



5 The table below shows four separate tests used to identify a dilute, aqueous sample of a compound.

Test Number	Test	Observation
1	Add HNO_3 to the sample	No bubbles
2	Flame test	Apple green
3	Add Cl^-	No precipitate forms

Which compound would produce the observations shown?

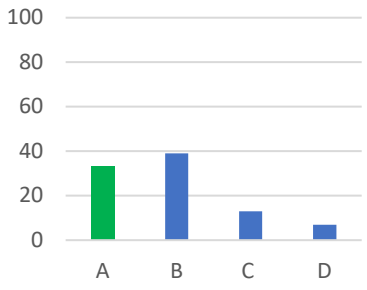
A. Barium nitrate
B. Copper(II) nitrate
C. Barium carbonate
D. Copper(II) acetate

6 Hydrogen sulfide can be removed from natural gas according to the equation below.

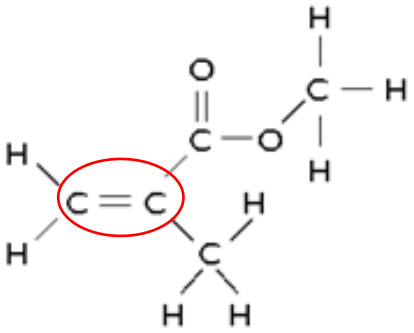
$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(s) + 2H_2O(g) \qquad \Delta H = -145 \text{ kJ mol}^{-1}$$

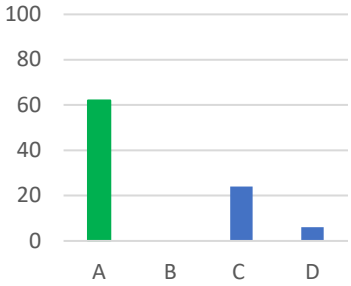
Which of the following would maximise the removal of hydrogen sulfide from this system?

A. Decreasing the volume of the vessel
B. Removing some sulfur from the system
C. Increasing the temperature
D. Adding water vapour to the system



7 Methyl methacrylate is a monomer that is able to undergo polymerisation. Its structural formula is featured below.





What type of polymerisation is most likely to occur for methyl methacrylate?

A. Addition
B. Hydration
C. Condensation
D. Esterification

8 A solution was known to contain either potassium phosphate or sodium iodide. Which of the following could be used to identify the salt present in the given solution?

A. Lead(II) nitrate (different colour ppt)
B. Iron(II) carbonate
C. Copper(II) acetate (only phosphate ppt)
D. Magnesium hydroxide

9 At a particular temperature, iodine trichloride dissociates into iodine gas and chlorine gas according to the equation below.

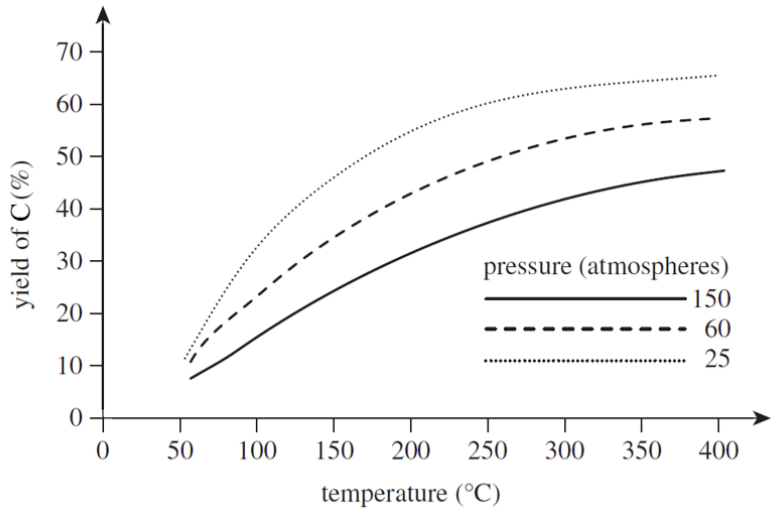
$$2ICl_3(g) \rightleftharpoons I_2(g) + 3Cl_2(g) \qquad \Delta H = 240 \text{ kJ mol}^{-1}$$

Initially, 0.60 mol of iodine trichloride was introduced into a 500 mL container and allowed to reach equilibrium. The concentration of chlorine gas at equilibrium was 0.60 mol L^{-1}.

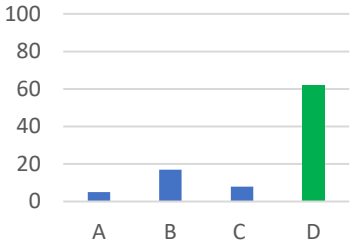
What is the value of K_{eq} at this temperature?

A. 0.068
B. 0.15
C. 0.30
D. 0.60

10 A manufacturer carried out tests to find the yield of an equilibrium reaction at different temperatures and pressures. The graph below shows the results obtained.



Which of the following equations best matches the results shown in the graph above?



A. $A(g) + B(g) \rightleftharpoons C(g)$ $\Delta H = -500\ kJ\ mol^{-1}$

B. $A(g) + B(g) \rightleftharpoons C(g)$ $\Delta H = +500\ kJ\ mol^{-1}$

C. $A(g) + B(g) \rightleftharpoons 3C(g)$ $\Delta H = -500\ kJ\ mol^{-1}$

D. $A(g) + B(g) \rightleftharpoons 3C(g)$ $\Delta H = +500\ kJ\ mol^{-1}$

Yield higher at lower pressure ➔ forward reaction produces more moles of gas

11 ~~Which of the following compounds is most likely to have the lowest solubility in water?~~

~~A. $(CH_3)_2COHCH_2CH_3$ (tertiary alcohol)~~

~~B. $CH_3CH_2CH_2CH_2CH_2OH$~~

~~C. CH_3OH~~

~~D. CH_3CH_2OH~~

12 Ascorbic acid (Vitamin C), a monoprotic acid, has the molecular formula of $C_6H_8O_6$ and a K_a value of 8×10^{-5} at 25°C. A tablet containing 250 mg of Vitamin C was dissolved in 100 mL of water at 25°C. What is the pH of this solution?

