NESA number: ……………………………….

FABER EST SUAE QUISQUE FORTUNAE

1849

2024

Higher School Certificate

Year 12 Trial Examination

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Board approved calculators may be used
- Write using black pen
- Draw diagrams using pencil
- A ruler is required

Write your NESA number at the front of each booklet.

Total marks – 100

Weighting – 30%

Use the data and formula sheet provided

Section I – 20 marks (pages 3 – 14)

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

Section II – 80 marks (pages 15 - 35)

- Attempt questions 21 – 34
- Allow about 2 hours and 25 minutes for this section.
- Additional writing space is at the end of this section.

This paper MUST NOT be removed from the examination room

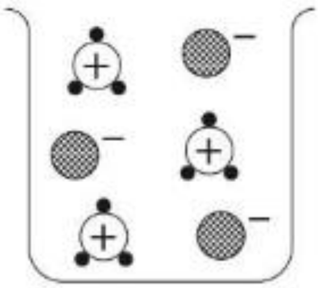
Section I – 20 marks

Attempt Questions 1-20

Allow about 35 minutes for this section

1. Which diagram represents ionisation of a weak acid?

A.



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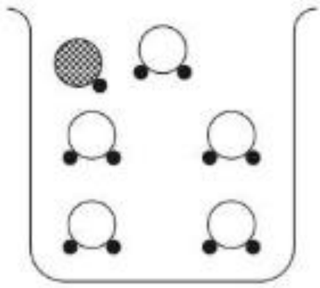

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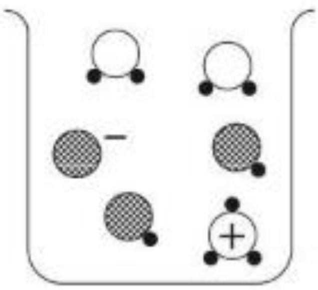

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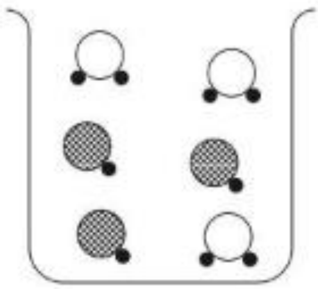
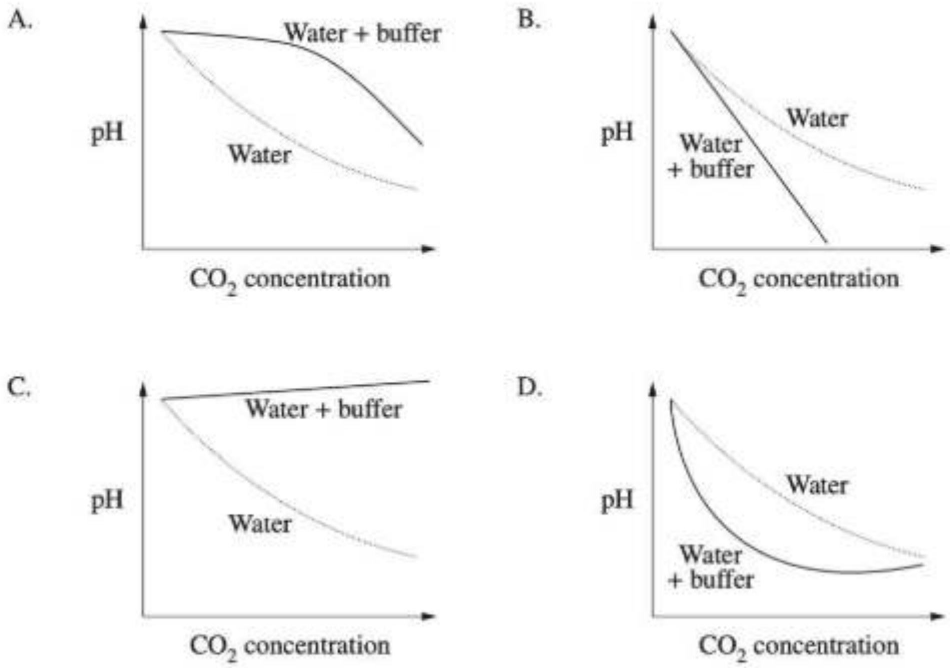


KEY

2. Increasing amounts of carbon dioxide were dissolved in two beakers, one containing water and one a mixture of water and a buffer. The pH in each beaker was measured and the results graphed.

Which graph best represents the results?



3. Which combination of equimolar solutions would produce the most basic mixture?

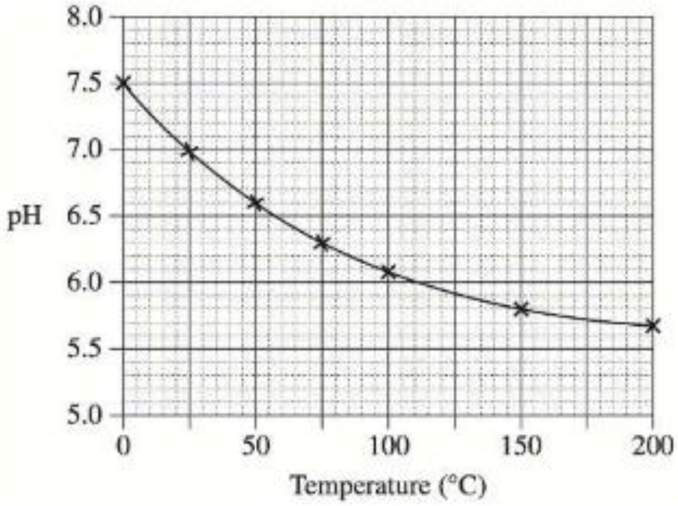
(A) Acetic acid and barium hydroxide

(B) Acetic acid and sodium carbonate

(C) Sulfuric acid and barium hydroxide

(D) Sulfuric acid and sodium carbonate

4. The graph shows the pH of a solution of a weak acid, HA, as a function of temperature.



What happens as the temperature decreases?

(A) HA becomes less ionised and the H+ concentration increases.

(B) HA becomes less ionised and the H+ concentration decreases.

(C) HA becomes more ionised and the H+ concentration increases.

(D) HA becomes more ionised and the H+ concentration decreases.

5. Which indicator in the table would be best for distinguishing between lemon juice (pH = 2.3) and potato juice (pH = 5.8)?

	Indicator	*Colour at different pH*	
(A)	Crystal violet	0.2 – yellow	1.8 – blue
(B)	Methyl orange	3.2 – red	4.4 – yellow
(C)	Bromothymol blue	6.0 – yellow	7.6 – blue
(D)	Phenolphthalein	8.2 – colourless	10.0 – pink

6. Chlorine gas (Cl_2) and carbon monoxide gas (CO) are placed into a sealed container and kept at a temperature of 25°C. Phosgene gas ($COCl_2$) is produced as follows:

$$Cl_2\ (g) + CO\ (g) \rightleftharpoons COCl_2\ (g)$$

Which statement about this reaction is correct?

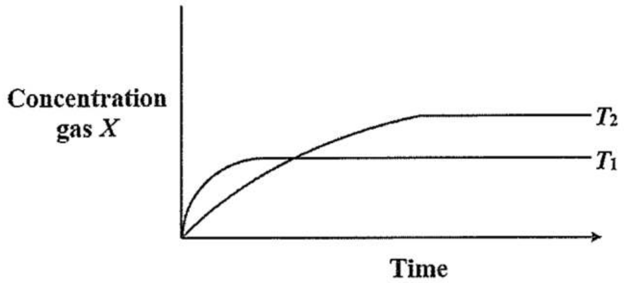
(A) All the Cl_2 and CO will be converted into $COCl_2$

(B) At a temperature of 25°C the $COCl_2$ will not form

(C) The forward reaction will continue to occur until the concentration of $COCl_2$ remains constant

(D) When the forward and reverse reactions become equal the concentration of the $COCl_2$ becomes constant

7. An equilibrium reaction is carried out at two different temperatures – T_1 and T_2. The concentration of the product gas X is recorded over time.



Based on this graph, which of the following statements is correct?

(A) A greater concentration of gas X is constantly produced for temperature T_1.

(B) Equilibrium is achieved at the same time for both temperatures.

(C) The initial rate of reaction is greater for temperature T_1 than T_2.

(D) Temperature T_2 is definitely higher than temperature T_1.

