Student Number

Girraween High School

2022 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used

Total Marks: 100

Section I – 20 marks (pages 1 – 8)

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

Section II – 80 marks (pages 10 – 25)

- Attempt questions 21–30
- Allow about 2 hours and 25 minutes for this part

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.

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:

A ☒ B ☒ ← *correct* C ○ D ○

1 What is the principal intermolecular force that must be overcome when hexane (C_6H_{14}, BP = 69°C) is vaporised?

A. Hydrogen bonding

B. Covalent bonding between carbon atoms

C. Dipole-dipole forces

D. Temporary dipole-dipole forces

2 In which one of the following would the position of equilibrium **not** be affected by a volume change at constant temperature?

A. $2CO\,(g) + O_2(g) \rightleftharpoons 2CO_2(g)$

B. $C_2H_6\,(g) \rightleftharpoons C_2H_4\,(g) + H_2(g)$

C. $N_2O_4\,(g) \rightleftharpoons 2NO_2(g)$

D. $CO\,(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$

3 How many different compounds have the formula C_5H_{12}?

A. 1

B. 2

C. 3

D. 4

4 The solubility of magnesium chloride ($MgCl_2$) may be represented as X mol L^{-1}.

Which expression may be used to determine the solubility product, K_{sp} for magnesium chloride?

A X

B X^2

C $3X^2$

D $4X^3$

5 What is the pH of a 0.20 M solution of sodium benzoate, $Na(C_6H_5COO)$?
The K_a of benzoic acid, C_6H_5COOH, is 6.5×10^{-5}.

A. 5.26

B. 8.74

C. 9.09

D. 11.56

6 Methanoic acid and ethanoic acid are both weak acids with the following K_a values:

	K_a
methanoic acid (HCOOH)	1.82×10^{-4}
ethanoic acid (CH_3COOH)	1.74×10^{-5}

Two separate solutions were prepared, one of 0.1 mol L^{-1} methanoic acid and the other of 0.1 mol L^{-1} of ethanoic acid.

Which one of the following would be present at the highest concentration at 25° C?

A. CH_3COOH in the ethanoic acid solution

B. CH_3COO^- in the ethanoic acid solution

C. HCOOH in the methanoic acid solution

D. $HCOO^-$ in the methanoic acid solution

7 Two chemical reactions occur as follows:

$$CH_2{=}CHCH_2CH_2CH_3 + X \rightarrow \text{2-chloropentane}$$

$$\text{2-chloropentane} + \text{sodium hydroxide solution} \rightarrow Y$$

X and Y are given by

	X	Y
A.	Cl_2	$CH_3CH_2CH_2CHOHCH_3$
B.	HCl	$CH_3CH_2CH_2CHOHCH_3$
C.	Cl_2	$CH_3CH_2CH_2CH_2CH_2OH$
D.	HCl	$CH_3CH_2CH_2CH_2CH_2OH$

8 The following table shows the value of the autoionisation constant of pure water at various temperatures and at a constant pressure.

Temperature (°C)	0	25	50	75	100
K_w	1.1×10^{-15}	1.0×10^{-14}	5.5×10^{-14}	2.0×10^{-13}	5.6×10^{-13}

Given this data, which one of the following statements about pure water is correct?

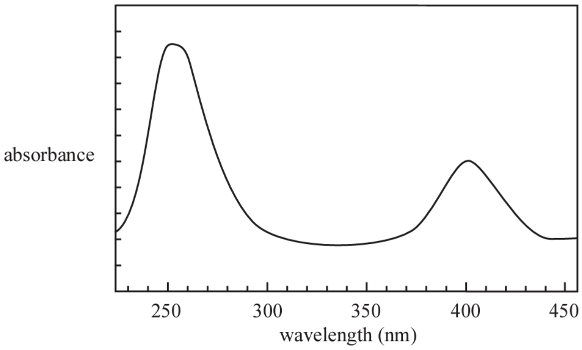
A. The $[OH^-]$ will decrease with increasing temperature.

B. The $[H_3O^+]$ will increase with increasing temperature.

C. Its pH will increase with increasing temperature.

D. Its pH will always be exactly 7 at any temperature.

9



The UV-visible spectrum of a certain compound is shown above. 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 used
III The spectrum is a result of electrons falling back from higher to lower electron 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 following statements are true?

A. I and II

B. II and III

C. I, II and III

D. I, II and IV

10 If Solution X has a pH of 3 and Solution Y has a pH of 6, we can conclude that

A. $[H^+]$ in Solution X is 1000 times that of $[H^+]$ in Solution Y.

B. $[H^+]$ in Solution X is half that of $[H^+]$ in Solution Y.

C. $[OH^-]$ in Solution Y is twice that of $[OH^-]$ in Solution X.

D. Solution Y must contain a stronger acid than Solution X.

11 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. Each solution will react completely with 10.0 mL of 0.10 M NaOH solution.

D. The concentration of H_3O^+ ions will be greater in the CH_3COOH solution.

12 The indicator HIn is used in a titration between hydrochloric acid and magnesium hydroxide solutions. The following equation represents how the indicator works.

$$\underset{\text{green}}{HIn(aq)} \leftrightharpoons H^{+}(aq) + \underset{\text{purple}}{In^{-}(aq)}$$

The indicator is added to 20.0 mL of magnesium hydroxide solution in a conical flask and the hydrochloric acid is added via a burette until the end point is observed. The acidic and basic solutions are of similar concentrations and the flask is swirled continuously as the acid is added.

