STUDENT NUMBER: ……..

PENRITH SELECTIVE HIGH SCHOOL

HSC CHEMISTRY 2024

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

PART A

Multiple Choice (20)

- Attempt Questions 1 – 20
- Allow about 30 minutes
- Provide responses on the Multiple Choice Answer Sheet

PART B

Written response (80)

- Attempt Questions 21 – 35
- Allow 2 hrs and 30 minutes

TOTAL: / 100

THIS EXAM PAPER MUST BE SUBMITTED AT THE END OF THE EXAMINATION

PART A - MULTIPLE CHOICE QUESTIONS

1. The oxidation of sulfur dioxide, SO_2, to sulfur trioxide, SO_3, can be represented by the following equation:

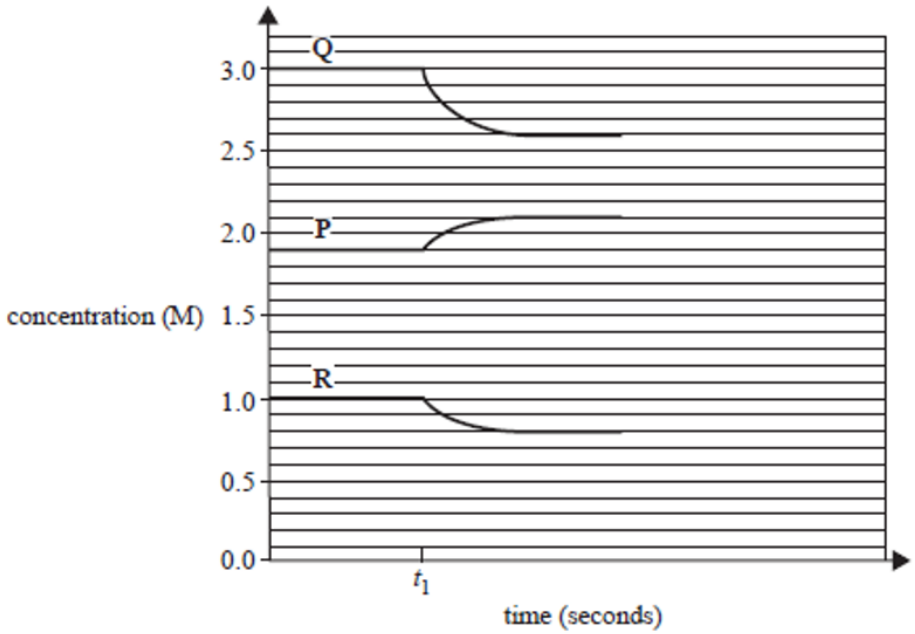
$$2SO_2(g) + O_2(g) \leftrightharpoons 2SO_3(g) \qquad \text{Keq} = 1.75 \text{ at } 1000°C$$

An equilibrium mixture has a concentration of 0.12M SO_2 and 0.16M O_2. The temperature of the container is 1000°C.

The equilibrium concentration of SO_3 at 1000°C is

a) 1.5×10^{-4} M
b) 4.0×10^{-3} M
c) 1.2×10^{-2} M
d) 6.3×10^{-2} M

2. The following concentration-time graph refers to a mixture of three gases, P, Q and R in an enclosed 5L container. At t_1 the mixture is heated.



The equilibrium system that represents the graph is:

a) $P(g) \leftrightharpoons 2Q(g) + R(g)$ and the forward reaction is exothermic
b) $2Q(g) \leftrightharpoons P(g) + R(g)$ and the forward reaction is endothermic
c) $2Q(g) + R(g) \leftrightharpoons P(g)$ and the forward reaction is exothermic
d) $P(g) + 2Q(g) \leftrightharpoons R(g)$ and the forward reaction is endothermic

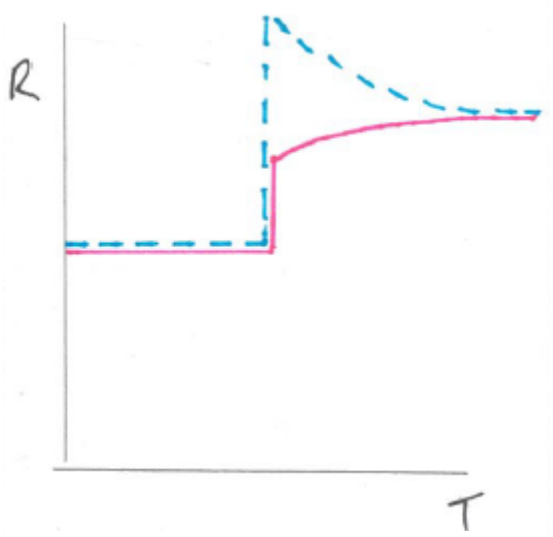
3. The reaction between hydrogen and nitrogen to make ammonia is shown below:

$$3H_2(g) + N_2(g) \leftrightharpoons 2NH_3(g) \qquad \Delta H < 0$$

In a system containing all three gases, if the volume is halved, which of the rate-time graphs shown below represents the system as it establishes a new equilibrium?