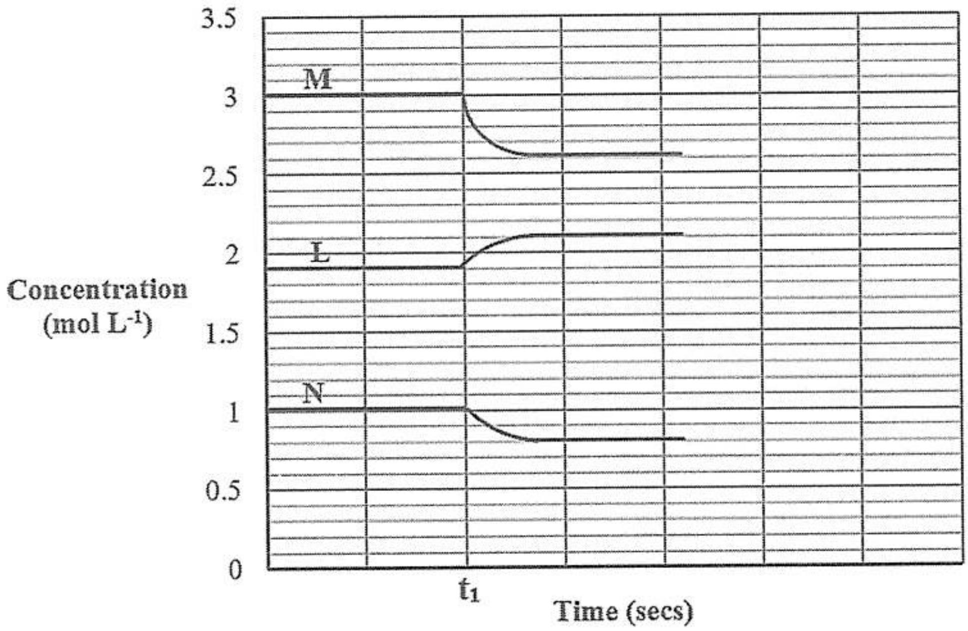
8. Consider the following equilibrium.

$$HA(aq) + B^-(aq) \rightleftharpoons A^-(aq) + HB(aq) \quad Keq = 2.5$$

Which row of the table correctly identifies the weakest acid and the strongest base in the equilibrium?

	Weakest acid	*Strongest base*
(A)	HA	B^-
(B)	HA	A^-
(C)	HB	B^-
(D)	HB	A^-

9. Three gases L, M and N in a sealed 5.0 L container react to form an equilibrium. The graph shows how the concentration of these gases changes at time t_1 when the mixture is heated.



Which is correct in the reaction in this graph?

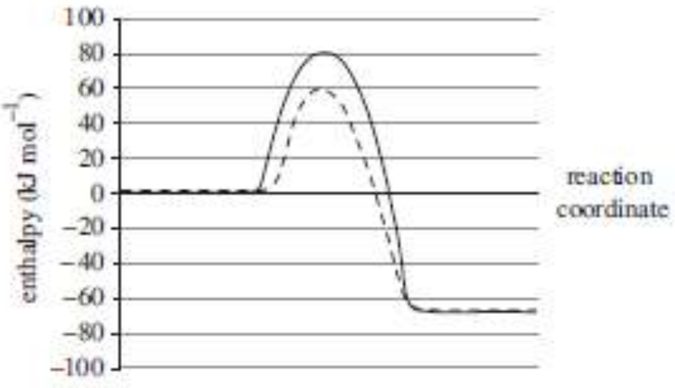
(A) $L(g) \rightleftharpoons 2M(g) + N(g)$ and the forward reaction is exothermic

(B) $2M(g) \rightleftharpoons L(g) + N(g)$ and the forward reaction is endothermic

(C) $2M(g) + N(g) \rightleftharpoons L(g)$ and the forward reaction is exothermic

(D) $L(g) + 2M(g) \rightleftharpoons N(g)$ and the forward reaction is endothermic

10. A particular reaction can occur with or without a catalyst. The energy profile of this reaction, both catalysed and uncatalysed are shown.



Which row of the table best matches the reaction as shown by the energy profile?

	Ea of uncatalysed reaction (kJ mol^{-1})	ΔH of uncatalysed reaction (kJ mol^{-1})	Ea of ctalysed reactio (kJ mol^{-1})	ΔH of catalysed reaction (kJ mol^{-1})
(A)	-80	70	-60	70
(B)	80	-150	80	60
(C)	80	-70	60	-70
(D)	20	80	150	-80

11. Hydrogen and iodine react according to the following equilibrium reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \Delta H < 0$$

A mixture of hydrogen gas and iodine gas was placed in a container, sealed and allowed to reach equilibrium. Changes were made to the mixture and the mole amounts of reactants and product were measured.

I The volume of the container was increased with the temperature remaining constant.

II Hydrogen gas was added to the container with the volume and temperature remaining constant.

III An inert gas was added to the container with the volume increasing and temperature remaining constant.

IV The temperature of the gases was decreased with the volume remaining constant.

Which changes would result in an increase in the number of moles of hydrogen iodide formed?

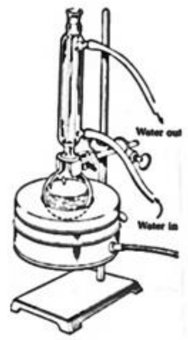
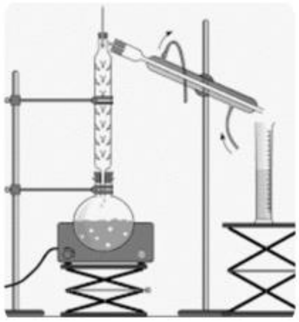
(A) I and III only

(B) I and IV only

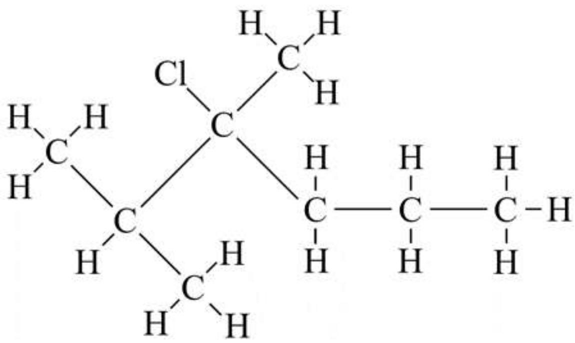
(C) II and III only

(D) II and IV only

12. Which diagram below best shows the main equipment required to isolate a pure sample of a prepared synthetic ester?

(A)	**(B)**
	
(C)	**(D)**
	

13. What is the systematic name for this compound?



(A) 1,1-dimethyl-2-chloro-2methylpentane

(B) 2-chloro-1,1,2-trimethylpentane

(C) 2,3-dimethyl-3-chlorohexane

(D) 3-chloro-2,3-dimethylhexane

14. Designing industrial synthesis processes to maximise the number of reactions that have a high '**atom economy**' is one aim of 'green chemistry', which is a movement towards lowering the environmental impact of the chemical industry and the products it creates.

> ***The atom economy for a chemical reaction is a measure of the amount of atoms from the starting materials that are present in the useful products at the end of the reaction. Having a high atom economy means any by-products of a reaction, which may not have a significant use, are minimised.***

Of the general reactions below, which would have the highest atom economy?

(A) Addition of bromine to an alkene.

(B) Elimination of water from alkanols.

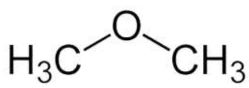
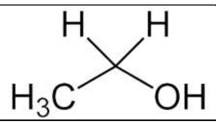
(C) Hydrolysis of an alkyl alkanoate.

(D) Substitution of an alkane by reaction with a halogen.

15. Ethers are a family of organic compounds which contain only carbon, hydrogen and oxygen.

The oxygen atom in an ether is joined to carbon atoms on either side by single bonds, as shown in the example of dimethyl ether in the table below.

Some information about dimethyl ether and ethanol is also shown in the table.

	Dimethyl ether	**Ethanol**
Structural formula		
Formula weight	46.068	46.068
Boiling point (K)	308	351
Solubility in water (g/100 g water)	6.1	infinitely soluble

Which explanation best accounts for the differences in the properties of dimethyl ether and ethanol shown in the table?

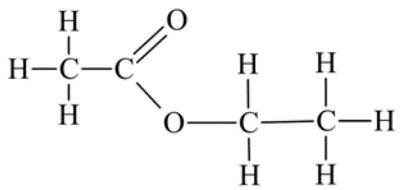
(A) Ethanol molecules are more polar than dimethyl ether molecules.

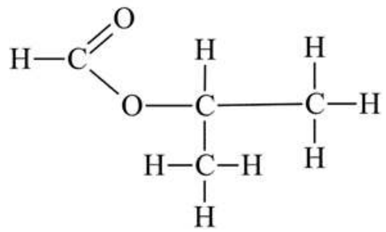
(B) The hydrogen bonds in ethanol are stronger than those in dimethyl ether.

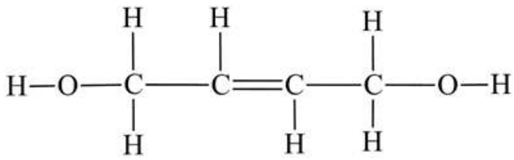
(C) The hydrogen bonding is more extensive in ethanol than in dimethyl ether.