Which one of the following statements describes the expected observations for the colour of the solution in the conical flask?

A. solution starts green and turns purple after the addition of approximately 10 mL

B. solution starts green and turns purple after the addition of approximately 40 mL

C. solution starts purple and turns green after the addition of approximately 10 mL

D. solution starts purple and turns green after the addition of approximately 40 mL

13 Which of the following compounds forms a 0.100 mol L^{-1} aqueous solution with a pH closest to 7.00?

A. sodium ethanoate

B. ethanol

C. ethanamine

D. 2,3-dihydroxypropanoic acid

14 The halogenation of a 2-methylbut-2-ene with iodine will produce:

A. 1,2-iodo-2-methylbutane

B. 2,3-diiodo-2-methylbutane.

C. 2,3-iodo-2-methylbutane

D. 2,3-diiodopentane

15 Which of the following will decrease [Cl^-] in a saturated solution of $PbCl_2$?

I. Addition of a small amount of water
II. Addition of a small amount of $AgNO_3$*(aq)*

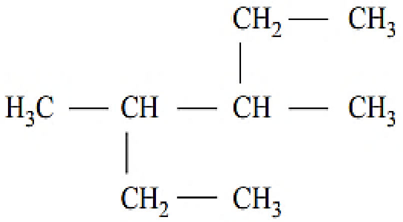
A. I only

B. II only

C. Both I and II

D. Neither I nor II

16 What is the correct systematic name for the following compound?



$$\begin{array}{ccccccc} & & & & CH_2 & - & CH_3 \\ & & & & | & & \\ H_3C & - & CH & - & CH & - & CH_3 \\ & & | & & & & \\ & & CH_2 & - & CH_3 & & \end{array}$$

A. 2-ethyl-3-methylpentane

B. 3-methyl-4-ethylpentane

C. 3,4-dimethylhexane

D. 2,3-diethylbutane

Questions 17 and 18 refer to the following equilibrium:

Propanone (C_3H_6O) can be made from propan-2-ol using a copper-zinc catalyst.

$$C_3H_8O\ (g) \rightleftharpoons C_3H_6O\ (g) + H_2\ (g) \qquad \Delta H = -54\ \text{kJ mol}^{-1}$$

17 At equilibrium at a particular temperature, 10% of the propan-2-ol is converted to propanone. In order to increase the percentage yield of propanone at equilibrium, you should

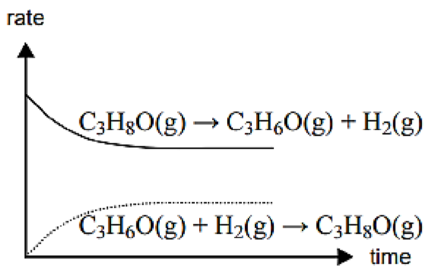
A. lower the temperature and lower the pressure.

B. lower the temperature and raise the pressure.

C. raise the temperature and lower the pressure.

D. raise the temperature and raise the pressure.

18 When propan-2-ol reacts to form an equilibrium mixture with propanone and hydrogen, which one of the following best represents how the rates of the forward and backwards reactions change over time?



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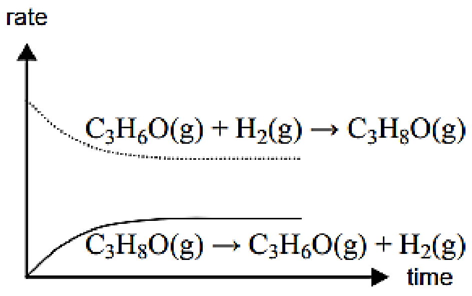

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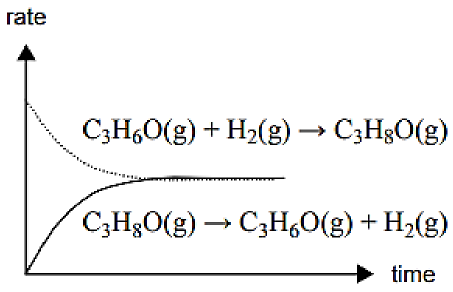

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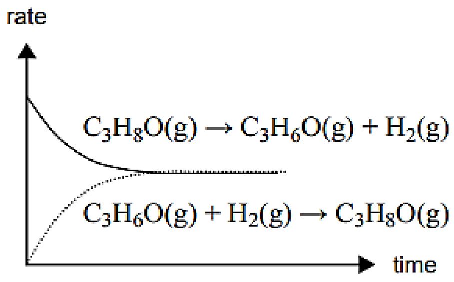
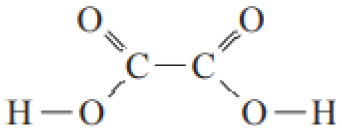


D

19 The structure of oxalic acid is shown below.



A 25.0 mL solution of oxalic acid reacts completely with 15.0 mL of 2.50 M NaOH.

The concentration of the oxalic acid solution is

A. 0.667 M

B. 0.750 M

C. 1.33 M

D. 1.50 M

20 A 20.0 mL aliquot of a solution of sodium propanoate (C_2H_5COONa) was titrated with a standardised 0.1042 M solution of HCl. The titre volume was 21.20 mL. The pK_a of propanoic acid is 4.87.

Which of the following is closest to the pH at equivalence point?