Note: The forward reaction is the solid line. The reverse reaction is the dashed line.

a)



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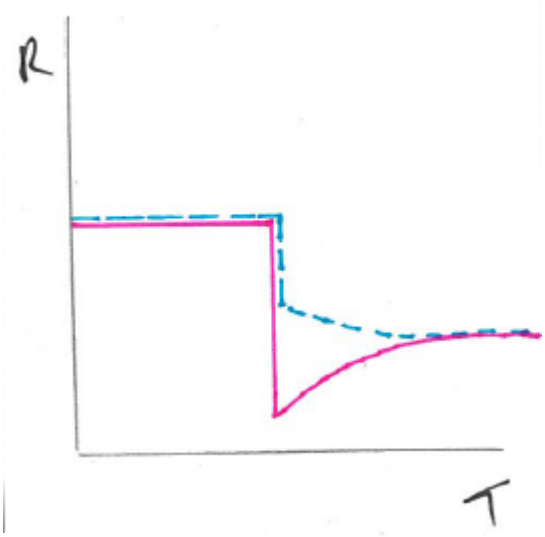

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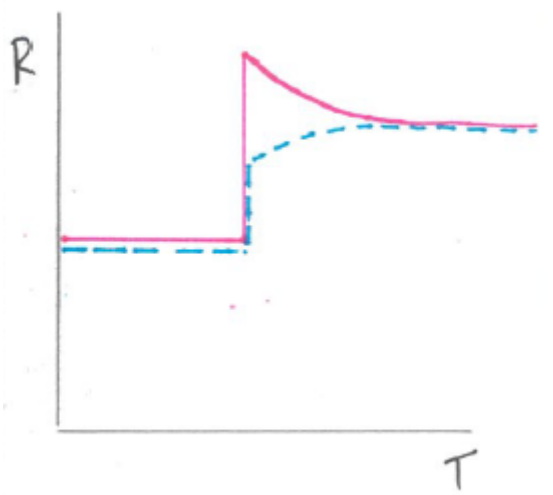

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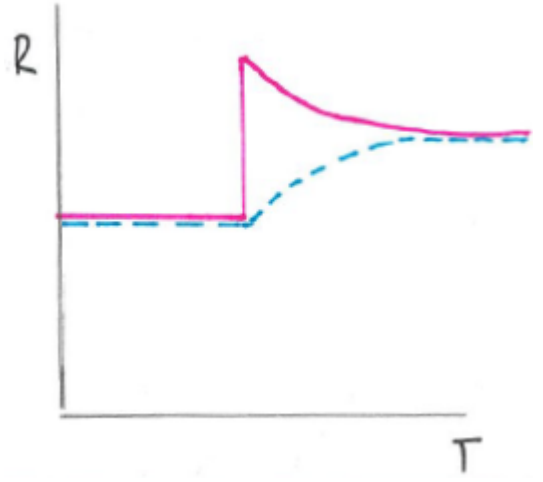


4. For the reaction: $3H_2(g) + N_2(g) \leftrightharpoons 2NH_3(g) \qquad \Delta H < 0$

a) a catalyst increases the number of collisions between the reactants.
b) the rate of the forward and reverse reaction increases when the temperature increases.
c) a catalyst reduces the activation energy of the forward and backward reactions by the same proportion
d) the activation energy of the forward reaction is greater than the activation of the reverse reaction.

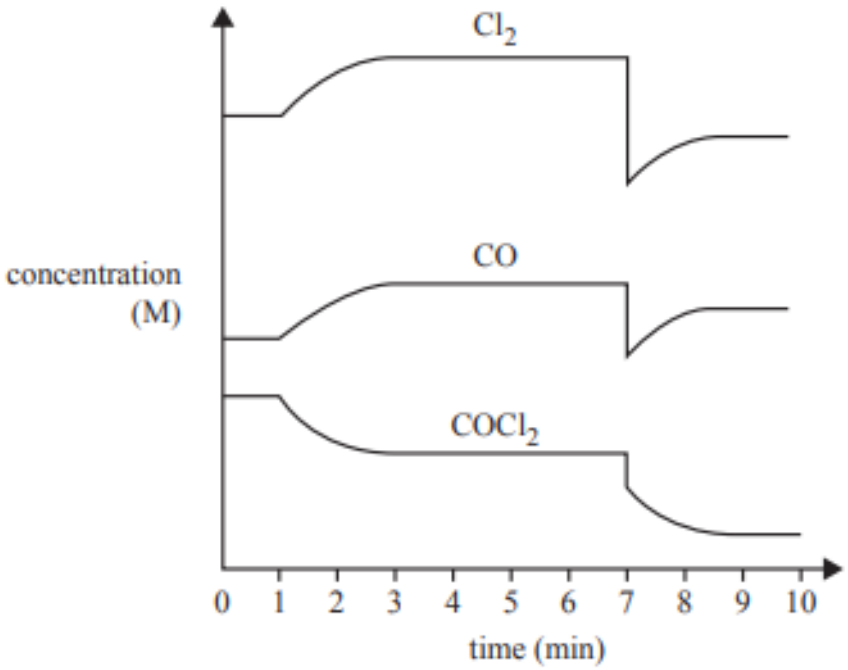
5. In a solution saturated with AgCl, the addition of NaCl causes the concentration of Ag^+ ions to:

   a) increase, because more Cl^- ions are available to react.
   b) decrease, because the common ion effect reduces the solubility of AgCl.
   c) remain unchanged, because NaCl does not contain silver ions.
   d) increase, because the solubility product (Ksp) increases.

6. The following equation represents the reactions between chlorine gas and carbon monoxide.

$$Cl_{2\,(g)} + CO_{\,(g)} \rightleftharpoons COCl_{2\,(g)} \qquad \Delta H = -108\ kJ/mol$$

The concentration-time graph below represents changes to the system.



Which of the following identifies the changes to the system that took place at 1 minute and at 7 minutes?