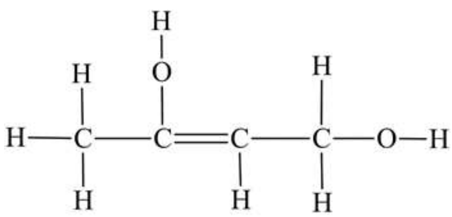
(D) The O-H bonds in ethanol are stronger than the C-O bonds in dimethyl ether.

16. Which isomer of $C_4O_2H_8$ would show three signals in its ^{13}C NMR spectrum?

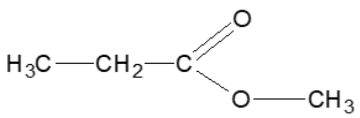
(A) 

(B) 

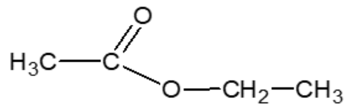
(C) 

(D) 

17. The structural formulae of five organic compounds, labelled A-E, are shown below.



A



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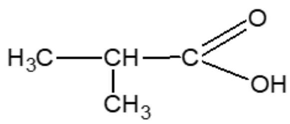

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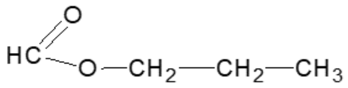

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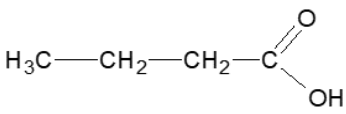


E

Which alternative below identifies a pair of these compounds which are examples of each type of structural isomer?

	Chain isomers	Functional group isomers	Position isomers
(A)	C and E	A and C	B and D
(B)	C and D	C and E	A and B
(C)	A and C	C and E	B and D
(D)	C and E	C and D	A and B

18. A sample of Teflon, polytetrafluoroethene, was found to have a molecular mass of 1.9×10^4 g mol^{-1}.

On average, how many monomer units are there in the polymer?

(A) 190

(B) 186

(C) 258

(D) 212

19. Which pieces of glassware should be used when preparing a primary standard solution?

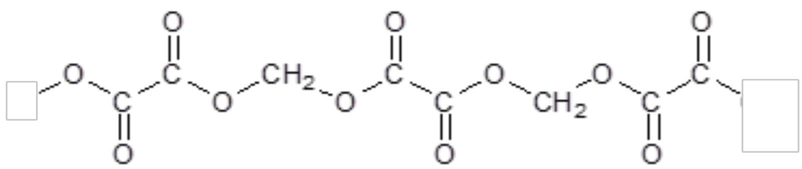
(A) Pipette, burette and conical flask

(B) Dropper, watch glass and pipette

(C) Beaker, filter funnel and volumetric flask

(D) Measuring cylinder, stirring rod and conical flask

20. The structure shown below represents a fragment of a polymer made from two different monomers.



Which option is correct with respect to the synthesis of this polymer?

	Type of polymerization	Reaction products
(A)	Condensation	Polymer and water
(B)	Addition	Polymer only
(C)	Condensation	Polymer only
(D)	Addition	Polymer and water

End of Section 1

Section II - 80 marks
Attempt Questions 21-34
Allow about 2 hours and 25 minutes for this part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (3 marks) **Marks**

A chemist is analysing an unknown organic compound with the molecular formula C_3H_8O. The following observations are made:

1. The compound does not decolorise a solution of bromine in dichloromethane.
2. The compound is treated with acidified potassium permanganate, which results in the formation of a carboxylic acid.

a) Based on the reaction with bromine, what can be inferred about the presence of a double bond in the compound?

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b) Based on the reaction with acidified potassium permanganate, what functional group is present in the compound?

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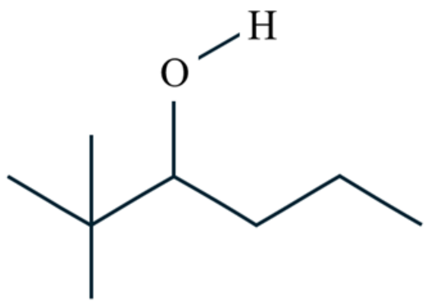
c) Propose a structure for the compound. **1**

Question 22 (2 marks) **Marks**

Draw the structural formula and name the major product of the dehydration of the compound shown below.



Structural formula of product: **1**

Systematic name: **1**

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Question 23 (3 marks) **Marks**

Sodium dihydrogen phosphate is an amphiprotic salt. Explain what is meant by the term 'amphiprotic'. Support your answer with chemical equations.

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Question 24 (3 marks)

Carbon monoxide (CO) is a poisonous and flammable gas that is used in the separation of metal from their oxides. It may be produced in the following manner.

$$CO_2(g) + H_2(g) \rightleftharpoons CO\ (g) + H_20\ (g)$$

At 600°C, 1.40 moles of carbon dioxide gas react with 1.0 mole of hydrogen gas in a 2.0 litre reaction vessel. At equilibrium, the vessel was found to contain 0.88 moles of carbon dioxide and 0.48 moles of hydrogen.

Use a correct expression to calculate the equilibrium constant (K_{eq}) for this reaction and what this indicates about the production of carbon monoxide gas at this temperature.

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Question 25 (4 marks) **Marks**

1.00 gram of lead (II) nitrate is dissolved in distilled water. The solution is made up to a volume of 100.0 mL. It is then added to 100.0 mL of a 0.001 mol L^{-1} solution of potassium iodide. The reaction takes place at 25 degrees Celsius.

Write a net ionic equation for this investigation and predict whether a precipitate would form when the two solutions are mixed. Include all calculations in your answer. **4**

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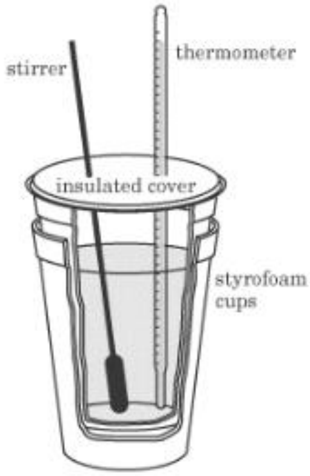
Marks

Question 26 (3 marks)

The diagram below shows a coffee cup calorimeter used by a student to measure the enthalpy of neutralisation of an acid-base reaction:



120mL of 0.500molL^{-1} sodium hydroxide was added to 60.0mL of 0.500molL^{-1} sulfuric acid.

Both solutions were at a temperature of 24.2°C.

After mixing, the final temperature was 26.3°C.

Calculate the enthalpy change per mole of water formed in this reaction

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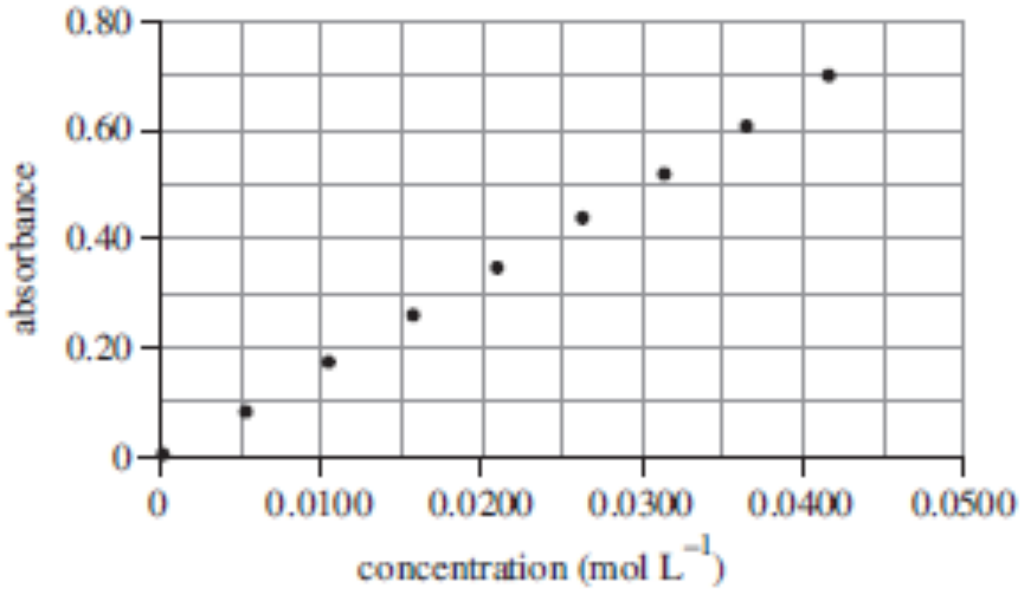
Marks

Question 27 (4 marks)

A colourimeter with an orange filter was used to analyse the concentration of copper ions in a solution. To calibrate the colourimeter, a distilled water blank and eight standards of Cu^{2+} were prepared. Their absorbances were measured to give the calibration curve shown.