A. 2.97

B. 3.47

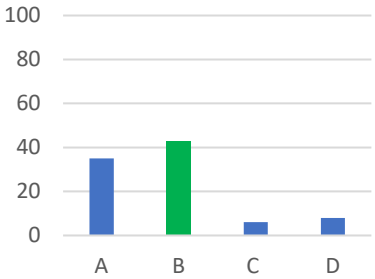
C. 3.70

D. 5.94

13 The complete combustion of propanol releases more heat per mol of fuel compared to the complete combustion of methanol. Which of the following statements best explains this phenomenon?

A. More energy is required to break the bonds in the propanol molecules.
B. More molecules of carbon dioxide are formed in the combustion of propanol.
C. More molecules of oxygen are required in the combustion of propanol.
D. The boiling point for propanol is higher.

Forming bonds releases heat energy – the more C=O bonds formed, the energy released per mol of fuel



14 The enthalpy of combustion for ethyne is -1301 kJ mol^{-1}. What is the mass of ethyne required to produce 20 MJ of heat energy when combusted?

A. 1.7 g
B. 15.4 g
C. 400 g
D. 461 g

Questions 15 and 16 refer to the equilibrium below.

$$HSO_4^-(aq) + HCO_3^-(aq) \rightleftharpoons SO_4^{2-}(aq) + H_2CO_3(aq)$$

The equilibrium lies to the product side.

15 Which of the following species is the conjugate acid?

A. HSO_4^-
B. HCO_3^-
C. SO_4^{2-}
D. H_2CO_3

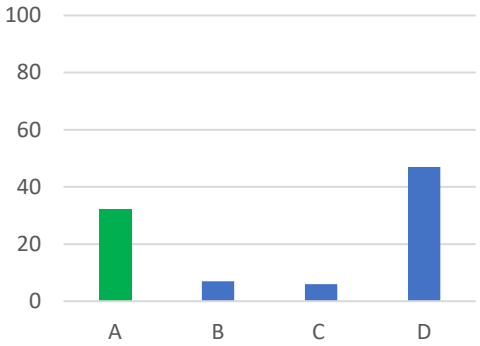
16 Which of the following species would have the highest K_a?

A. HSO_4^-

B. HCO_3^-

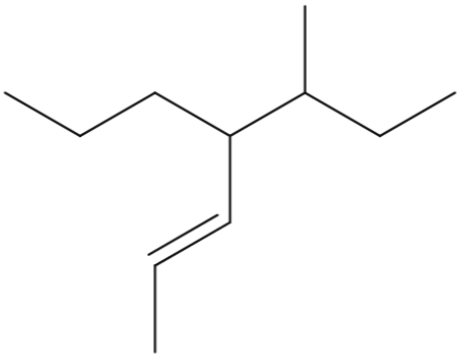
C. SO_4^{2-}

D. H_2CO_3



Read the stem carefully.

17 What is the IUPAC name of the following compound?



A. 5-methyl-4-propylhept-2-ene

B. 5-ethyl-4-propylhex-2-ene

C. 3-methyl-4-propylhept-5-ene

D. 2-ethyl-3-propylhex-4-ene

18 The table below shows the conductivity of a range of 0.01 mol L^{-1} solutions.

Solution	Conductivity (S m^2)
HBr	411
KOH	257
HCOOH	43
NH_3	11
H_3BO_3	0.14

Using the table above, which of the following statements is correct?

A. KOH is a stronger acid than HCOOH.

B. H_3BO_3 has low conductivity because it is triprotic.

C. HBr has a high degree of ionisation.

D. The OH^- ions are better conductors than H_3O^+ ions.

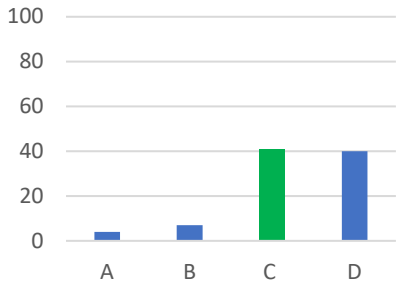
19 Which of the following compounds has the lowest molar solubility in water?

A. Barium nitrate

B. Calcium hydroxide

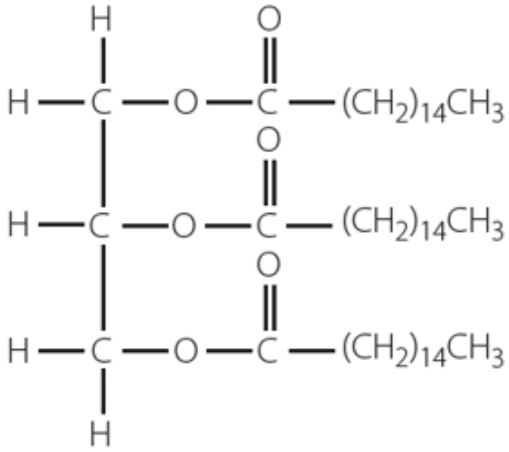
C. Iron (III) phosphate

D. Magnesium phosphate



Magnesium phosphate has the lowest Ksp BUT in order to compare this ionic compounds you must find s using their Ksp expressions (which are different due to the stoichiometric ratio of their constituent ions)

20 The esters of glycerol (propan-1,2,3-triol), which can be referred to as fats or oils, can be used to make soaps. This is done by reacting the ester functional groups with hydroxide ions to form glycerol and the carboxylate ions. The diagram below shows the structural formula of a particular fat used to make soap.



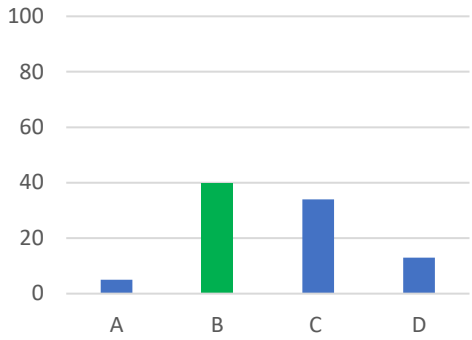
A student dissolved 8.0 g of sodium hydroxide in 50 mL of water and then added 10 g of the fat shown above. After the reaction mixture was heated, the soap product was extracted and found to weigh 6.45 g. The percentage yield in this process is closest to