	1 minute	7 minutes
a)	increase in temperature	increase in volume
b)	decrease in temperature	decrease in volume
c)	decrease in temperature	increase in volume
d)	increase in temperature	decrease in volume

7. Consider the following chemical equations:

$2NO_{2\,(g)} \rightarrow 2NO_{(g)} + O_{2\,(g)}$ $\Delta H = +\ 14\ kJ\ mol^{-1}$

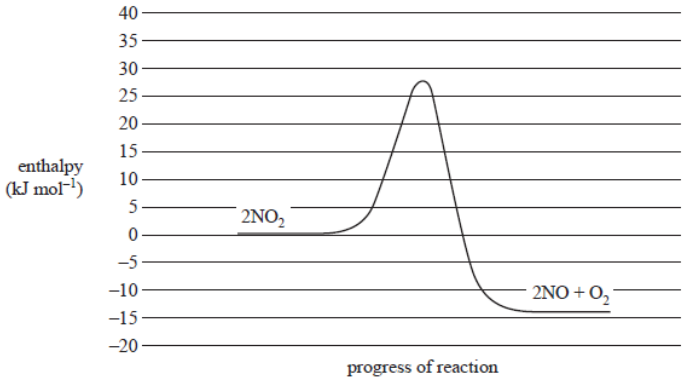
$NO_{2\,(g)} + CO_{(g)} \rightarrow CO_{2\,(g)} + NO_{(g)}$ $\Delta H = -\ 226\ kJ\ mol^{-1}$

$2NO_{2\,(g)} \rightleftharpoons N_2O_{4\,(g)}$ $\Delta H = -\ 57\ kJ\ mol^{-1}$

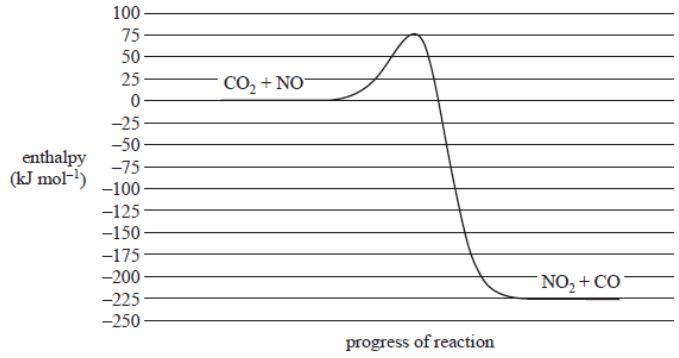
$N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2NO_{(g)}$ $\Delta H = +\ 181\ kJ\ mol^{-1}$

Which of the following graphs is consistent with the chemical equations above?

a)



b)



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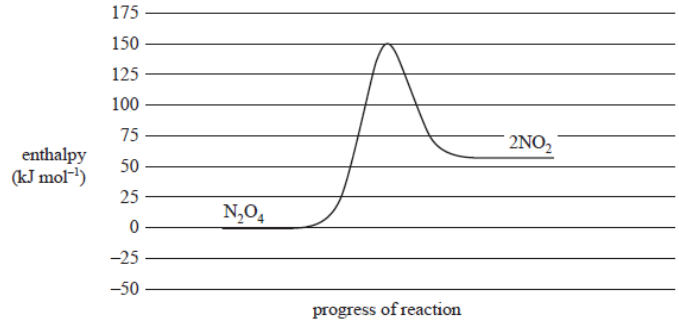

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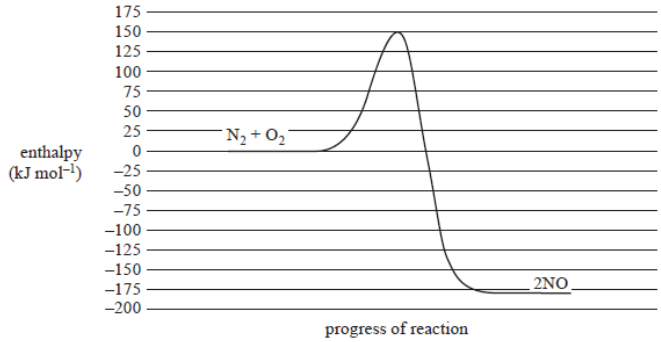


8. Which one of the following statements about 10.0 mL of 0.10 M HCl and 10.0 mL of 0.10 M CH_3COOH solutions is true?

   a) each solution will have the same electrical conductivity.
   b) each solution will react at the same rate with 1.00 g of magnesium ribbon.
   c) the concentration of H_3O^+ ions will be greater in the CH_3COOH solution.
   d) each solution will react completely with 10.0 mL of 0.10 M NaOH solution.

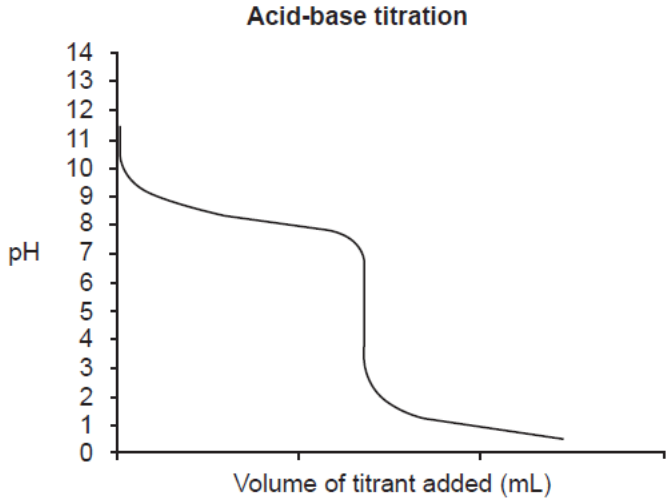
9. In an acid-base titration, which of the following is most likely to cause an error in the calculated concentration?

   a) measuring the volume at the top of the meniscus
   b) rinsing the burette with the titrant before the titration
   c) removing the funnel from the burette after filling before titration
   d) having the same member of the experimental team read the measurement on the burette