A 20.0 mL sample of a copper solution of unknown concentration was diluted to a total volume of 80.0 mL. This diluted solution recorded an absorbance of 0.500.

Use the graph to determine the mass of the copper ions contained in the 20.0 mL sample.

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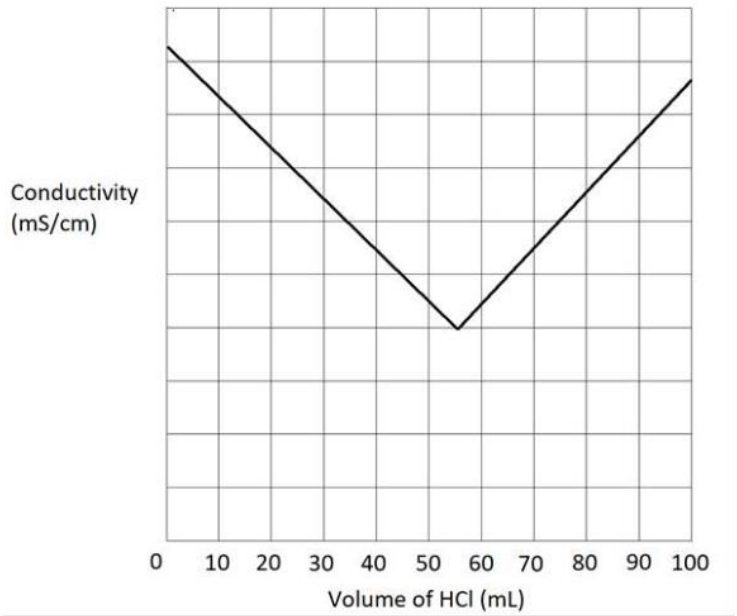
Marks

Question 28 (6 marks)

A student wanted to determine the concentration of a solution of potassium hydroxide. They did this by reacting a 25 mL aliquot with a standard solution of hydrochloric acid while measuring the conductivity of the solution. 10.00 mL volumes of 0.1012 M hydrochloric acid were incrementally added using a burette and the conductivity was measured after each addition. The student recorded the following data.



a) Explain the trend shown in the graph.

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b) Calculate the concentration of the potassium hydroxide solution.

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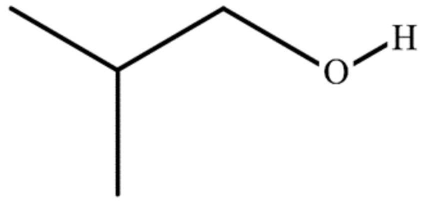
Question 29 (8 marks) **Marks**

Isobutanol has been investigated as a possible fuel source for internal combustion engines.



(a) Give the IUPAC name for the structure shown above.

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(b) Outline a procedure which could be used to estimate the heat of combustion of this fuel in a typical school laboratory.

Include a labelled diagram of the apparatus used as well as a justified safety precaution for this type of investigation. 4

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Question 29 continues on page 25.

Question 29 (continued) **Marks**

(c) 2-butanol is an isomer of isobutanol. Data from the mass spectra of the two compounds are shown in the table below.

Compound	Parent ion peak (m/z)	Base peak (m/z)
Isobutanol	74	43
2-butanol	74	45

Explain a similarity and a difference between the two spectra. **3**

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Marks

Question 30 (9 marks)

Carbonyl chloride ($COCl_2$) gas can be formed in an equilibrium reaction between carbon monoxide (CO) gas and chlorine (Cl_2) gas. A 10L vessel containing these gases under standard conditions, but not at equilibrium, was sampled. It was found that there were 0.11 moles of carbon monoxide, 0.63 moles of chlorine and 2.9 moles of carbonyl chloride present in the vessel. The equilibrium constant (Keq) for this reaction, under the conditions used, is 2.62×10^2.

(a) Write the equilibrium expression for this reaction.

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(b) After sampling, in which direction will the reaction shift in order to reach equilibrium? Justify your answer.

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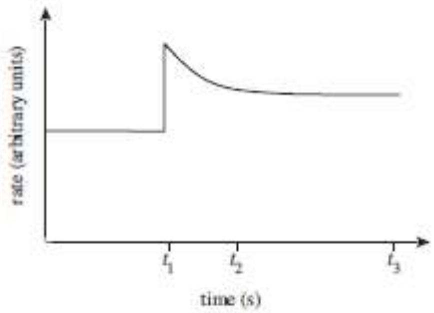
Question 30 continues on page 27.

Marks

Question 30 (continued)

(c) The mixture of carbon monoxide, chlorine and carbonyl chloride was allowed to come to equilibrium. The rate of reaction was monitored at a constant temperature. The diagram shows the rate of formation of carbonyl chloride over a period of time. At t_1, the volume of the reaction vessel was decreased.



Explain, using collision theory, the shape of the graph over time. Refer to any factors that affect the rate of reaction in your answer.

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Marks

Question 31 (8 marks)

The following table shows four acids which were tested for relative conductivity and pH:

Acid tested	*Relative Conductivity*	*pH*
Concentrated CH_3COOH (100% pure) known as glacial acetic acid	Does not conduct	Unable to measure
0.1 mol L^{-1} HCl solution	high	1.0
0.1 mol L^{-1} CH_3COOH solution	moderate	3.3
0.1 mol L^{-1} H_2SO_4 solution	high	0.7

a) Explain why the pH for glacial acetic acid is unable to be measured. **2**

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b) Explain the differences in the pH values for the 0.1 mol L^{-1} acids that were tested. Include relevant calculations. **6**

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Question 32 (14 marks) **Marks**

Ethanoic acid and methanol react reversibly to form methyl ethanoate and water. The following procedure was carried out by a chemistry student to estimate the equilibrium constant for this reaction.

- A mixture weighing 8.64 g was made by adding 0.08 mol of ethanoic acid and 0.12 mol of methanol. The mixture was left in a sealed glass syringe with a sliding piston which was placed in a water bath where its temperature was held steady at 60°C for 3 hours. After this time, the temperature of the water bath was reduced to 20°C. The syringe was left for 24 hours in the water bath. At this point, the system was **assumed** to be at equilibrium.

- The contents of the syringe were thoroughly mixed to form a homogenous mixture and 1.0 g of the mixture remaining in the syringe was measured out and titrated with 0.40 mol L^{-1} sodium hydroxide delivered from a burette. A mean volume of 21.20 mL of sodium hydroxide solution was needed to reach the end-point of the titration, when it was assumed all of the ethanoic acid present in the mixture had reacted with the sodium hydroxide.

(a) Write a balanced chemical equation, using structural formula, for the reaction between ethanoic acid and methanol which occurred in the first step of the outlined procedure. **2**

(b) Write a balanced chemical equation for the reaction taking place in the titration stage of the procedure.

.... **1**

(c) Use the data provided to calculate the number of moles of ethanoic acid remaining in the equilibrium mixture formed in the first step.

.... **2**

....

....

Question 32 continues on page 30.

Question 32 (continued) **Marks**

(d) Write the expression for the equilibrium constant, *K*, for the system described by your equation in (a).
Use molecular formulae for all species in their liquid state, including water, in the expression for *K*. **1**

....

(e) Use the data provided to estimate the value of *K* for the reaction forming methyl ethanoate at 20°C. Show all working.

.... **2**

....

....

....

....

....

(f) A few drops of concentrated H_2SO_4 are often added to mixtures of an alkanol and alkanoic acid when this type of reaction is carried out in a school laboratory.

What is the primary function of concentrated H_2SO_4 in this reaction?

.... **1**

(g) Propose a chemical reason for the omission of concentrated H_2SO_4 for this particular investigation. Explain your reasoning.

.... **2**

....

....

(h) Would you expect the omission of concentrated H_2SO_4 in this investigation to affect the accuracy of the estimate for *K*? Explain your reasoning.

.... **3**

....

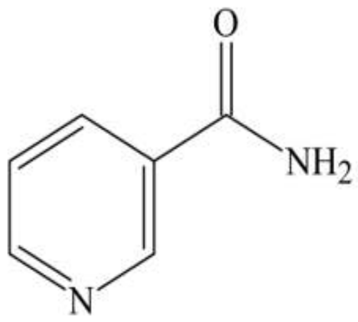
....

....

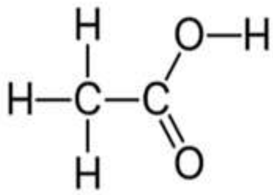
Question 33 (6 marks) **Marks**

Polyamides are a class of condensation polymer resulting from the reaction of an organic compound with an amide functional group with one containing the carboxyl functional group.