A. 53%

B. 62%

C. 65% (% mass of soap from mass of fat)

D. 68% (leaving out Na from soap molar mass)



$C_{51}H_{98}O_6 + 3NaOH \rightarrow C_3H_5(OH)_3 + 3NaC_{16}H_{31}O_2$

$n(NaOH) = 8.0 / (22.99+16+1.008) = 0.2000\ldots mol$

$n(C_{51}H_{98}O_6) = 10 / (51 \times 12.01 + 98 \times 1.008 + 16 \times 6) = 0.01238\ldots mol$

theoretical $n(NaC_{16}H_{31}O_2) = 0.01238\ldots \times 3 = 0.03716\ldots$ mol

expt $n(NaC_{16}H_{31}O_2) = 6.45 / (22.99 + 16 \times 12.01 + 31 \times 1.008 + 2 \times 16) = 0.02316\ldots$ mol

yield = $(0.02316\ldots / 0.03716\ldots) \times 100$

Section II

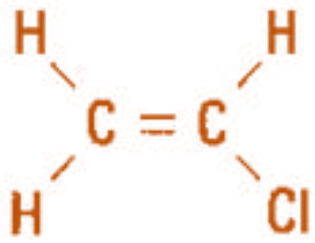
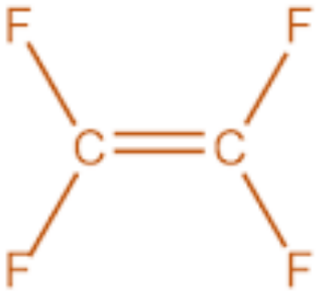
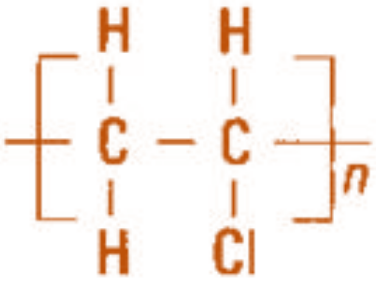
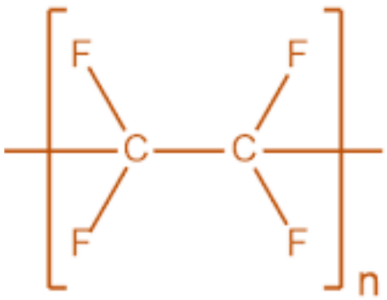
80 marks

Attempt Questions 21 – 34. Allow about 2 hours and 25 minutes for this section.

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response. Show all relevant working in questions involving calculations. If needed, extra writing space is available on pages 30 – 32.

Question 21 (4 marks)

Complete the following table. **4**

	Polyvinyl chloride	Polytetrafluoroethene
Monomer structural formula		
Polymer structural formula		
Property	e.g. strong, high melting point, flexible	e.g. non-stick, high melting point, waterproof
Use	e.g. water pipes, wire covering, raincoat, floor tiles	e.g. non-stick frying pans, waterproof fabric

Question 22 (4 marks)

A student mixed 500.0 mL of a 0.00123 mol L^{-1} solution of FeF_2 with 500.0 mL of a 0.00314 mol L^{-1} solution of KOH at 25ºC. **4**

Using calculations, determine if a precipitate will be formed from the mixture.

(n) 1 mark calculates number of mol for Fe^{2+} and OH^-

$n(Fe^{2+}) = 0.00123 \times 500.0 \times 10^{-3} = 0.000615$ mol

$n(OH^-) = 0.00314 \times 500.0 \times 10^{-3} = 0.00157$ mol

Note: c = n since in 1 L

(e) 1 mark Ksp or Q expression

$Ksp = [Fe^{2+}][OH^-]^2$

(q) 1 mark calculates Q (or longwinded approach using molar solubility) – did not award this mark if concentrations were substituted into Ksp

$Q = [0.000615][0.00157]^2 = 1.51 \times 10^{-9}$

(p) 1 mark determines if a ppt will form using above AND correct value from data sheet

Since $Ksp = 4.87 \times 10^{-17}$, Q > Ksp so a precipitate will form.

Common errors:

- Substituting concentrations using limiting reagent into Q
- Using Ksp value for lead hydroxide

Question 23 (4 marks)

a) Outline ONE advantage and ONE disadvantage of biofuels when compared to fossil fuel alternatives. **2**

Criteria	Mk
- Outlines ONE advantage and ONE disadvantage	2
- Outlines ONE advantage or disadvantage OR - Identifies ONE advantage and ONE disadvantage e.g. biofuels are more expensive and renewable	1

Advantage e.g.

- Made from renewable resources such as plant material that can be regrown
- Less incomplete combustion so less likely to produce carbon monoxide and soot emissions
- More biodegradable so less harm caused to the environment

Note: biofuels do NOT produce less carbon dioxide (it is the NET production that is lower due to carbon dioxide having been removed during the growth of the crops)

Disadvantage e.g.

- Lower heat of combustion or energy released per gram i.e. less energy efficient
- Slow reaction rate/refining process uses lots of energy/production cost ➔ could be expensive
- Requires food crops to be grown ➔ food shortages or land usage
- Incompatible with some vehicles; engine modifications needed

b) Outline ONE economic and ONE environmental implication of obtaining and/or using hydrocarbons. **2**

Criteria	Mk
- Outlines ONE economic and ONE environmental implication of obtaining and/or using hydrocarbons	2
- Outlines ONE economic OR ONE environmental implication of obtaining and/or using hydrocarbons OR - Identifies ONE economic and ONE environmental implication of obtaining and/or using hydrocarbons	1

Economic implications e.g.

- oil industry employs millions of people worldwide, providing stable jobs and incomes
- oil industry contributes significant taxes to the host country
- technological expansion; mass manufacturing; globalisation; industrialisation

Note: yes, costs are involved with the obtaining hydrocarbons but what is the overall economic impact?

Environmental implications e.g.

- oil spills can damage nearby ecosystems/organisms
- extracting hydrocarbons requires land clearing which can also damage ecosystems
- burning hydrocarbons produces a lot of harmful emissions that pollute the atmosphere

Note: CO_2 does not lead to acid rain or damage to the ozone layer

Question 24 (6 marks)

Sodium hydroxide reacts with the weak oxalic acid according to the following equation.

$$2NaOH(aq) + H_2C_2O_4(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

a) Explain why solutions of sodium oxalate are basic. Support your answer with a relevant chemical equation. **2**

1 mark provides the following chemical equation (this is the most relevant one!)