10. The equivalence point in an acid-base titration is the point at which the

    a) pH of the solution is 7
    b) indicator changes colour
    c) volume of acid equals the volume of base
    d) mole ratio of acid to base is equal to their stoichiometric ratio

11. For the titration curve given below, choose the most appropriate indicator.

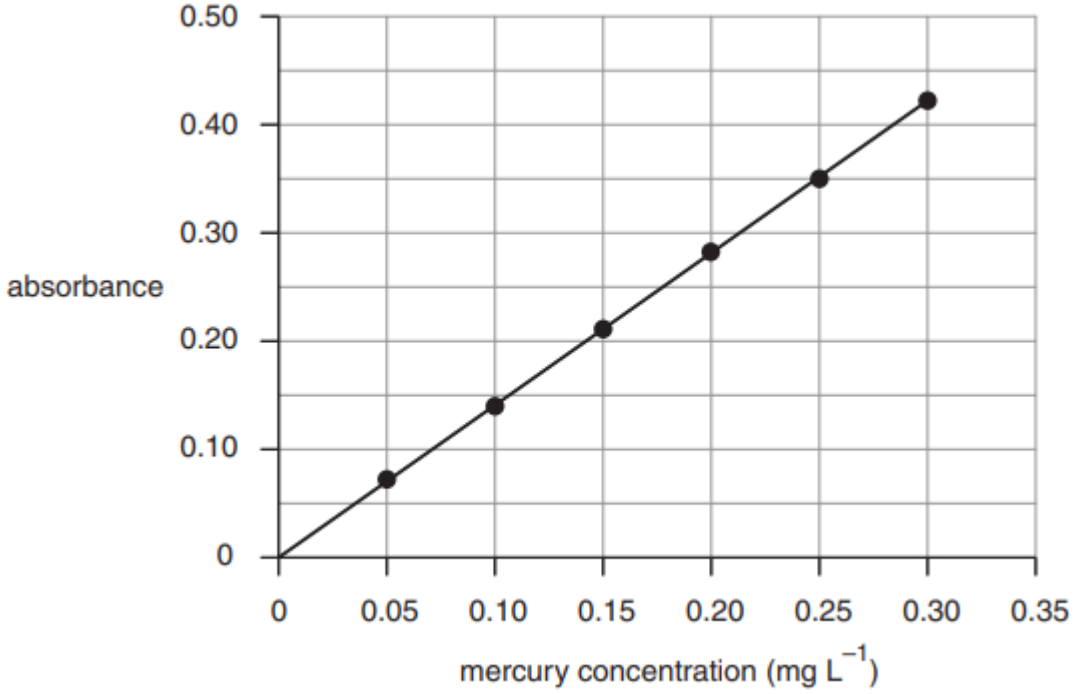


	Indicator Name	Indicator Range
a)	Methyl Yellow	2.1 – 3.3
b)	Bromocresol Green	3.8 – 5.4
c)	Bromothymol Blue	6.0 – 7.6
d)	Alzarine Yellow R	10.2 – 12.0

12. Which one of the following underlined species is acting as an acid?

a) $\underline{CH_3CH_2CH_2CH_2NH_2} + CH_3COOH \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+ + CH_3COO^-$
b) $HSO_3^- + NH_3 \rightleftharpoons \underline{SO_3^{2-}} + NH_4^+$
c) $NH_4^+ + CH_3COO^- \rightleftharpoons \underline{NH_3} + CH_3COOH$
d) $\underline{[Fe(H_2O)_6]^{3+}} + H_2O \rightleftharpoons [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$

13. Soil samples were taken from an industrial site where mercury was used in a chemical industry. Each sample was treated to release any mercury present into solution. Each solution was analysed by Atomic Absorption Spectroscopy (AAS) to determine the mercury concentration using the following calibration graph.



The absorbance of one solution from a soil sample was 0.58. The following suggestions were made to overcome the inadequacy of the calibration graph.

I Extend the graph so that the absorbance of 0.58 has a corresponding mercury concentration

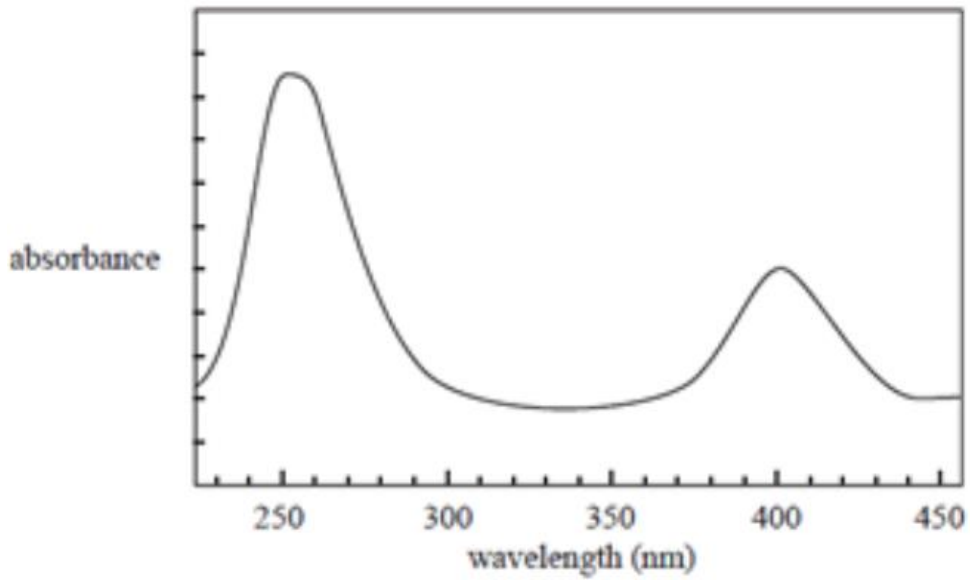
II Construct another calibration graph using more standard solutions so that the absorbance 0.58 has a corresponding mercury concentration

III Dilute the solution from the soil sample and calculate the mercury concentration by taking the dilution into account.