A. 3.02

B. 2.92

C. 2.93

D. 3.08

End of Section I

Student Number								

2022 Higher School Certificate Trial Examination

Chemistry

Section I – Multiple Choice Answer Sheet

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

Sample 1: 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 change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ***correct*** and drawing an arrow as follows.

A ○ **B** ○ **C** ~~●~~ **D** ~~●~~ ← correct

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

2022 Higher School Certificate Trial Examination

Examiner's Use Only		

Student Number	
Section I / 20	
Q. 21 – 23 /24	
Q 24-26 /24	
Q 27-30 /32	
Total /100	

Chemistry

Section II

80 marks
Attempt Questions 21 – 30
Allow about 2 hours 25 minutes for this section

Instructions

- Write your student number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations
- Extra writing paper is available, please raise your hand to request more paper. If you use extra paper, clearly indicate your student number and which question you are answering.

Please turn over

Question 21 (12 marks)

In an experiment, 1.0 mol of pure phosgene, $COCl_2$, is placed in a 3.0 L flask where the following reaction takes place:

$$COCl_2\,(g) \rightleftharpoons CO\,(g) + Cl_2\,(g) \qquad\qquad K_{eq} = 2.1 \times 10^{-8}$$

a) It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol. On the basis of the data provided, explain why this assumption is justified. **2**

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b) Calculate the equilibrium concentration, in mol L^{-1}, of carbon monoxide, CO. Assume that the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol. **3**

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c) What is the equilibrium concentration of chlorine gas? **1**

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Question 21 continues on the next page

Question 21 (continued)

In another experiment, carbon monoxide and chlorine were placed in a sealed flask and allowed to reach equi1ibrium. Phosgene was formed.

The temperature, pressure and volume were initially the same as in part (a) above.

d) Given the information in part (a), what is the equilibrium constant for this reaction? **1**

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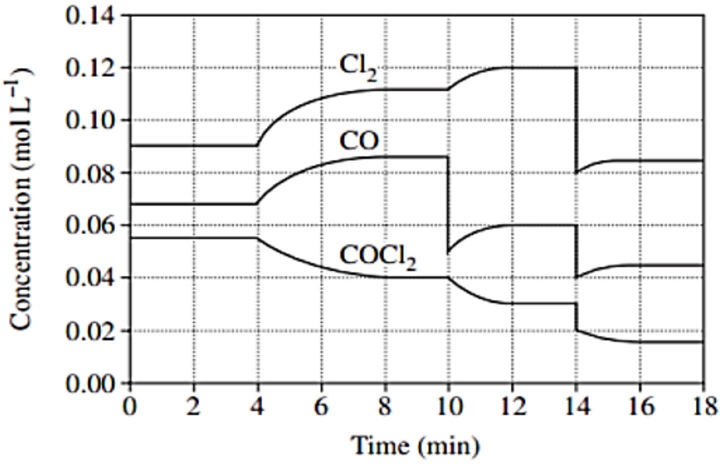
The graph below shows how the concentrations of reactants and products vary with time.

$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \quad \Delta H = +108 \text{ kJ}$



e) Identify the changes applied to the equilibrium at: **2**

Time = 10 minutes ………………………………………………………………………

Time = 14 minutes ………………………………………………………………………

f) Explain, using collision theory, the reason for the change at time = 4 minutes. **3**

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Question 22 (7 marks)

At a particular temperature, a saturated aqueous solution of $Ca(OH)_2$ has pH = 12.40.

a) What is the concentration of hydroxide ions in this solution? **2**

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b) What is the K_{sp} of $Ca(OH)_2$ at this temperature? **2**

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c) A sample of $Ca(OH)_2$ is suspended in 100.0 mL of water. The mixture is stirred vigorously and 3 M sulfuric acid is added dropwise to it while monitoring the pH of the solution. At the point that the pH reaches 7.0, there is solid calcium sulfate suspended in the solution. **3**

Write an equation for the reaction of sulfuric acid and calcium hydroxide.

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Explain why calcium sulfate solid, but not calcium hydroxide, is present when the pH reaches 7.0.

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Question 23 (5 marks)

Some rocks were thought to consist of insoluble silica (SiO_2) and calcium carbonate ($CaCO_3$). The fraction of $CaCO_3$ in an 8.64 g sample of the crushed rock was determined by mixing the sample with excess hydrochloric acid. The acid reacts with $CaCO_3$ according to the following equation.

$$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The resulting solution was filtered and the SiO_2 that was collected was washed and dried. The mass of SiO_2 was found to be 1.55 g.

a) Calculate the expected percentage of $CaCO_3$ in the original rock sample. **2**

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b) In order to check the result from part a), excess ammonium oxalate solution was added to the filtered solution. The calcium ions present precipitate as $CaC_2O_4.H_2O$. **3**

The $CaC_2O_4.H_2O$ was collected by filtration, washed and dried. It was then heated to convert it to CaO and a mass of 3.87 g was obtained.

Calculate the percentage of $CaCO_3$ in the rock sample from this data.

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Question 24 (15 marks)

Industrially, ethanol, C_2H_5OH, is made by either of two methods.
One method uses ethene (ethylene), C_2H_4, which is derived from crude oil. The other method uses a sugar such as sucrose, $C_{12}H_{22}O_{11}$, and yeast in aqueous solution.