$C_2O_4^{2-}(aq) + H_2O(l) \rightarrow HC_2O_4^-(aq) + OH^-(aq)$

Note: accepted production of $H_2C_2O_4$ but better to use the above!

1 mark explanation (must acknowledge the Na^+ - though this alone does not warrant a mark) e.g.

Na^+ are spectator ions and therefore have no impact on pH. However, the oxalate ion is able to hydrolyse water and produce hydroxide ions, resulting in a basic solution.

Note:

- Avoid saying Na^+ are neutral
- $C_2O_4^{2-}$ is NOT the conjugate of $H_2C_2O_4$ (no marks gained for saying this; mentioning this also restricted your answer to a 1 out of 2)

b) A student wants to determine the concentration of a sample of oxalic acid using a standardised solution of sodium hydroxide. The student is provided with the following indicators. **2**

Indicator	*Colour Change*	*pH range over which colour changes*
Bromocresol green	yellow-blue	3.8 – 5.4
4-nitrophenol	colourless-yellow	5.7 -7.6
phenolphthalein	colourless-pink	8.3 – 10.0

Using the table above, determine the most appropriate indicator for this titration and justify your choice.

1 mark determines most appropriate indicator i.e. phenolphthalein

1 mark justification (MUST link to the data) e.g. this titration is between a strong base and a weak acid, resulting in a basic salt being produced. Therefore, at the equivalence point, the pH of the solution will be >7, corresponding to the pH range (8.3 – 10.0) for phenolphthalein.

Comments:

- Insufficient to say 'the solution is basic' – what solution??
- End point and equivalence point are NOT interchangeable

c) Provide chemical equations to show the amphiprotic nature of the hydrogen oxalate ion. **2**

1 mark per correct equation

$HC_2O_4^-(aq) + OH^-(aq) \rightarrow C_2O_4^{2-}(aq) + H_2O(l)$

$HC_2O_4^-(aq) + H_3O^+(aq) \rightarrow H_2C_2O_4(aq) + H_2O(l)$

Mistake carried for using H_2O or $H_2C_2O_4$

Question 25 (7 marks)

Benzoic acid, C_6H_5COOH, is used as a preservative in certain foods to prevent the growth of moulds. This acid has a K_a value of 6.5×10^{-5} at 25°C.

a) How many grams of benzoic acid are needed to prepare 1.0 L of a solution with a pH of 2.80 at 25°C? **4**

1 mark calculates $[H_3O^+]$

$[H_3O^+] = 10^{-2.80} = 0.001584\ldots$ mol L^{-1}

1 mark calculates $[C_6H_5COOH]$eqm

$K_a = [C_6H_5COO^-][H_3O^+]/[C_6H_5COOH] = 6.5 \times 10^{-5}$

$[0.001584\ldots][0.001584\ldots]/[C_6H_5COOH] = 6.5 \times 10^{-5}$

$[C_6H_5COOH]eqm = [0.001584\ldots][0.001584\ldots]/6.5 \times 10^{-5} = 0.03864\ldots$ mol L^{-1}

1 mark calculates $[C_6H_5COOH]$initial

$[C_6H_5COOH]initial = 0.03864\ldots + 0.001584\ldots = 0.04018\ldots$ mol L^{-1}

1 mark calculates mass of C_6H_5COOH

$m(C_6H_5COOH) = 0.04018\ldots \times (7 \times 12.01 + 6 \times 1.008 + 2 \times 16.00) = 4.90$ g

Mark deduction for units (no one got this deduction!

b) A solution of benzoic acid and sodium benzoate was made at 25°C and was measured to have a pH of 4.48. When NaOH was added to the solution, there was little change to the pH. This was also observed when HCl was added. Using a relevant chemical equation, explain these observations. **3**

Criteria	Mark
• Correct equation(s) with phase descriptors • Explains effect of addition of OH- and H3O+ • Links to minimal change in pH	3
• Correct equation(s) with phase descriptors • Explains effect of either OH- or H3O+ OR • Explains effect of addition of OH- and H3O+ but does not link to minimal change in pH	2
• Some relevant information	1

$C_6H_5COOH(aq) + H_2O(l) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$

When NaOH is added, the hydroxide ions react with the hydronium ions in the buffer system, decreasing its concentration. As a result, the system shifts to the right to minimise the disturbance. Therefore, there is little change to the pH.

When HCl is added, hydronium ion concentration of the system increases. As a result, the system shifts to the left to minimise the disturbance. Therefore, there is little change to the pH.

Also accepted:

$C_6H_5COOH(aq) + OH^-(aq) \rightleftharpoons C_6H_5COO^-(aq) + H_2O(l)$

$C_6H_5COO^-(aq) + H_3O^+(aq) \rightleftharpoons C_6H_5COOH(aq) + H_2O(l)$

If you used both/either of these eqns, you had to say that there was minimal pH change due to the consumption of the H+/OH- ions, not because the reactions produce water etc.

Question 26 (3 marks)

The pH of the oceans has been maintained by the following equilibria. **3**

1. $CO_2(g) \rightleftharpoons CO_2(aq)$
2. $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3\ (aq)$
3. $H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

Since the start of the industrial age, the pH of the oceans has been decreasing. It is estimated that the pH of the ocean will fall from 8.14 to 7.90 over the next 50 years.

Using the equations provided, explain how the combustion of fossil fuels is responsible for the change in pH of the ocean.

1 mark links combustion of fossil fuels to $[CO_2]$

Combustion of fossil fuels releases carbon dioxide into the atmosphere, resulting in an increase in $[CO_2(g)]$.

1 mark links the above to changes to the position for ALL three equilibria

Note: some did not achieve this mark as the shifting of eqm/increase in yield was not mentioned. If you do not talk about how eqm shifts, you are essentially just stating the equation…

This increase in $[CO_2(g)]$ causes the system to favour the forward reaction for reaction 1, increasing $[CO_2(aq)]$. As a result, reaction 2 also shifts to favour the forward reaction, increasing $[H_2CO_3(aq)]$. Finally, for reaction 3, the forward reaction is also favoured to minimise the disturbance, resulting in an increase in $[H_3O^+]$.

1 mark links the increase in H_3O^+ to pH

Due to increasing $[H_3O^+]$, pH of the ocean has fallen.

Question 27 (6 marks)

The equilibrium between two different coloured Co(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, has been used by ecologists in qualitative tests to determine water content in soil.