Which of these actions could be taken to produce an accurate result?

a) I or II only
b) II or III only
c) I or III only
d) I, II or III

14. The UV-visible spectrum of a solution of a certain compound is shown below.



Consider the following statements about this compound and its UV-visible spectrum.

I The amount of light absorbed by a solution of this compound depends on its concentration

II The amount of light absorbed by a solution of this compound depends on the wavelength of light

III The spectrum is a result of electrons falling back from higher to lower electronic energy levels

IV The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at 250 nm.

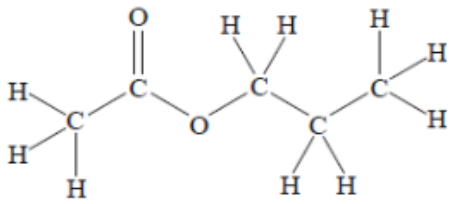
Which of the above statements are TRUE?

a) I and II
b) II and III
c) I, II and III
d) I, II and IV

15. Which of the following techniques is used to distinguish between 1,1,1-trichloropropane and 1,2,3-trichloropropane?

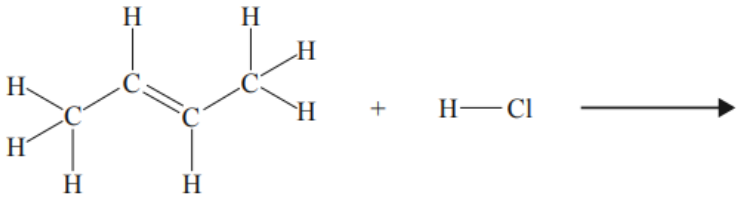
a) Atomic absorption spectroscopy
b) UV-visible spectroscopy
c) Proton-NMR spectroscopy
d) Gravimetric analysis

16. The systematic IUPAC name for the molecule shown below is



a) Ethyl ethanoate
b) Ethyl propanoate
c) Propyl ethanoate
d) Methyl propanoate

17. The systematic IUPAC name for the product formed below is



a) 1-chlorobutane
b) 2-chlorobutane
c) 3-chlorobutane
d) 4-chlorobutane

18. How many structural isomers have the molecular formula C_3H_6BrCl?

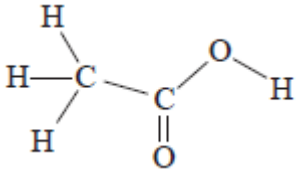
a) 4
b) 5
c) 6
d) 7

19. The spectroscopy information for an organic molecule is given below.

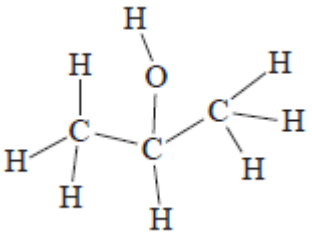
Number of peaks in ^{13}C NMR	2
Number of sets of peaks in ^{1}H NMR	3
m/z of the last peak in the mass spectrum	60
Infrared spectrum	An absorption peak appears at 3350 cm^{-1}

The organic molecule is

a)



b)



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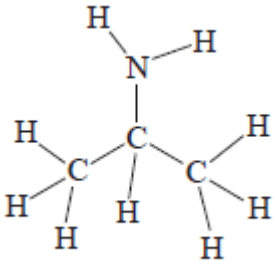
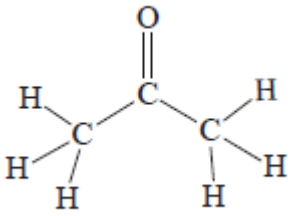


d)



20. The ^{1}H NMR spectrum of an organic compound has three unique sets of peaks: a singlet, a septet and 2 doublets.

The compound is:

a) 3-methyl butanoic acid
b) 2-methyl propanoic acid
c) 2-chloro-2-methylpropane
d) 1,2-dichloro-2-methylpropane

PART B – SHORT RESPONSES

Question 21 **5 marks**

4.0 moles of gas X and 4.0 moles of gas Y are pumped into a 2.0 L container. The container is sealed and the reaction is allowed to reach equilibrium at 400°C, as shown by the equation below:

$$2X(g) + 3Y(g) \leftrightharpoons X_2Y_3(g)$$

a) Write the equilibrium expression for the above reaction. 1m

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b) At equilibrium, there are 0.5 moles of X_2Y_3 present in the container. Calculate the value of the equilibrium constant. 4m

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Question 22 **8 marks**

The solubility constant for lead chloride at 25°C, is 1.70×10^{-5}.

a) Calculate the molar solubility of lead chloride at 25°C. 2m

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b) At 25.0°C, if 20.0 mL of a 0.100 M solution of lead (II) nitrate is mixed with 40.0 mL of a 0.100 M solution of sodium chloride, would a precipitate form? 3m

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c) Calculate the maximum mass of precipitate that will form in this solution. 3m

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Question 23 **2 marks**

Some foods contain toxins which will need to be removed for safe consumption. One of the methods utilised by Aboriginal and Torres Strait Islanders is leaching. Leaching is the process of dissolving the toxins in water to remove them.

Using a specific example, explain how the process of leaching by submerging food in shallow lakes or streams removes water soluble toxins. 2m

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Question 24 **4 marks**

A saturated solution of silver chromate, Ag_2CrO_4, has a $K_{sp} = 1.1 \times 10^{-12}$.