The production of C_2H_5OH from $C_{12}H_{22}O_{11}$ and yeast proceeds according to the equation

$$C_{12}H_{22}O_{11}\,(aq) + H_2O\,(l) \rightarrow 4C_2H_5OH\,(aq) + 4CO_2\,(g)$$

a) Determine the mass, in grams, of pure C_2H_5OH that would be produced from 1.25 kg of $C_{12}H_{22}O_{11}$ dissolved in water. **1**

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b) How is ethanol derived from ethene? Include a balanced equation in your response and identify the type of reaction. **3**

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c) C_2H_5OH can be converted into ethanoic acid, CH_3COOH, in the presence of Reagent X. Identify Reagent X and identify this type of reaction. **2**

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Question 23 continues on the next page

Question 24 (continued)

d) Ethanol is described as a primary alcohol. **3**
Draw the structure of 2-methylpropan-2-ol, classify it as a primary, secondary or tertiary alcohol and explain your classification.

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e) Describe how tertiary alcohols can be distinguished from primary and secondary alcohols in the laboratory. **2**

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f) Outline the benefits and problems of using ethanol produced from sugars as a biofuel replacement for fuels based on petroleum. **4**

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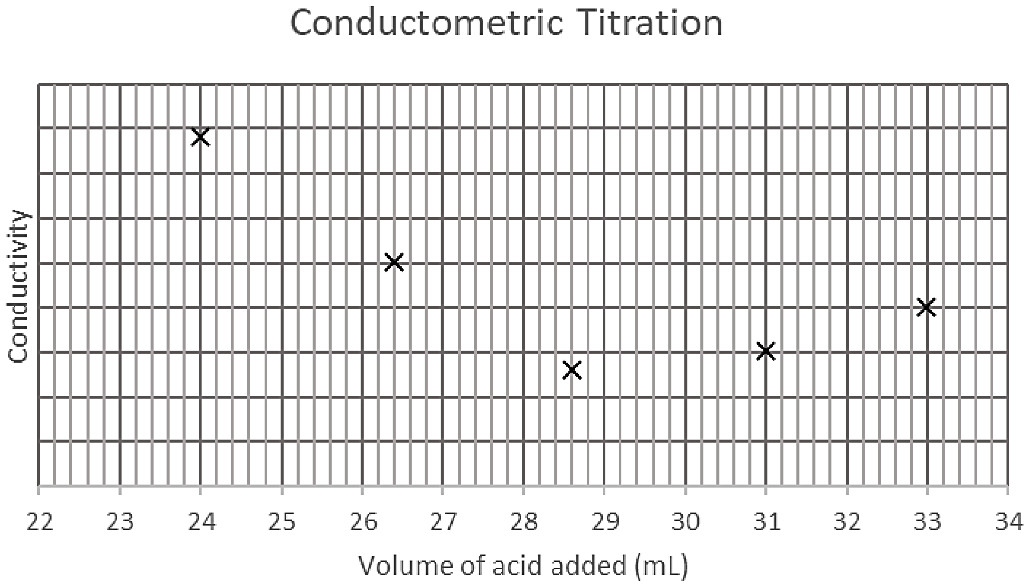
Question 25 (6 marks)

A conductometric titration was carried out using 25.00 mL of barium hydroxide and 0.100 mol^{-1} sulfuric acid. Conductivity measurements were recorded at five different intervals and the results plotted on the graph below.



a) Using information from the graph, calculate the concentration of the barium hydroxide solution. Include a suitable chemical equation in your answer. **3**

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Question 25 continues over the page

Question 25 (continued)

b) The titration was performed in a thermally insulated vessel. The sulfuric acid and barium hydroxide solutions were 20.2ºC at the start of the titration. **3**
The enthalpy of neutralisation is -57.6 kJ mol^{-1}.

Calculate the final temperature of the solution when 40.0 mL of the acid is added to 25.00 mL of the base.

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End of Question 25.

Question 26 is on the following page.

Question 26 (3 marks)

A sample of an unknown metal salt is to be analysed. The cation in the metal salt is known to be one of Ba^{2+}, Ca^{2+}, Mg^{2+} or Cu^{2+} and the anion is known to be one of Cl^-, OH^-, CO_3^{2-} or SO_4^{2-}. **3**

The metal salt is dissolved in water and the resulting colourless solution is divided into four equal samples to be tested, labelled A, B, C and D. The results of the tests are shown in the table. Note: silver sulfate is soluble in dilute acid.

	Test(s) conducted	*Result*
Sample A	A solution of NaOH is added.	A white precipitate forms.
Sample B	Test 1: A dilute solution of HNO_3 is added.	There is no visible reaction.
	Test 2: A solution of $AgNO_3$ is added.	There is no visible reaction.
Sample C	Test 1: A solution of $BaCl_2$ is added.	A white precipitate forms.
	Test 2: A solution of HCl is added.	There is no visible reaction.
Sample D	A small sample of the solution was heated in the flame of a Bunsen burner.	The flame of the Bunsen burner does not change colour.

Identify the metal salt. Support your answer with at least ONE net ionic equation.

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Question 27 (5 marks)

Some properties of but-1-ene, 1-fluoropropane, propan-1-ol and ethanamide are shown in the table. **5**

Compound	*Molar mass (g mol-1)*	*Solubility in water*
But-1-ene	56	insoluble
1-fluoropropane	62	Slightly soluble
Propan-1-ol	60	soluble
Ethanamide	59	soluble

Explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram.