Solutions of cobalt chloride are pink, due to the formation of the complex ion, $[Co(H_2O)_6]^{2+}$. The equilibrium equation is shown below.

$$\underbrace{CoCl_4^{2-}(aq)}_{\text{blue}} + 6H_2O(\ell) \rightleftharpoons \underbrace{Co(H_2O)_6^{2+}(aq)}_{\text{pink}} + 4Cl^-(aq)$$

a) Using Le Chatelier's Principle, explain the change in colour if drops of concentrated HCl were added to the system. **2**

1 mark explanation using LCP

As HCl is added, $[Cl^-]$ increases and the system will shift to decrease this by favouring the reverse reaction.

1 mark identifies colour change **and** increase in blue ion

As a result, the **$[CoCl_4^{2-}]$ increases** and solution would become **more blue/purple** in colour.

Question 27 continues on the next page.

b) In a second experiment, a solution of cobalt chloride was prepared and separated into three test tubes. One test tube was placed in a beaker of water at room temperature, while the other two were placed in a beaker of ice water and a beaker of hot water, respectively. The following observations were made. **4**

	Ice water	**Room temperature**	**Hot water**
Colour of solution	pink	purple	blue

Using your understanding of collision theory, explain the observations above.

1 mark relates effect of temperature on KE of particles and collisions

When temperature increases, kinetic energy of all the particles in the system increases, resulting in more frequent, successful collisions (more collisions with energy > E_A).

1 mark explicitly identifies that the rate of BOTH the forward and reverse reaction would change with change in temperature

Therefore, the rate of both the forward and reverse reactions will increase.

1 mark explains why the endothermic reaction is impacted more

The proportional increase in rate of reaction is **greater for the endothermic reaction** as it has a greater activation energy, resulting in the endothermic reaction being favoured.

Similarly, when temperature decreases, rate of both the forward and reverse reaction decreases, but the endothermic reaction has a **larger proportional decrease**, so the exothermic reaction is favoured.

1 mark links the above to the observations, including stating whether exothermic/endothermic

The reaction mixture appears blue when heated, indicating that the reverse reaction is favoured when temperature is increased. This is due to the reverse reaction being endothermic. When cooled, the solution turns pink as the forward reaction is favoured because it is exothermic.

Common mistakes:

- Endothermic reaction is ALWAYS affected more by the increase/decrease in temp. Some students got this correct to then contradict themselves later in their response
- The purple soln is not purple because it is at equilibrium. It just means the blue and pink ion are present in equal concs
- One reaction does not stop just because the other is favoured
- Concentration of reactants and products does not affect changes in eqm due to temperature. This is all about E_A and whether the reaction is endothermic/exothermic

Question 28 (5 marks)

150.0 mL of a 0.564 mol L^{-1} barium hydroxide solution was placed in a well-insulated beaker. The temperature of the solution was 20.3ºC. Subsequently, 400 mL of a 1.25 mol L^{-1} nitric acid solution was placed in another beaker and brought to the same temperature. The two solutions were then mixed, and the final maximum temperature was recorded to be 23.7 ºC. Assume that the density of the solutions was 1.00 g mL^{-1}.

a) Calculate the molar enthalpy of neutralisation. **3**

(q) 1 mark calculates q

$q = m\ c\ \Delta T = (150.0 + 400) \times 10^{-3} \times (23.7 - 20.3) \times 4.18 \times 10^{-3} = 7816.6$ J

(n) 1 mark calculates n(reactants) available

$Ba(OH)_2 + 2HNO_3 \rightarrow Ba(NO_3)_2 + 2H_2O$

$n(Ba(OH)_2) = 0.564 \times 0.150 = 0.0846$ mol ===> limiting reagent

$n(HNO_3) = 1.25 \times 0.4 = 0.5$ mol

(H) 1 mark calculates molar enthalpy

$n(H_2O) = 0.0846 \times 2 = 0.1692$ mol

$\Delta H = -(7816.6 \times 10^{-3}) / 0.1692 = -46.197\ldots = -46.2$ kJ mol^{-1}

Mark deduction for sig figs

Common error:

- absence of negative sign
- stoich ratio to determine $n(H_2O)$

b) A student repeated this experiment with the same volume and concentration of barium hydroxide solution, but this time used 400 mL of 1.25 mol L^{-1} hydrochloric acid. The initial temperature of the solutions was once again 20.3°C. **2**

Predict if the final temperature would be higher, lower or the same as the original reaction and justify your response.

1 mark identifies final temperature will be the same

1 mark justification (MUST acknowledge strength of acid AND n(H_2O) produced) e.g.

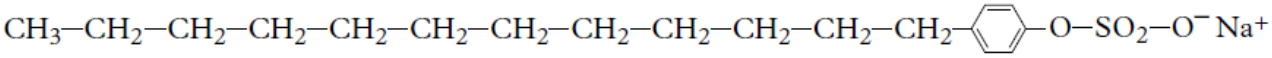
HCl is a **strong** and monoprotic acid like HNO_3 so will be completely dissociated in solution and the quantity used will produce the **same number of moles of water**. This means the energy released when forming the molecules of water will be the same.

Common error:

- Not explicitly addressing **strength** OR **n(H_2O)**
- Nitric acid is strong! ➔ mark deduction for incorrect chemistry

Question 29 (5 marks)

Sodium laurylbenzene sulfonate is used as a detergent in cleaning products and in pesticides. Its structure is shown below. **5**



With reference to its structure, explain the cleaning action of sodium laurylbenzene sulfonate.

1 mark identifies long hydrocarbon chain as non polar

1 mark identifies O-SO2-O- / sulfonate group as anionic/polar

1 mark identifies that sodium laurylbenzene sulfonate will dissociate in water to produce laurylbenzene sulfonate ions

1 mark relates structure to interactions with oil and water i.e. non polar region can dissolve in oil and polar region can dissolve in water

1 mark relates the above to formation of micelles that lift/suspend oil particles in water to be washed away

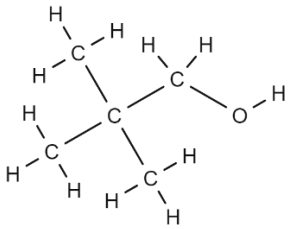
Examiners Comments:

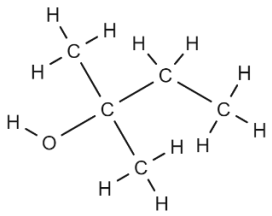
Many candidates omitted to state that sodium laurylbenzene sulfonate will dissociate in water.