If 0.010 M of silver nitrate ($AgNO_3$) is added to the solution, calculate the molar solubility of Ag_2CrO_4. 4m

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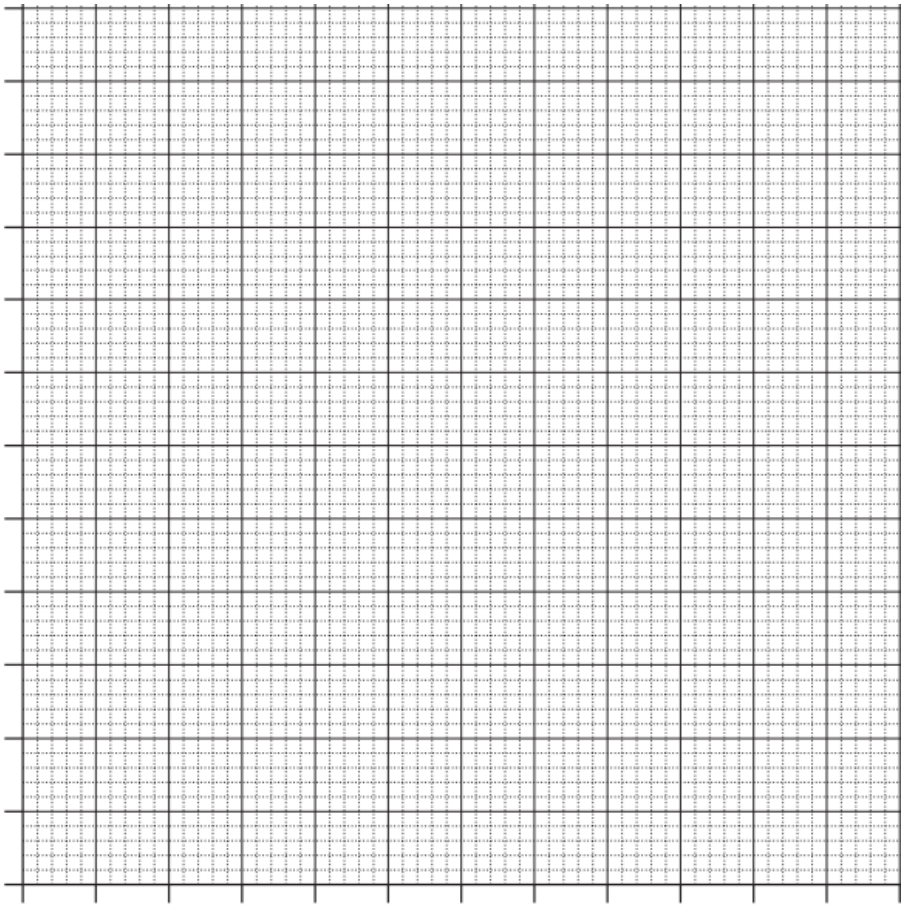
Question 25 **6 marks**

The K_w values for the self-ionisation of water at 100.0 kPa are given here for a number of different temperatures.

Temperature (°C)	K_w
0	0.114×10^{-14}
25	1.00×10^{-14}
50	5.48×10^{-14}
75	19.9×10^{-14}
100	51.3×10^{-14}

a) Construct a graph for the data given with a curve of best fit. 3m



b) Determine the pH of water at 60 °C 3m

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Question 26 **7 marks**

The Australian Government RDI (recommended daily intake) of Vitamin C for an adult is 45 mg.

Vitamin C is the common name for ascorbic acid $C_6H_8O_6$, it is necessary for the absorption of iron.

Students undertook an experiment using a redox titration to determine the concentration of Vitamin C in a 25.00 mL sample of pineapple juice, they then used this information to determine how much pineapple juice would need to be consumed to meet the RDI requirements.

Vitamin C (ascorbic acid) reacts with iodine solution. A starch based indicator is used in this reaction to determine the endpoint. When the endpoint has been reached the solution will produce a blue colour.

The reaction that occurs is

$$C_6H_8O_6\,(aq) + I_2(aq) \rightarrow C_6H_6O_6\,(aq) + 2H^+(aq) + 2I^-(aq)$$

The students were given a 0.0100M solution of I_2, but found that when they performed a titration using this solution the volume of titrant used was approximately 1.00 mL. They diluted the solution by a factor of 10 to use a 0.00100M solution in the burette.

25.00mL of pineapple juice was titrated with 0.00100M I_2 four times and the results obtained a given below.

Titration	***Volume of I_2 (mL)***
1	13.50
2	13.35
3	13.32
4	13.38

Question continued over the page

a) Determine the volume of pineapple juice that would need to be consumed to fulfil the RDI for Vitamin C for an adult. 4m

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b) Explain why the students diluted the iodine solution in this experiment. 3m

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Question 27 **3 marks**

A buffer of carbonic acid (H_2CO_3)/hydrogen carbonate (HCO_3^-) is present in blood plasma to maintain a pH between 7.35 and 7.45.

Explain why a 100 mL buffer solution of carbonic acid/hydrogen carbonate does not change in pH significantly when 10 drops of HCl are added to it, yet when 10 drops of HCl are added to 100 mL of distilled water there is a significant change in pH? 3m

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Question 28 **3 marks**

Use Brønsted-Lowry theory to explain why the pH of ammonia solution is greater than 7.0 at 25 °C. Include at least one appropriate equation in your answer. 3m

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Question 29 **4 marks**

Consider the following equilibrium reactions involving ethanoic acid (CH_3COOH), methanoic acid (HCOOH) and their conjugate bases.