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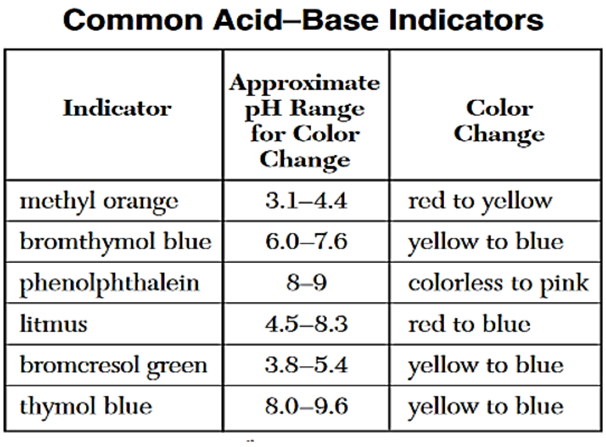
Question 28 (8 marks)



Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.1–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8–9	colorless to pink
litmus	4.5–8.3	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

a) Which of the above indicators could be used to distinguish between solutions of 0.1 mol L^{-1} sodium hydroxide and 0.1 mol L^{-1} hydrochloric acid? Justify your answer. **2**

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b) A student claims that thymol blue can be used to distinguish between weak and strong bases. Assess this claim. **2**

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Question 28 continues over the page

Question 28 (continued)

c) Explain, using examples of titrations, why different titrations require the use of different acid-base indicators. Include a sketch of a titration curve in your answer. **4**

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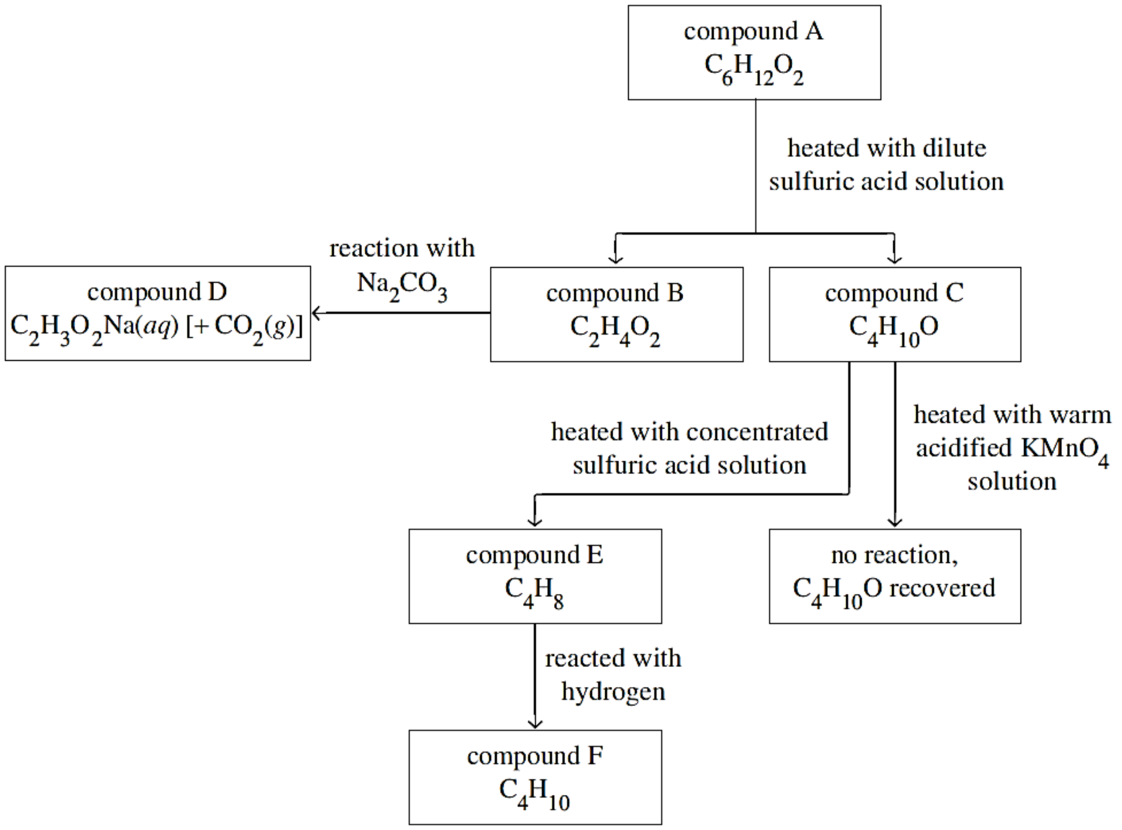
End of Question 28

Question 29 is on the following page

Question 29 (7 marks)

7

The flow chart shows reactions involving six different organic compounds, A–F.



Draw the structural formula of compounds A–F and use the information provided to justify your answers.

Compound	*Structural formula*	*Justification*
A		
B		

Question 29 continues on the next page

Question 29 (continued)

C		
D		
E		
F		

Question 30 (12 marks)

Wines and other alcoholic drinks can spoil when the alcohol (ethanol) they contain oxidises to acetic acid (ethanoic acid). An acidity regulator, monosodium citrate, is often added to drinks to prevent the formation of acetic acid. The monosodium citrate does this by acting as a buffer.