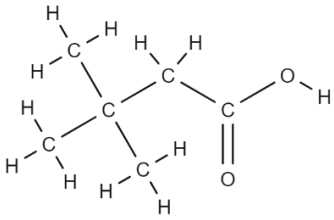
Some candidates referred to polar or hydrophilic ends/heads without identifying which part of the molecule this was.

Question 30 (9 marks)

The structural formulae for Compound A, B and C are shown below.

A 

B 

C 

a) Describe how you could distinguish between the compounds featured above using simple reactions in a school laboratory. Include relevant reagents and observations in your response. **4**

2 marks reagent and observations distinguish between tertiary and primary alcohol

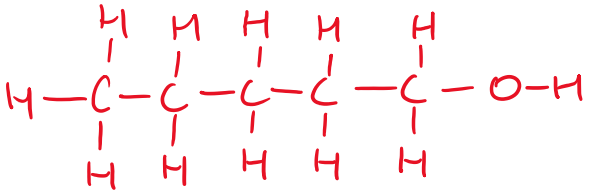
2 marks reagent and observations distinguish between alcohols and acid

Examiner's Comment : Some candidates attempted to name Compounds A & B if nomenclature was incorrect a Mark was deducted, please note students were not asked to name compounds.

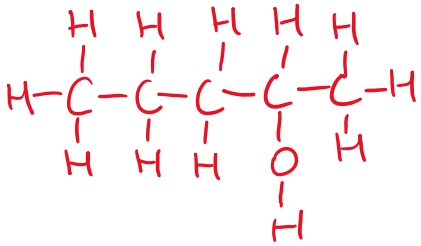
Question 30 continues on the next page.

b) Compounds A and B are isomers. Draw FIVE other isomers of this compound and provide their IUPAC names. **5**

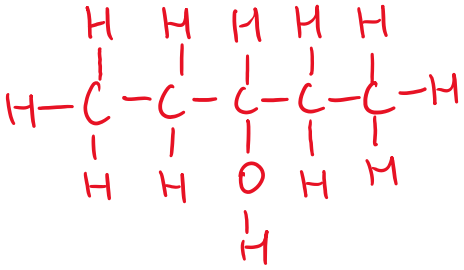
Examiner's Comment : Some candidates provided the structure and name of Compound B.



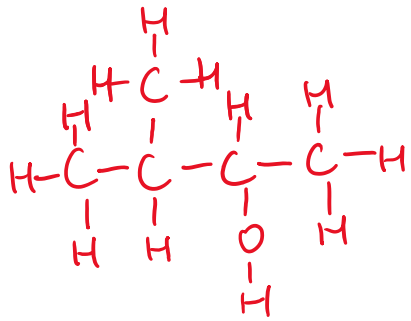
pentan-1-ol



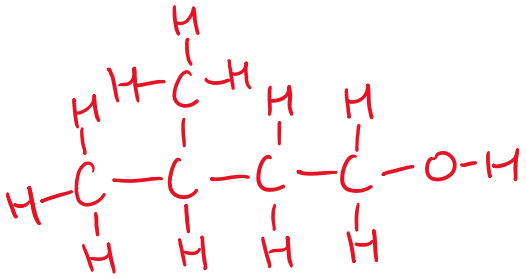
pentan-2-ol



pentan-3-ol



3-methylbutan-2-ol



3-methylbutan-1-ol

Criteria	Mk
5 correctly drawn isomers and corresponding IUPAC names	5
AT LEAST 4 correct isomers and 4 correct IUPAC names	4
AT LEAST 3 correct isomers and 3 correct IUPAC names	3
AT LEAST 2 correct isomers and/or 2 correct IUPAC names	2
1 correct isomer or name	1

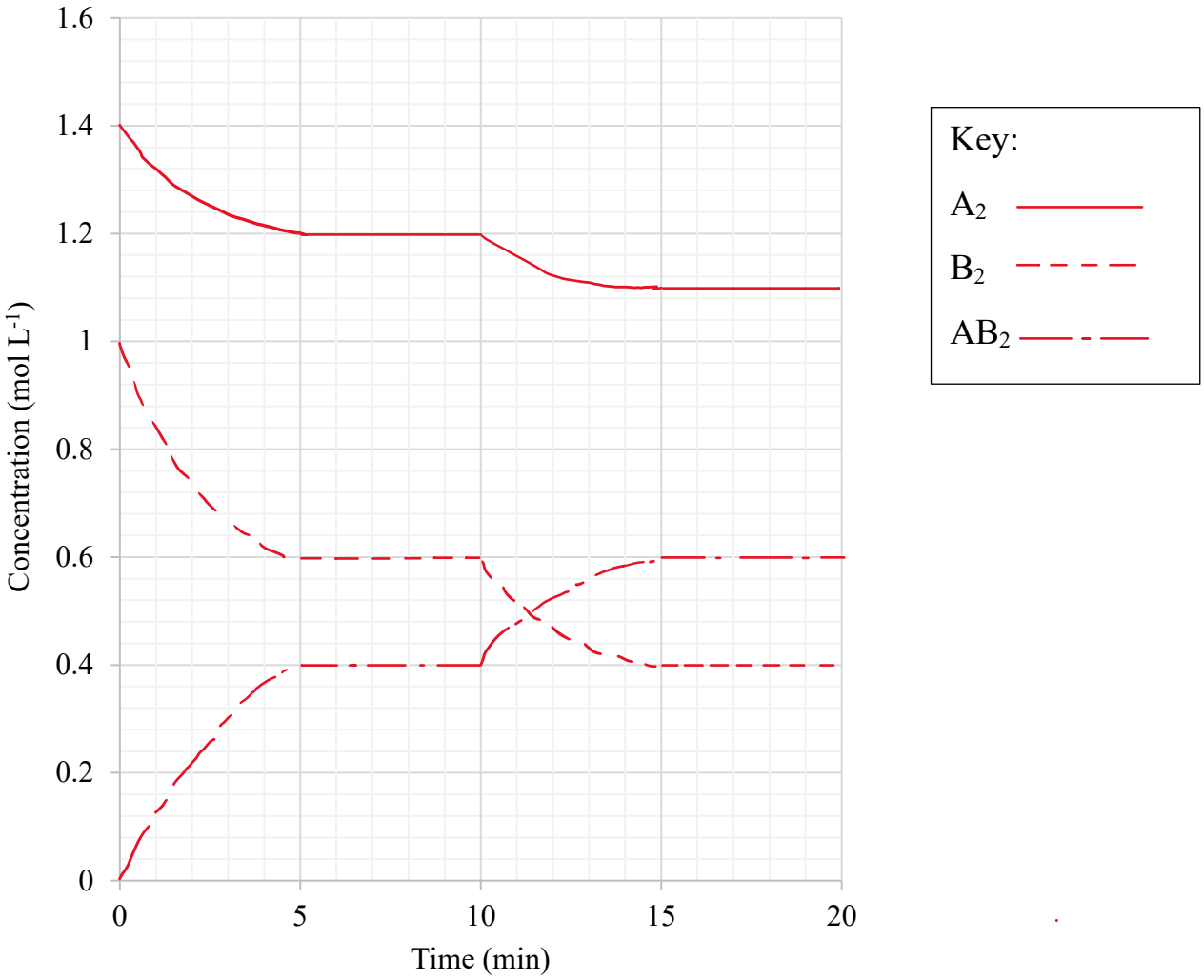
Question 31 (6 marks)