1. $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
2. $HCOOH \rightleftharpoons HCOO^- + H^+$

The equilibrium constants for these reactions are given by their respective acid dissociation constants K_{a1} and K_{a2}. The pK_a values are:

$pK_{a1} = 4.76$

$pK_{a2} = 3.75$

Now consider a third equilibrium reaction involving the transfer of a proton from ethanoic acid to methanoate ion.

3. $CH_3COOH + HCOO^- \rightleftharpoons CH_3COO^- + HCOOH$

Using the given pK_a values, derive the pK_a value for the third reaction. 4m

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Question 30 **9 marks**

3-hydroxybutanoic ($C_4H_8O_3$) acid is a chemical compound that exhibits antimicrobial, insecticidal and antiviral activities and is also used as a platform for producing antibiotics, vitamins and pheromones.

a) Draw the structural formula for 3-hydroxybutanoic acid. 2m

b) An undergraduate student enrolled in the Research School of Chemistry was challenged with determining whether the liquid in an unlabelled bottle was 3-hydroxybutanoic acid or butanoic acid. The student had to do this by conducting a range of analytical techniques and interpreting the spectral data.

Compare and contrast the information that would be observed and provided in each of the spectral data for 3-hydroxybutanoic acid and butanoic acid. 5m

- Mass spectrometry
- Carbon Nuclear Magnetic Resonance
- Proton Nuclear Magnetic Resonance

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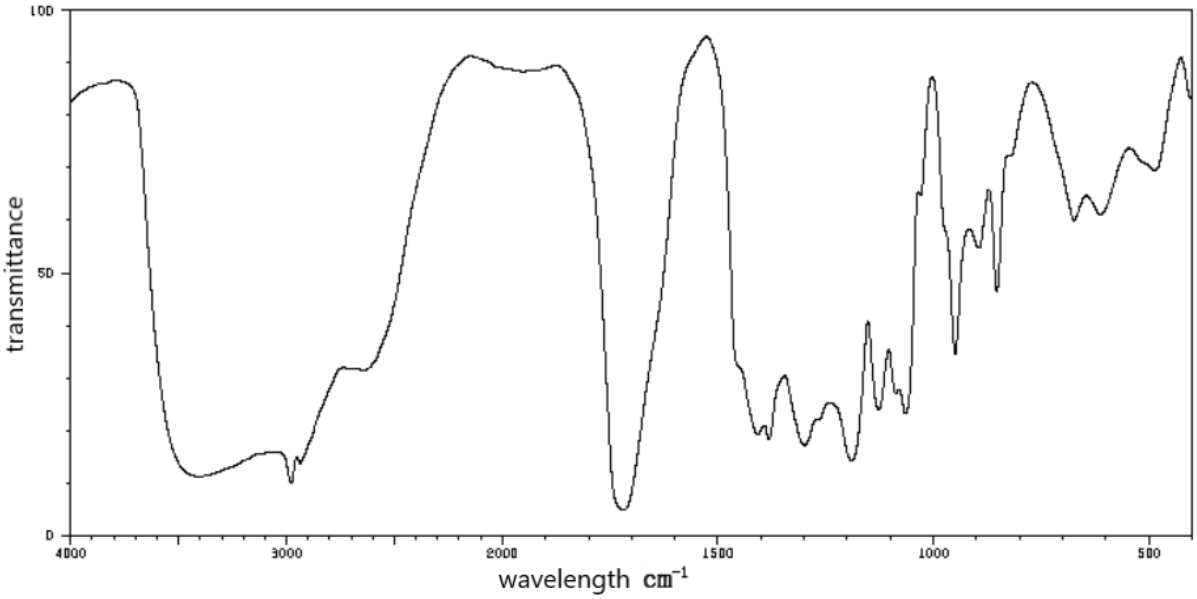
c) Observe the following Infrared spectroscopic data collected by the student.



What compound is the chemical likely to be? Explain with reference to the Infrared spectrum. 2m

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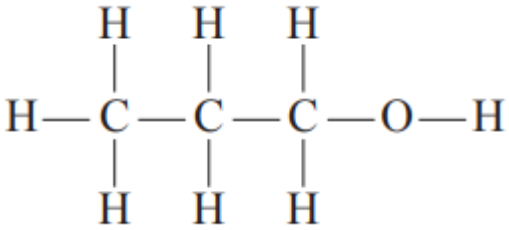
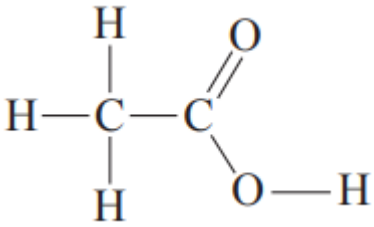
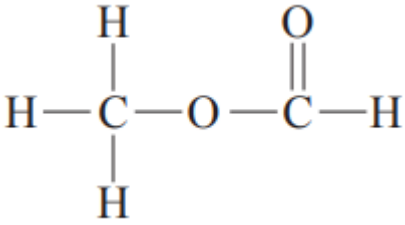
Question 31 **4 marks**

The following table provides information about THREE organic compounds, X, Y and Z.

Compound	Structural formula	Molar mass ($g\ mol^{-1}$)	Boiling point (°C)
X		60	97
Y		60	118
Z		60	31

With reference to the information provided in the table, account for the differences in boiling points between the THREE organic compounds. 4m

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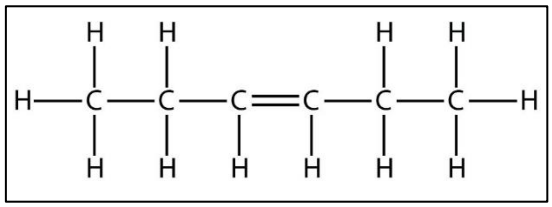
Question 32 **9 marks**

The following diagram represents a reaction pathway starting with hex-3-ene.