A citric acid/dihydrogen citrate ion buffer can be prepared from citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$.

a) Write an equation for the buffer system ($H_3C_6H_5O_7$ / $H_2C_6H_5O_7^-$) containing citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$. **2**

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Buffers that contain equal concentrations of both components are most effective. This buffer solution is prepared by mixing 100.0 mL of citric acid solution with 100.0 mL of monosodium citrate solution. The citric acid solution, $H_3C_6H_5O_7(aq)$, has a concentration of 0.200 mol L^{-1}.

b) Calculate the mass of monosodium citrate, $NaH_2C_6H_5O_7$, that would need to be dissolved in 100.0 mL of distilled water to make the most effective buffer solution. **3**

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c) If a citric acid buffer was prepared to a pH of 3.5, what would be the concentration of the hydroxide ion at 25.0°C? **3**

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Question 30 continues on the following page

Question 30 (continued)

d) Explain why only a small change in pH is observed in this buffer solution when a small amount of sodium hydroxide solution is added, compared to adding a similar amount of sodium hydroxide solution to a system that is not a buffer solution. Support your answer with at leas ONE chemical equation. **4**

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End of Examination

Extra paper

Extra paper

2022 YEAR 12 TRIAL EXAMINATION

CHEMISTRY – MARKING GUIDELINES

Section I

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

Section II – 80 marks

Question 21 (11 marks)
21 (a) (2 marks)

Criteria	Marks
- Explains that the equilibrium constant is very small AND - Explains that this means that the amount of $COCl_2$ reacted will not be significant when compared with 1.0 mole initially present	2
- Explains that the equilibrium constant is very small OR - Explains that this means that the amount of $COCl_2$ reacted will not be significant when compared with 1.0 mole initially present	1

Sample answer

The equilibrium constant is extremely small so the amount of CO and Cl_2 produced and amount of $COCl_2$ reacted in getting to equilibrium is so small that (to two significant figures) the number of moles of $COCl_2$ at equilibrium will still be approximated to 1.0 mol.

21 (b) (3 marks)

Criteria	Marks
- Correct answer	3
- Incorrect answer but with correct $[COCl_2\,(g)]$ AND correct expression for K_{eq}	2
- Incorrect answer but with correct $[COCl_2\,(g)]$ OR correct expression for K_{eq}	1

Sample answer

At equilibrium,

$$K_a\ COCl_2\ (g) = \frac{[CO\ (g)]\,[Cl_2\ (g)]}{[COCl_2\ (g)]} = 2.1 \times 10^{-8}$$

If $[CO] = [Cl_2] = y$ mol/L and $[COCl_2\ (g)] = 1.0/3$ mol/L (since the volume is 3.0 L)

$K_a\ COCl_2\ (g) = [y]\,[y] / 0.333 = 2.1 \times 10^{-8}$

$y^2 = 2.1 \times 10^{-8} \times 0.333$

$y = \sqrt{(2.1 \times 10^{-8} \times 0.333)}$ mol/L

$y = 8.4 \times 10^{-5}$ mol/L

Hence $[CO] = 8.4 \times 10^{-5}$ mol/L (which is small by comparison with 1.0 mol, so the original assumption was correct).

21 (c) (1 mark)

Criteria	Mark
• Recognises that [$Cl_2(g)$] = [$CO(g)$]	1

Sample answer

The equilibrium concentration of Cl_2 is the same as [$CO(g)$]= 8.4×10^{-5} mol/L
Any other value even close to this is not accepted.

21 (d) (1 mark)

Criteria	Mark
• Calculates the equilibrium constant	1

Sample answer

$K_{eq} = 1/(2.1 \times 10^{-8}) = 0.476 \times 10^{8} = 4.8 \times 10^{7}$

21 (e) (2 marks)

Criteria	Marks
• Identifies the changes applied to the equilibrium at t= 10 minutes AND t=14 minutes	2
• Identifies the changes applied to the equilibrium at t= 10 minutes OR t=14 minutes	1

Sample answer

At time = 10 minutes, CO is removed from the equilibrium.
At time = 14 minutes, the volume of the container is increased by a third, so the concentration of the gases is reduced by a third.

21 (f) (3 marks)

Criteria	Marks
• Identifies the change at t=4min • Explains, using collision theory, the reason for the change at t=4min	3
• Identifies the change at t=4min • Attempts to explain the reason for the change at t=4min	2
• Identifies the change at t=4min	1

Sample answer

Sample answer

At time = 4 minutes the temperature is increased. The forward reaction is endothermic and the concentrations of the products, CO and Cl_2 have increased so an increase in temperature must have occurred. (1 mark)
This result because an endothermic reaction has a greater activation energy than the backward and a temperature increase results in a greater proportion of particles of $COCl_2$ having sufficient energy to react than for the exothermic reaction (CO and Cl_2).
States that since forward reaction is endothermic, greater number of $COCl_2$ molecules acquired activation energy as compared to CO and Cl_2 molecules due to high activation energy. (1 mark)
States that there are greater number of successful collisions between $COCl_2$ molecules thus favouring the forward reaction. (1 mark)

(Once a new equilibrium is achieved at a higher temperature and the rates of both forward and backward reactions have equalised, there are more of the products of the reaction than previously)

Question 22 (7 marks)

22 (a) (2 marks)

Criteria	Marks
• Correctly calculates [OH^-]	2
• Correctly calculates the pOH	1

Sample answer

pH = 12.40, so pOH = 14.00 – 12.40 = 1.60

[OH^-] = 10^{-pOH} = $10^{-1.60}$ = 0.025 mol/L (only 2 s.f. justified)

(full answer = 0.02511886432M)

22 (b) (2 marks)

Criteria	Marks
• Correct answer, with correct reasoning and full working	2
• Some evidence of correct understanding of how to determine [OH^-]	1

Sample answer

Let the solubility of $Ca(OH)_2$ be s.