Gases A_2 and B_2 react according to the equation below.

$$A_2(g) + 2B_2(g) \rightleftharpoons 2AB_2(g) \qquad \Delta H < 0$$

A mixture of A_2 and B_2 was placed into a sealed vessel. The initial concentration of A_2 was 1.4 mol L^{-1} and the initial concentration of B_2 was 1.0 mol L^{-1}. At 5 minutes, the system had reached equilibrium where the concentration of A_2 was 1.2 mol L^{-1}. The system remained at equilibrium until at 10 minutes, the temperature of the system was reduced. At 15 minutes, the system re-established equilibrium.

a) On the graph below, complete the key and draw a trendline for each of the chemical species involved in this equilibrium to show their changes in concentrations over time. **4**



Question 31 continues on the next page.

1 mark per region of graph

In 0 to 5 min gradient should be concave up for A_2 and B_2 to indicate slowing rate of reaction and concave up for AB_2.

In 10 to 15 min stoichiometric ratio of change in products and reactants to be correct

Mark deduction for missing or incorrect key or for sudden jump or rise (vertically) of products or reactants.

b) Calculate the K_{eq} at 7 minutes. **2**

1 mark intrapolates correct data (mistake carried based on trendline)

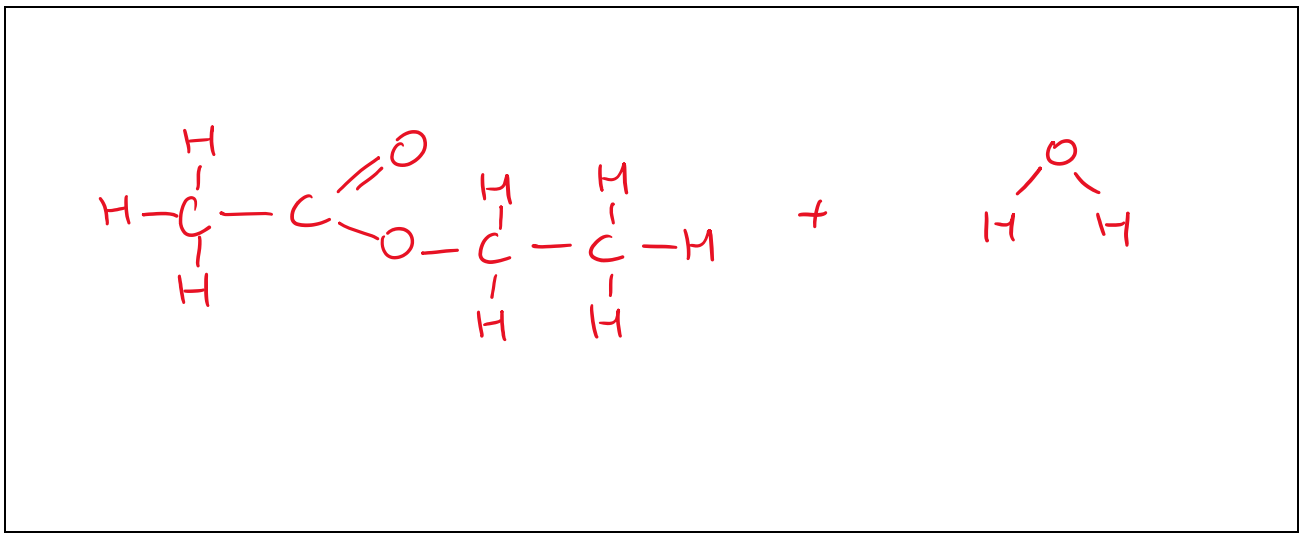
1 mark correction substitution into Keq

$K = [AB_2]^2 / [A_2][B_2]^2 = [0.4]^2 / [1.2][0.6]^2 = 0.37037\ldots = 0.4$

Question 32 (9 marks)

0.050 mol of ethanoic acid was reacted with 0.050 mol of ethanol in 100 mL of solution at a certain temperature. The reaction mixture was then cooled, and the excess ethanoic acid was titrated needing 34 mL of 0.50 mol L^{-1} NaOH for neutralisation.

a) Draw the structural formulae of the products formed in the reaction between ethanoic acid and ethanol. **2**



b) What reagent could be added to act as a catalyst for this reaction? **1**

Concentrated sulfuric acid

c) Identify a laboratory technique that could be used to help this reaction reach equilibrium quicker and provide another advantage of using this technique. **2**

1 mark identifies the technique i.e. reflux

1 mark provides another advantage e.g. keeps volatile reactants in the reaction vessel

Question 32 continues on the next page.