The structures below show the composition of two organic molecules.



Nicotinamide



ethanoic acid

(a) Draw the functional group present in amides. **1**

(b) Could the reaction of the two molecules above result in the formation of a polyamide? Explain your answer. **3**

………

………

………

………

………

………

Question 33 continues on page 32.

Question 33 (continued)

Marks

(c) An amide with the molecular formula $C_2H_4N_2O_2$ is subjected to reaction conditions which allow for its conversion into a polyamide.

Draw a possible structural formula for this amide and name the molecule formed as a by-product of the condensation polymerisation of the amide drawn.

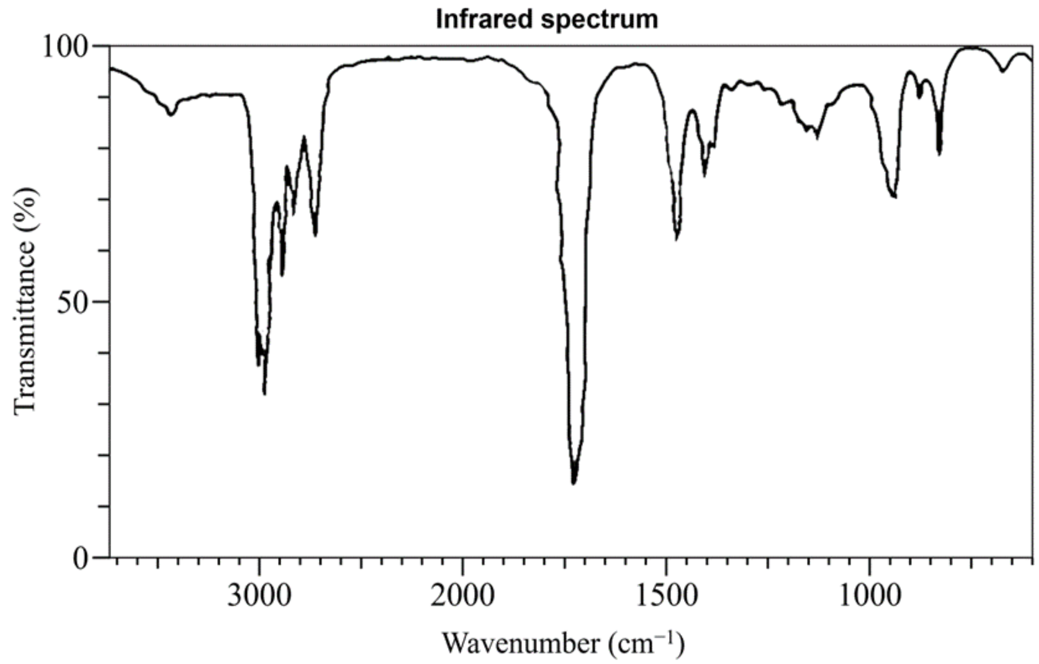
2

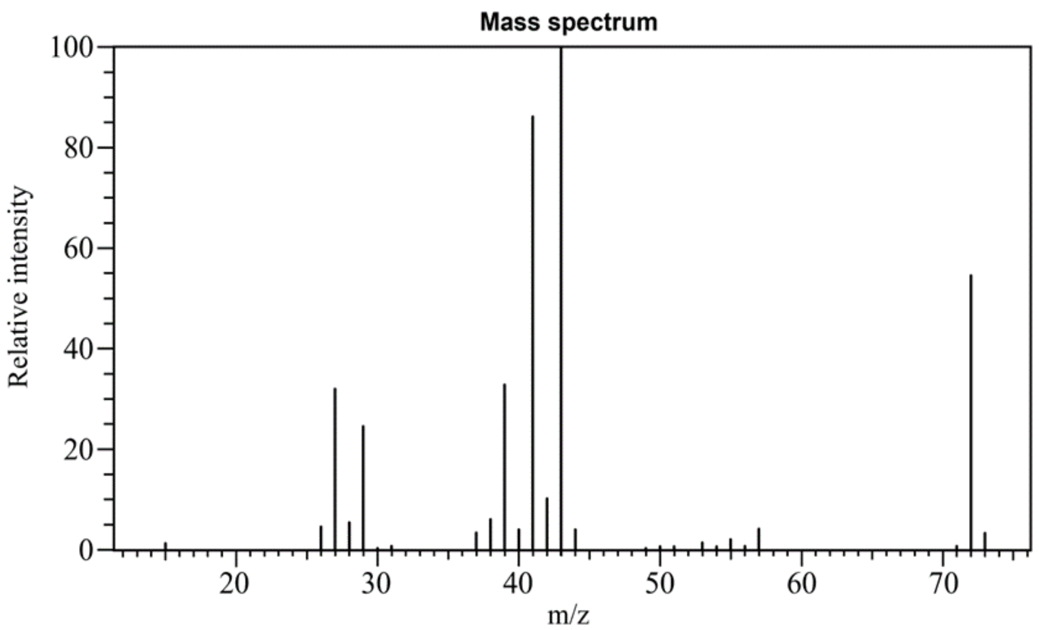
Name of by-product.

…….

Question 34 (7 marks)

An unknown compound was investigated using several techniques. The results are shown in the spectra below.

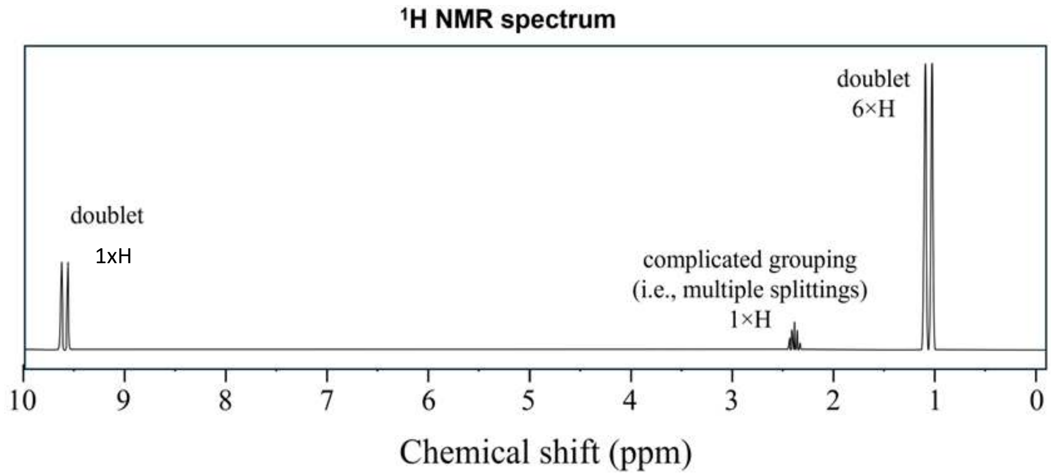


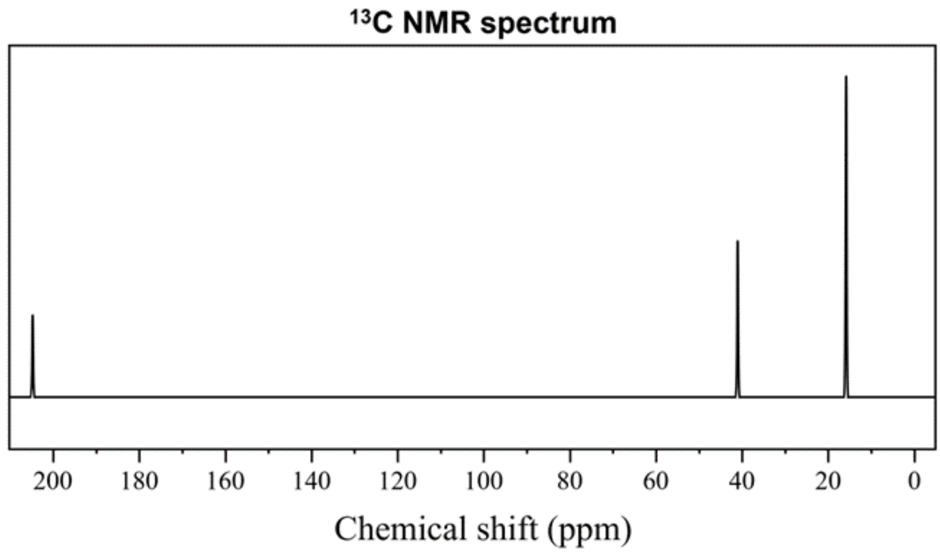


Question 34 continues on page 34.

Question 34 (continued)

Marks





Draw and name the compound that was investigated.

Support your answer with evidence from the spectra.

……. **7**

…….

…….

…….

Continue your answer to Question 34 on page 35.