K_{sp} $Ca(OH)_2 = [Ca^{2+}] [OH^-]^2$

If $[Ca^{2+}] = 0.5 \times 0.025$

$[OH^-] = 0.025$

K_{sp} $Ca(OH)_2 = [Ca^{2+}] [OH^-]^2 = (0.5 \times 0.025)(0.025)^2 = 7.8 \times 10^{-6}$

(unrounded answer = $7.924465962 \times 10^{-6}$)

K_{sp} $Ca(OH)_2 = [Ca^{2+}] [OH^-]^2 = (0.5 \text{ x } 0.025) \text{ x } (0.025)^2 = 7.8 \text{ x } 10^{-6}$

22 (c) (3 marks)

Criteria	Marks
• Writes a correct equation • Explains that all the hydroxide ions from calcium hydroxide have been neutralised by the H_2SO_4 when pH reaches 7 – **C** • Explains that calcium sulfate solid is insoluble and hence will exist and it is a neutral salt so will not react further with water – **E**	3
• TWO of the above	2
• ONE of the above	1

Sample answer

$Ca(OH)_2\ (s) + H_2SO_4\ (aq) \rightarrow CaSO_4\ (s) + 2H_2O\ (l)$

At pH =7, all the calcium hydroxide has been neutralised by the sulfuric acid. No free hydroxide ions from calcium hydroxide remain.

The resultant solution contains calcium ions and sulfate ions. However, these react to form a precipitate of calcium sulfate. The salt is neutral and does not react further with the water to maintain the pH of 7.

Question 23 (5 marks)

23 (a) (2 marks)

Criteria	Marks
• Correct answer with full working	2
• Some correct steps	1

Sample answer

$$m(\text{CaCO}_3) = 8.64 - 1.55$$
$$= 7.09 \text{ g } *$$
$$\% \text{ CaCO}_3 = \frac{7.09}{8.64} \times 100$$
$$= 82.1\% *$$

23 (b) (3 marks)

Criteria	Marks
• Correct answer with full working • Answer reported to 3 sig figs	3
• Correct answer with full working	2
• Some correct steps	1

Sample answer

$$n(\text{CaO}) = \frac{3.87}{56.1}$$
$$= 0.0690 \text{ mol}$$

1 mark

$$n(\text{CaCO}_3) = 0.0690 \text{ * mol}$$
$$m(\text{CaCO}_3) = 0.0690 \times 100.1$$
$$= 6.91 \text{ g}$$

1 mark

$$\% \text{ CaCO}_3 = \frac{6.91}{8.64} \times 100$$
$$= 79.9\% *$$

1 mark

Question 24 (15 marks)
24 (a) (1 mark)

Criteria	Mark
• Correct answer	1

Sample answer
MM $C_{12}H_{22}O_{11}$ = 342
342 g sucrose produces 184 g ethanol
Hence 1.25 kg sucrose produces (1.25/0.342) x 184 g ethanol = 673 g (3 s.f.)

24 (b) (3 marks)

Criteria	Marks
• Identifies the reaction requires a strong acid catalyst (diluted). • Outline the reaction is hydration/addition reaction where OH and H are added across the double bond. • Writes a correct equation showing the reversible arrow.	3
• TWO of the above	2
• ONE of the above	1

Sample answer

$$C_2H_4\,(g) + H_2O\,(g) \overset{\text{dil. strong acid}}{\rightleftharpoons} C_2H_6O\,(aq)$$

Ethanol is manufactured by reacting steam and ethene, in the presence of an acid catalyst to add the OH group and H across the double bond. The reaction is an addition/hydration reaction and is reversible with only a small % of the ethene converted into ethanol.

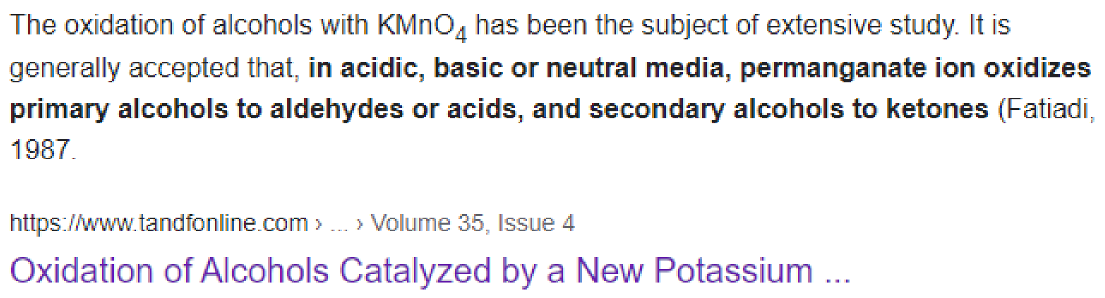
24 (c) (2 marks)

Criteria	Marks
• Identifies an oxidising agent such as acidified potassium dichromate or $KMnO_4$ (acidified/neutral/basic)/ chromic acid (H_2CrO_4) AND • Identifies the reaction as oxidation	2
• Identifies an oxidising agent such as acidified potassium dichromate OR • Identifies the reaction as oxidation	1

Sample answer
Ethanol is converted to ethanoic acid by oxidation using an oxidising agent such as acidified potassium dichromate solution.