d) Calculate the equilibrium constant for this reaction. **4**

1 mark calculates n(NaOH) and n(CH_3COOH)

n(NaOH) = 34 x 10^{-3} x 0.5 = 0.017 mol

n(CH_3COOH) = 0.017 x 1/1 = 0.017 mol

1 mark calculates [CH_3COOH]eqm, [CH_3COOH]initial and [C_2H_5OH]initial

[CH_3COOH]eqm = 0.017 / 100 x 10^{-3} = 0.17 mol L^{-1}

[CH_3COOH]initial = [C_2H_5OH]initial = 0.05 / 0.1 = 0.5 mol L^{-1}

1 mark calculates remaining eqm [ ]s

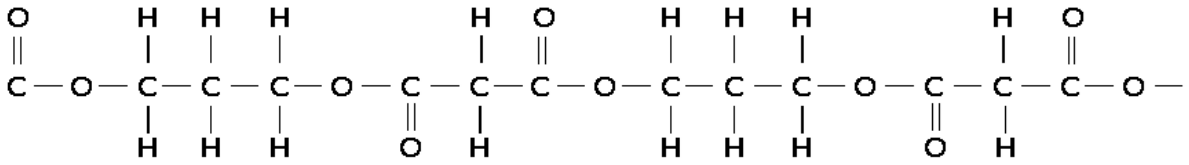
	CH_3COOH	+	C_2H_5OH	➔	$CH_3COOC_2H_5$	+	H_2O
I	0.5		0.5		0		-
C	-x		-x		+x		-
E	0.17		0.17		0.33		-

1 mark calculates Keq

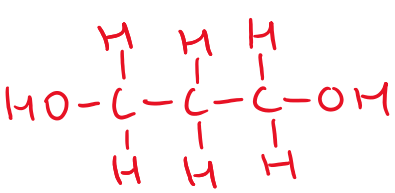
K = [$CH_3COOC_2H_5$] / [CH_3COOH][C_2H_5OH] = [0.33]/[0.17]^2 = 11.418… = 11

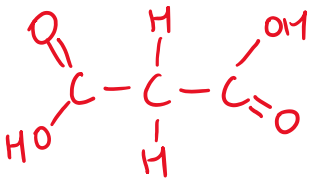
Question 33 (5 marks)

The following structural diagram shows a section of Polymer A



a) Draw the monomers for Polymer A. **2**





b) Determine the molar mass of a section of Polymer A that consists of 40 monomers. **3**

1 mark calculates M(monomer 1) and M(monomer 2) OR repeating section *(mistake carried from part a) ONLY if the numbers match your incorrect monomers)*

1 mark understands 40 monomers = 20 x monomer A + 20 x monomer B *(mistake carried if you drew only one monomer for part a))*

1 mark understands final structure of polymer e.g. removal of water molecules (Method 1), extra H and OH on the ends (Method 2)

Method 1

M(monomer featured on the left) = [12.01 x 3 + 16.00 x 2 + 1.008 x 8] = 76.094

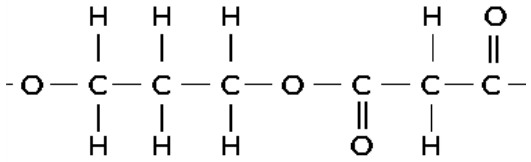
M(monomer featured on the right) = [12.01 x 3 + 16.00 x 4 + 1.008 x 4] = 104.062

M(polymer) = 20(76.094 + 104.062) – 39 x (1.008 x 2 + 16.00) = 2900.496 = 2900 g mol^{-1}

Method 2

M(repeated section i.e. $O(CH_2)_3OCOCH_2COO$) = [12.01 x 6 + 16.00 x 4 + 1.008 x 8] = 144.124

M(polymer) = 20(144.124) + (1.008 + 16.00 + 1.008) = 2900.496 = 2900 g mol^{-1}



add H add OH

also accepted leaving answer as M(polymer) = 20(144.124) due the interpretation of the word ‘section’

Question 34 (7 marks)

Fill in the blanks in the following flow chart. 7

must have H^+ and correct formulae

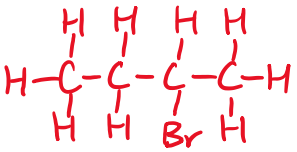
Alternatively: $HBr/Br/Br_2$

but-2-ene

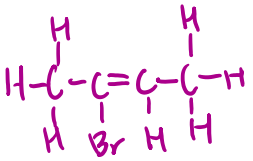
Reagent: HBr

C_4H_7Br

Structural formula:



IUPAC name: 2-bromobutane



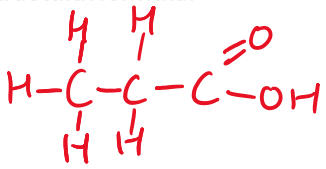
2-bromobut-2-ene

propanal

Reagent: H^+/MnO_4^- or $H^+/Cr_2O_7^{2-}$

$C_3H_6O_2$

Structural formula:

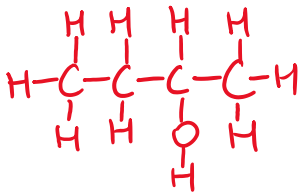


C must be bonded to O

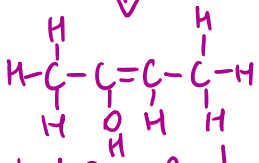
IUPAC name: propanoic acid

$+OH^-$

Structural formula:



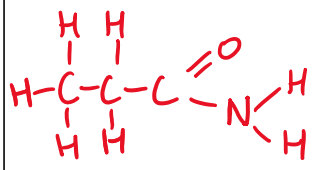
IUPAC name: butan-2-ol



but-2-en-2-ol or butan-2-ol

$+NH_3$

Structural formula:



IUPAC name: propanamide

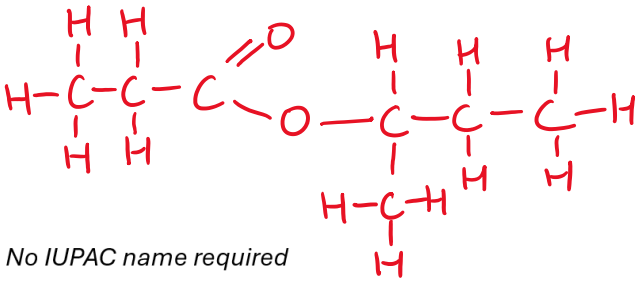
no locant number

-ide not -ine

Reagent: H^+/MnO_4^- or $H^+/Cr_2O_7^{2-}$

butan-2-one

Structural formula:



No IUPAC name required

End of Exam