Question 34 (continued)

End of Section 2

Additional writing space. Clearly indicate which question you are responding to.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C	A	A	B	B	D	C	C	A	C	D	B	D	A	A	B	B & D	A	C	A

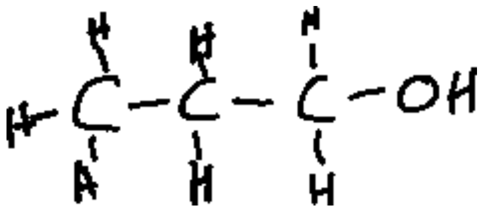
Question 21

Answer:

a) The fact that the compound does not decolorize a solution of bromine in dichloromethane indicates that it does not contain a carbon-carbon double bond or triple bond (it is not an alkene). (1 mark)

b) The reaction with acidified potassium permanganate resulting in the formation of a carboxylic acid indicates the presence of a primary alcohol functional group in the compound, as primary alcohols are oxidized to carboxylic acids under these conditions. (1 mark)

c) Given the molecular formula C_3H_8O and the presence of an alcohol functional group, the compound is propan-1-ol. (1 mark)



Question 22

Marking Criteria	Marks
• Draws a correct structure and correctly names compound	**2**
• One of the above	**1**

2,2-dimethyl hex-3-ene

Question 23

Marking Criteria	Marks

• Explains that amphiprotic compounds can:
  ○ donate and accept a proton.
  or
  ○ act as a **Bronsted-Lowry** acid and base
• Supports the explanation using at least TWO **fully correct equations** (including states of matter) showing appropriate example(s) of an amphiprotic compound that is **clearly** acting as a:
  ○ Bronsted-Lowry acid (donating a proton)
  and
  ○ Bronsted-Lowry base (accepting a proton)
	3

• ONE component of the above criteria is missing or incorrect.	2
• TWO components of the above criteria are missing or incorrect.	1

$NaH_3PO_4{}^{+}{}_{(aq)}$ does not exist

Question 24

Criteria	Mark
• Writes the correct equilibrium constant expression • Calculates the correct K_{eq} value • Makes a correct statement relating the K_{eq} value to the production of gas	3
• Writes a relevant equilibrium constant expression and calculates its K_{eq} value • Makes a correct statement relating the K_{eq} value to the production of gas	2
• Writes a relevant equilibrium constant expression and calculates its K_{eq} value OR • Makes a correct statement relating the K_{eq} value to the production of gas	1

Sample answer:

	$[CO_2]$	$[H_2]$	$[CO]$	$[H_2O]$
Initial	0.7	0.5	0	0
Change	0.7 – 0.44	0.5 – 0.24	0.26	0.26
Equilibrium	0.44	0.24	0.26	0.26

$$K_{eq} = \frac{[CO][H_2O]}{[CO_2][H_2]} = (0.26) \times (0.26)/[0.44] \times [0.24] = 0.64$$

As $K_{eq} < 1$, the equilibrium lies towards the reactants side. Carbon monoxide gas production is not favoured.

$H_2O_{(g)}$ is in the SAME state as all the other species. It MUST be included.

IF $H_2O_{(l)}$ AND the other species are (aq), then omit it from K_{eq}

All moles should have been divided by 2 (the volume) to get concentration. In this example you got lucky that the divide by 2 cancels out (since the coefficients are all one AND the species of reactants and products are equal)

$$K_{eq} = \frac{[CO][H_2O]}{[CO_2][H_2]}$$

$$= \frac{\text{mol } CO \cancel{\div 2} \quad \text{mol } H_2O \cancel{\div 2}}{\text{mol } CO_2 \cancel{\div 2} \quad \text{mol } H_2 \cancel{\div 2}}$$

lucky

Question 25

Criteria	Mark
• Provides a correctly balanced net ionic equation • Uses appropriate processes to calculate the ionic product (Q_{sp}) for the reaction • Correctly predicts that no precipitate will form by comparing Q_{sp} to the reaction's K_{sp}	4
• Provides a correctly balanced net ionic equation • Uses appropriate processes to calculate the ionic product (Q_{sp}) for the reaction	3
• Provides a correctly balanced ionic equation • Uses SOME appropriate processes to calculate an ionic product (Q_{sp}) for the reaction	2
• Provides a correctly balanced ionic equation • Uses an appropriate process to calculate an ionic product (Q_{sp})	1

Sample answer:

$Pb^{2+}(aq) + 2I^-(aq) \rightleftharpoons PbI_2(s)$

n $Pb(NO_3)_2$ = m/M = 1/(207.2 + 28.02 + 96) = 3.02×10^{-3}

$\therefore$ $[Pb^{2+}]$ in total solution = n/V = $3.02 \times 10^{-3}/0.2 = 0.0151$

n KI = c × V = 0.001 × 0.1 = 0.0001

$\therefore$ $[I^-] = 0.0001/0.2 = 0.0005$

Q_{sp} PbI_2 = $[Pb^{2+}][I^-]^2 = 0.0151 \times 0.0005^2 = 3.8 \times 10^{-9}$

K_{sp} PbI_2 = $[Pb^{2+}][I^-]^2 = 9.8 \times 10^{-9}$

$Q_{sp} < K_{sp}$ No precipitate will form.

Question 26

Calculation

- Must use correct equation
- Answer must have the correct units
- Equation must be balanced with the correct states

Criteria	Marks
• Gives a balanced chemical equation **AND** • Performs the correct calculation **AND** • Gives the correct answer	3
• Gives a balanced chemical equation **AND** • Performs the correct calculation **OR** gives the correct answer	2
• Shows some understanding of the calculation	1

(a) $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

1 mole of sulfuric acid (a diprotic acid) reacts with 2 moles of alkali to form 2 moles of water.

$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$

moles of water formed = moles of sodium hydroxide

$$= \frac{120}{1000} \times 0.500$$

$$= 0.0600 \text{ mol}$$

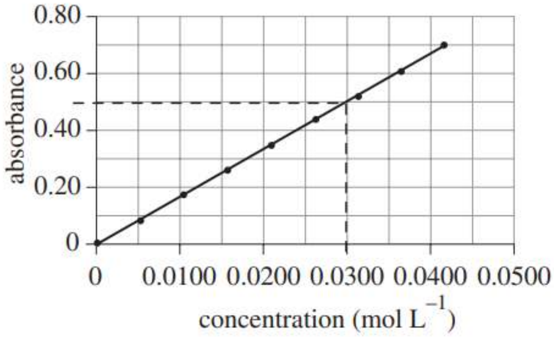
heat change (q) = $mc\Delta T$

$$= \frac{(120 + 60)}{1000} \times 4.18 \times 10^3 \times (26.3 - 24.2)$$

$$= 0.8 \times 4.18 \times 2.1 = 1.58 \text{ kJ}$$

$$\therefore \Delta H = \frac{-q}{n(\text{water})} = \frac{-1.58 \text{ kJ}}{0.06 \text{ mol}} = -26.3 \text{ kJ mol}^{-1} \text{ (exothermic)}$$

Question 27



From the graph, $[Cu^{2+}] = 0.0300$ mol L^{-1} for the diluted solution. $n(Cu^{2+}) = 0.0300 \times 0.0800 = 0.00240$ mol (contained within 20.0 mL original solution) mass of $Cu^{2+} = 0.00240 \times 63.55 = 0.153$ g	Mod 8 Analysis of Inorganic Substances CH12–4, 12–7 Bands 3–4 • Shows on graph how the initial figure is obtained. AND • Determines the mass. AND • Shows all relevant working 4
	• Determines the mass. AND • Shows all relevant working 3
	• Shows substantially correct working 2
	• Provides some relevant information 1

Question 28

a) Explain the trend shown in the graph.

Marking Criteria	Marks
• Explains that the decrease in conductivity it because of the hydroxide ions concentration decreasing. • Identifies the lowest point of conductivity as the equivalence point. • Explains that the increase in conductivity is because of the hydrogen ion concentration increasing	3
• Correctly links either the decrease or increase in conductivity to the increase or decrease of hydrogen or hydroxide ions • Identifies the lowest point of conductivity as the equivalence point.	2
• Links conductivity to the concentration ions in solution	1

b) Calculate the concentration of the potassium hydroxide solution.

Marking Criteria	Marks
• Selects the correct volume of HCl (54-56 mL) • Calculates the number of moles of HCl • Calculates the concentration of KOH	3
• One mistake of the above	2
• Attempts of the above steps	1

moles HCl =moles KOH If student read off the equivalence point as 55 mL

0.1012 x 55/1000 = [KOH] x 25/1000

Therefore [KOH] = 0.22 M

Question 29

29.a.