Hex-3-ene

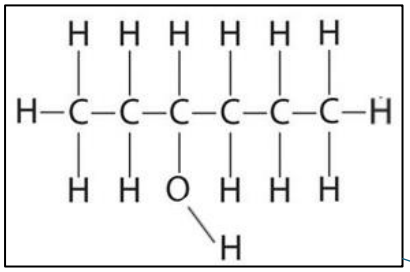


Reagent(s)

HBr (aq)

Compound A

Hexan-3-ol

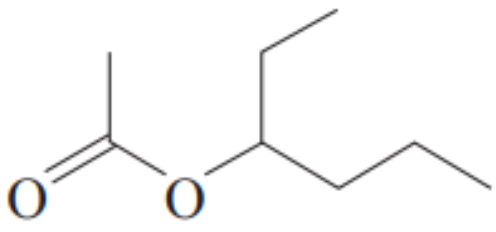


Conc H_2SO_4/heat

Compound C

H^+ / MnO_4^- (aq)

Compound D



Compound B

a) State the reagent(s) required to convert hex-3-ene to hexan-3-ol 1m

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b) Name and draw the structural formula for a tertiary alcohol that is an isomer of hexan-3-ol. 2m

c) Complete the reaction pathway by drawing in the structural formula of Compound A, Compound B and Compound C in the space provided. 3m

d) Justify the reaction conditions required for the chemical reaction to produce Compound D. 3m

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Question 33 **3 marks**

Compare the solubility of a primary alcohol, such as propan-1-ol, to a primary amine, such as propan-1-amine, in water. Provide relevant and labelled diagrams to support your answer.

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Question 34 **7 marks**

Methanamine (CH_3NH_2) is a weak base that is the building block of many commercially used organic substances.

a) Write the equation for the dissociation of methanamine in water. 1m

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b) Given $K_b = 4.38 \times 10^{-4}$, determine the pH of a solution of methanamine with a concentration of 0.250 M. 3m

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c) Methylammonium chloride CH_3NH_3Cl is an acidic salt made from methanamine. What concentration of methylammonium chloride is needed to produce a solution with a pH of 12.00? 3m

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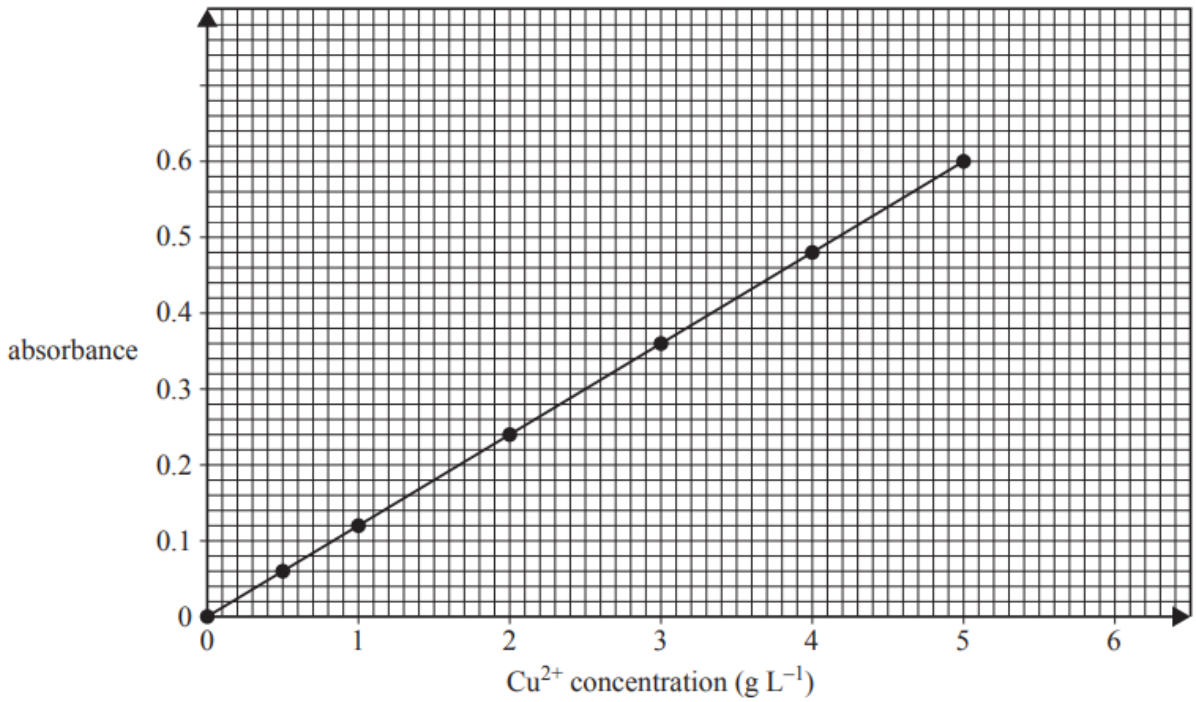
Question 35 **6 marks**

Brass is an alloy of copper and zinc. To determine the percentage of copper in a particular sample of brass, an analyst prepared a number of standard solutions of copper (II) ions and measured their absorbance using an atomic absorption spectrometer (AAS).

The calibration curve obtained is shown below.



a) A 0.198 g sample of brass was dissolved in acid and the solution was made up to 100.00 ml in a volumetric flask. The absorbance of this test solution was found to be 0.13. Calculate the percentage by mass of copper in the brass sample. 3m

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b) If the analyst had made up the solution of the brass sample to 20.00 ml would the result of the analysis have been equally valid? Explain. 2m

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c) Name another analytical technique that could be used to verify the result obtained from part a). 1m

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END OF EXAMINATION