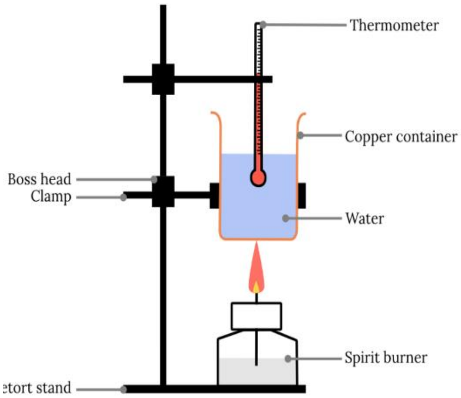
Marking Criteria	Marks
• Provides IUPAC name	**1**

2-methylpropan-1-ol

29.b.

Marking Criteria	Marks
• Describes a procedure with justified safety precaution, labelled diagram of apparatus used, and a step to minimise heat loss to the surroundings.	**4**
• Mostly complete procedure.	**3**
• Some steps taken towards measuring the heat of combustion.	**2**
• A relevant step.	**1**

Measure and record mass of water, m_{water}, in beaker using electronic balance.
Measure and record mass of isobutanol. m_{fuel}, in spirit burner using electronic balance. Ensure no isobutanol has dripped or spilled outside of the spirit burner so that unexpected flames are not produced.
Construct the apparatus as shown in the diagram.



Record temperature of water T_i.
Cover beaker on all sides and top with aluminium foil, leaving only the bottom exposed.
Ignite isobutanol in spirit burner and keep flame as close to beaker as possible.
When isobutanol supply is exhausted, record water temperature, T_f.
Use $Q = m_{water}c(T_f - T_i)$ to find the energy released by the combustion of isobutanol.
Use $Heat\ of\ combustion = \frac{energy}{number\ of\ moles} = \frac{Q}{\left(\frac{m_{fuel}}{MM_{isobutane}}\right)}$ to find the heat of combustion of isobutane in J mol^{-1}.

29.c.

Marking Criteria	Marks
• Explains a similarity and a difference in terms of the properties of the chemical species.	**3**
• Explains a similarity or a difference in terms of the properties of the chemical species.	**2**
• Provides some relevant information.	**1**

The empirical formula for both molecules is $C_4H_{10}O$ therefore they have the same molecular mass and the same parent ion peak in their mass spectra, at m/z = 74.
Isobutanol can break to form the fragment CH_3CHCH_3 which has a mass of 43 amu.
2-butanol can break to form the CH_3CHOH fragment which has a mass of 45 amu.
These fragments give rise to the base peaks in the respective mass spectra.

Responses must include the exact fragments in each molecule in their responses

Question 30

(a)	The equation of the reaction is: $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$ Therefore, the equilibrium expression of the reaction is: $\frac{[COCl_2]}{[CO][Cl_2]}$	Mod 5 Factors that Affect Equilibrium CH12–12 Band 2 • Writes the correct equilibrium expression 1
(b)	Finding the reaction quotient (Q) gives: $Q = \frac{[COCl_2]}{[CO][Cl_2]}$ $= \frac{[0.29]}{[0.011][0.063]}$ $= 418.47$ $\approx 4.2 \times 10^2$ (to two significant figures) This is not the same as the value quoted for the equilibrium constant (2.62×10^2), so the system is not at equilibrium. $Q > K_{eq}$ and Q will have to decrease. This will occur if the products decrease and reactants increase. Therefore, the direction of the reaction will shift from right to left, favouring products going to reactants. *Note: To use molar concentrations per litre, the values of reactants and products need to be divided by 10 because the container is 10 L.*	Mod 5 Calculating the Equilibrium Constant CH12–6, 12–12 Band 6 • Calculates Q. AND • Compares Q to the equilibrium constant. AND • Identifies the direction of the reaction. AND • Gives an appropriate justification . . . . .4 • Any THREE of the above points. . .3 • Any TWO of the above points. . . . .2 • Provides some relevant information 1

For [CO] = 0.11 moles / 10 Litres = 0.011 M

For [Cl_2] = 0.11 moles / 10 Litres = 0.063 M   and for

For [$COCl_2$] = 0.11 moles / 10 Litres = 0.29 M

(c)	The rate of formation (reaction rate) of carbonyl chloride is dependent on the frequency of successful collisions between the reactant (CO and Cl_2) particles. The greater the number of collisions, the greater the rate of reaction. The system is at equilibrium from t_0 to t_1, so the number of collisions of reactants will be steady, as shown by the horizontal line on the graph. At t_1, the volume decreases suddenly; particles will be closer together and collide more frequently. Additionally, molar concentrations of the reactants [CO] and [Cl_2] increase. The rate of the reaction is proportional to the concentration of the reactants, and an increase in concentration leads to a sudden increase in the rate of reaction. This is shown by the vertical line on the graph. From t_1 to t_2, the system compensates for the pressure increase caused by the volume decrease. It does this by moving the position of equilibrium to the side with fewer particles (the right-hand side, $COCl_2$). As the reactants are consumed by the forward reaction, the rate of the forward reaction gradually decreases until a new equilibrium position is reached. The new rate of reaction is still higher than before the volume decreased because the system has only partially compensated for this change. This is because the final concentrations of the reactants [CO] and [Cl_2] are higher than the concentrations at the original equilibrium.	Mod 5 Static and Dynamic Equilibrium Mod 5 Factors that Affect Equilibrium CH12–6, 12–12 Band 6 • Gives a detailed explanation. AND • Refers to specific points on the graph. AND • Uses collision theory appropriately. AND • Refers to concentration OR pressure . . . . .4 • Gives an explanation. AND • Refers to specific points on the graph. AND • Uses collision theory appropriately. OR • Refers to concentration OR pressure . . . . .3 • Gives an explanation. AND • Refers to the graph OR collision theory. OR • Mentions concentration OR pressure . . . . .2 • Provides some relevant information 1

Question 31

Marking Criteria	Marks
• Identifies for an acid to conduct it must be in a solution of ions. (i.e. the acid dissociates in water to form ions) • State that glacial acetic acid is not a solution of ions, since no water is present, and cannot conduct	2
• ONE of the above criteria is missing or incorrect.	1

Marking Criteria	Marks
For EACH **0.1 $molL^{-1}$ acid** (i.e. HCl, H_2SO_4, CH_3COOH), students: • Explain thoroughly the differences in pH values in terms of: ○ **relative strength** of the acid ○ **number of protons** present (i.e. monoprotic, diprotic) • Support their response with an **appropriate calculation** (e.g. [H^+]) • Clearly **link ALL the highlighted relationships** above.	6
For EACH 0.1 $molL^{-1}$ acid (i.e. HCl, H_2SO_4, CH_3COOH), students: • Explain generally the differences in pH values in terms of: ○ relative strength of the acid ○ number of protons present (i.e monoprotic, diprotic) • Support their response with an appropriate calculation (e.g. [H^+]) OR For EACH 0.1 $molL^{-1}$ acid (i.e. HCl, H_2SO_4, CH_3COOH), students: • Explain thoroughly the differences in pH values in terms of: ○ relative strength of the acid ○ number of protons present (i.e monoprotic, diprotic) • Include an appropriate calculation (e.g. [H^+]) Note - a least ONE appropriate calculation in the response	4-5
For the 0.1 $molL^{-1}$ acids (i.e. HCl and/or H_2SO_4 and/or CH_3COOH), students: • Identify the differences in pH values in terms of: ○ relative strength of the acid and/or ○ number of protons present (i.e. monoprotic, diprotic) • May include an appropriate calculation (e.g. [H^+])	2 - 3
• Some relevant information	1

Acetic acid CH_3COOH and Hydrochloric acid HCl are monoprotic acids. While Acetic acid is a weak acid that undergoes partial ionisation in solution, Hydrochloric acid is a strong acid that ionises fully in solution.

Sulfuric acid H_2SO_4 is a strong diprotic acid that ionises fully in solution to produce two hydrogen ions $2H^+$.

$H_2SO_4 \rightarrow 2H^+. + SO_4^{2-}$

Since there are more hydrogen ions in solution than hydrochloric acid and lower pH, sulfuric acid is a stronger acid, than HCl

For H_2SO_4 , the concentration of hydrogen ions in solutions is found by pH = -log[H+] , that is

0.7 = -log[H+] → [H+] = 0.199M and for HCl: 1 = -log[H+] → [H+] = 0.1M

Since Acetic acid is a weak monoprotic acid it only ionises partially in solution to produce hydrogen ions H^+ in solution with a concentration of 0.0005M found by using

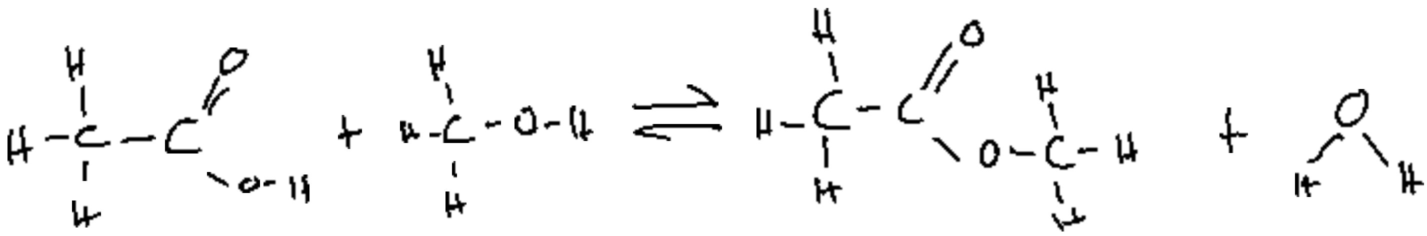
3.3 = -log[H+] → [H+] = 0.0005M and since it also has the highest pH it makes it weaker than Hydrochloric and sulfuric acid.

*Students must show all the three appropriate calculations in their responses since the question requires relevant calculations.

Question 32

32.a.

Marking Criteria	Marks
• Uses structural formula to show the balanced chemical equation for the esterification reaction.	2
• Uses structural formula to show the balanced chemical equation for the esterification reaction, with a significant error.	1



32.b.

Marking Criteria	Marks
• Writes a correctly balanced chemical equation.	1

NaOH(aq) + CH_3COOH(aq) ⍰ $NaCH_3COO$ (aq) + H_2O (l)

32.c.

Marking Criteria	Marks
• Calculates the correct number of moles of CH_3COOH remaining in the sample tested.	2
• Calculates the correct number of moles of CH_3COOH in the titrated sample.	1

n(NaOH) = cV = 0.4 x 0.0212 = 0.00848 mol

Thus $n(CH_3COOH)_{\text{remaining in equilibrium mixture}}$ = 0.00848 mol (1 : 1 ratio)

This is for 1.0g sample.

Moles remaining in mixture 0.00848 × 8.64 = 0.073 mol in total

32.d.

Marking Criteria	Marks
• Writes the expression for the equilibrium constant.	**1**

$K = [C_3H_6O_2]\ [H_2O] / [C_2H_4O_2][CH_4O]$

also accepted $K = [CH_3COOCH_3][H_20]/[CH_3COOH][CH_3OH]$

32.e.

Marking Criteria	Marks
• Calculates K for the reaction from the data provided with sufficient working.	**2**
• Completes one correct step in the calculation.	**1**

From Step (c)

	$C_2H_4O_2$	CH_3OH	$C_3H_6O_2$ +	H_2O
I	0.08	0.12		
C	-0.007	-0.007	+0.007	+0.007
E	0.073	0.113	0.007	0.007

$K = 0.007^2 / 0.073 \times 0.113 = 0.007^2 / 0.008249 = 0.000049 / 0.008249 = 0.0059$

32.f.

Marking Criteria	Marks
• Identifies the reason for adding $[H_2SO_4]$ in an esterification reaction.	**1**

Addition of concentrated H_2SO_4 is due to the fact it acts a catalyst for the esterification reaction, increasing the reaction rate.

OR

Concentrated H_2SO_4 acts as dehydrating agent and bonds to free water molecules, thus causing a shift to the right, increasing the yield of ester.

32.g.

Marking Criteria	**Marks**
• Provides a reason for not adding H_2SO_4 with sufficient chemical justification. (need to specify the effect on K	**2**
• Identifies a correct reason for not adding H_2SO_4 without sound justification.	**1**

Since the equilibrium mixture was analysed by titration with NaOH, any H_2SO_4 added would still remain (as a catalyst is not consumed by a reaction), and this would also react with the NaOH, thus not allowing for an accurate estimate for only the CH_3COOH remaining in the equilibrium mixture. Thus any estimate of K based on the investigation would be inaccurate.

32.h.

Marking Criteria	**Marks**
• Identifies omitting the catalyst will result in a level of inaccuracy in the estimate of K, with an explanation that demonstrates a thorough knowledge of acid-base and equilibrium concepts.	**3**
• Identifies omitting the catalyst will result in a level of inaccuracy in the estimate of K, with an explanation that demonstrates sound knowledge of acid-base and equilibrium concepts.	**2**
• Provides some relevant information.	**1**

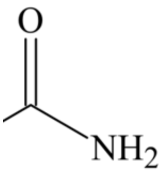
The omission of H_2SO_4 in the initial esterification step will result in a level of inaccuracy in the estimate for K. Since the catalyst was not added, it will take the system longer to come to a state of equilibrium, as catalysts speed up both the forward and reverse rate but do not affect the position of equilibrium. The system analysed is approaching equilibrium from the left. If it was not actually at equilibrium, the value for the moles of CH_3COOH remaining may be too high, resulting in an estimate of K lower than the actual accepted value.

Question 33

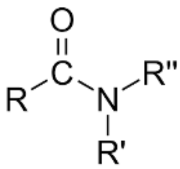
33.a.

Marking Criteria	Marks
• Draws the functional group.	**1**

$CONH_2$



or



33.b.

Marking Criteria	Marks
• States that the molecules shown could not react to form a condensation polymer with sound justification demonstrating knowledge of condensation polymerisation reactions and the requirements for each reacting molecule.	**3**
• States that the molecules shown could not react to form a condensation polymer with some justification demonstrating a basic knowledge of condensation polymerisation reactions and the requirements for each reacting molecule.	**2**
• Provides some relevant information.	**1**

The molecules could not undergo a condensation polymerisation reaction because they each contain only the 1 required functional group. The amide group on nicotinamide could react with the -OH in the carboxyl group on ethanolic acid, but this would only result in formation of a dimer. Since there are no functional groups of either end of the molecules, no further molecules can join to form a long-chained polymer.

For a polyamide to form, one molecule would need to be a diamide (have an amide group on each end of the molecule) and the other a dicarboxylic acid (containing a -COOH group at each end of the molecule).

33.c.

Marking Criteria	**Marks**
• Draws correct structural formula and names the by-product.	**2**
• Either draws the structural formula or names the by-product.	**1**

By-product: NH_3 (ammonia)

Question 34

Marking Criteria	Marks
• Specific evidence from all spectra used to justify chosen compound (2-methylpropanal). • Extensive understanding of each spectroscopic method demonstrated. • Correct name given. • Correct structure drawn.	**7**
• Demonstrates thorough understanding of each method to justify a structure.	**6**
• Refers to evidence from spectra that supports a named and drawn structure.	**4-5**
• Some understanding of the evidence from spectra demonstrated.	**2-3**
• Some relevant information.	**1**

Infrared

- Narrow features 2700–3000 cm^{-1} ⇒ C–H
- Large feature ~1725 cm^{-1} ⇒ C=O
- Nothing significant 3300–3500 cm^{-1} ⇒ no N–H
- No broad feature in the 2500–3550 cm^{-1} region: no O–H

Mass spectrum

- Parent ion at m/z = 72
- Base peak at 43
- Together these indicate cleavage to form fragments with masses of 43 and 29.
    - m=29 could be CH=O, which would mean that m=43 is from C_3H_7

Proton NMR

- 9.6ppm Doublet caused by 1 hydrogen atom. This is likely CH neighbouring CH.
- 1.1ppm Doublet caused by 6 hydrogen atoms. This is likely caused by two CH_3 groups bound to a CH.
- 2.4ppm Complicated multiplet caused by one hydrogen atom. This is the CH that is in between a COH and the $(CH_3)_2$.

So we have CH—CH—CH_3

|

CH_3

- The terminal CH does not have enough bonds, so it is likely the site of the double-bond to oxygen:

i.e., O=CH—CH—CH_3

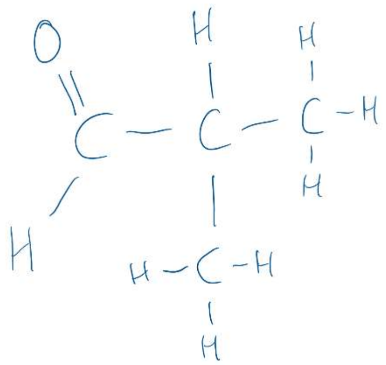
|

- CH_3

^{13}C NMR

- Three environments for carbon atoms.
- The peak at ~205 ppm indicates C=O in an aldehyde or ketone.
- The peak at ~41 ppm could be from a carbon atom that neighbours the C=O
- The peak at ~18 ppm could be from a carbon atom with only single bonds.

The structure that satisfies all the evidence from the spectra is that of 2-methylpropanal.



Looking back at the mass spectrum, we see the expected peaks for:

CHO at 29

CH_3 at 15 (small)

Loss of CH_3 at 57

The peak at m/z=41 is probably from C_3H_5 following the loss of the CHO fragment and two H atoms.