Note: neutral sodium dichromate produces an aldehyde. Acidified dichromate promotes the overoxidation of the aldehyde to carboxylic acid. Hence answer MUST be $H^+/Cr_2O_7^{2-}$.
https://www.sciencedirect.com/topics/chemistry/sodium-dichromate

For $KMnO_4$, the oxidation of primary alcohol into acids under all conditions (acidic/ basic/neutral)



The oxidation of alcohols with $KMnO_4$ has been the subject of extensive study. It is generally accepted that, **in acidic, basic or neutral media, permanganate ion oxidizes primary alcohols to aldehydes or acids, and secondary alcohols to ketones** (Fatiadi, 1987.

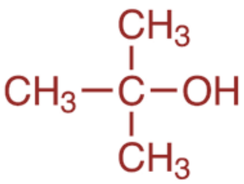
https://www.tandfonline.com › ... › Volume 35, Issue 4

Oxidation of Alcohols Catalyzed by a New Potassium ...

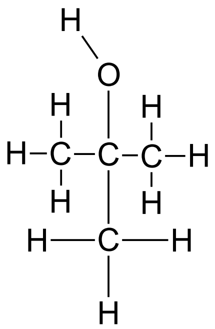
24 (d) (3 marks)

Criteria	Marks
• Draws the correct structure • Classifies the alcohol as a tertiary alcohol • Explains the classification of tertiary alcohols	3
• TWO of the above	2
• ONE of the above	1

Sample answer:



$$CH_3-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{C}}-OH$$



2-methylpropan-2-ol is a tertiary alcohol. Tertiary alcohols have the –OH group attached to a carbon which is attached to THREE other carbon atoms.

24 (e) (2 marks)

Criteria	Marks
• Identifies the reagent used and outline the expected observations for 1° & 2° alcohols; before & after. • Outline the expected observations for 3° alcohol; before & after.	2
• Outlines some correct information about the method or results	1

Sample answer (to be modified)

Primary, secondary and tertiary alcohols can be distinguished by experiments to oxidise the samples, using coloured oxidising agents such as acidified potassium permanganate or acidified potassium dichromate.

Primary & secondary alcohols can be oxidised to form alkanoic acids. The oxidising agent will change colour (from orange/dark yellow to green using acidified potassium dichromate). $H^+/KMnO_4$ can also be used. When heated, the purple $KMnO_4$ decolourises in the presence of 1° & 2° alcohols to colourless.

Tertiary alcohols are not oxidised by oxidising agents, so no change in colour of the oxidising agent occurs.

24 (f) (4 marks)

Outline the benefits and problems of using ethanol produced from sugars as a biofuel replacement for fuels based on petroleum.

Criteria	Marks
• Outlines at least 2 significant benefits and 2 significant problems of using ethanol as a biofuel	4
• Outlines at least 3 significant benefits or problems of using ethanol as a biofuel	3
• Outlines at least 2 significant benefits or problems of using ethanol as a biofuel	2
• Outlines 1 significant benefit or problem of using ethanol as a biofuel	1

Sample answer

Benefits of using Ethanol produced from sugars:

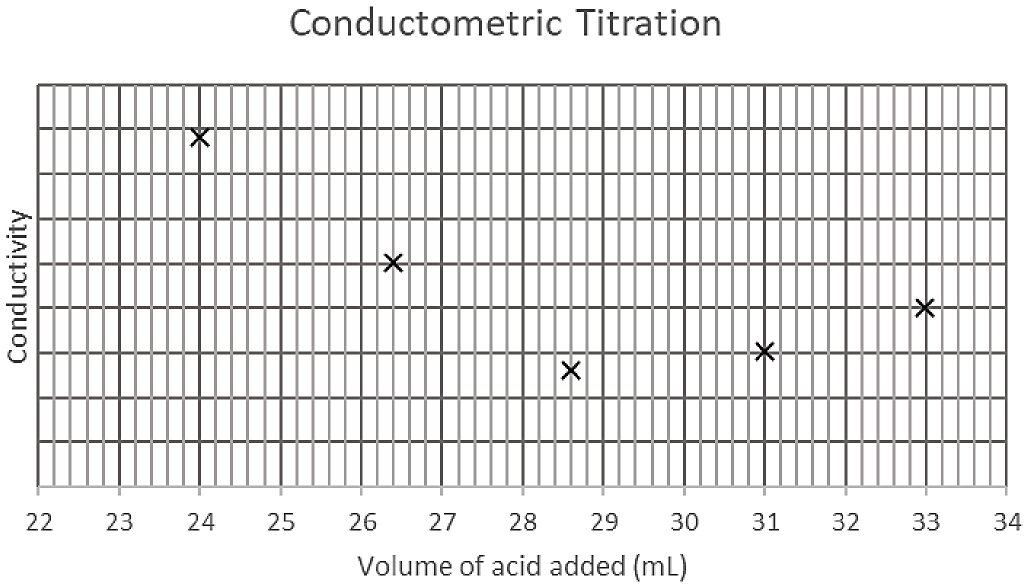
- It is a renewable fuel since it can be produced by fermentation of sugars from crops which can be grown and processed relatively quickly, unlike fuels based on petroleum which are non-renewable since they take millions of years to produce.
- When compared with octane (the main component of petroleum-based fuel used in vehicles), ethanol burns more cleanly, meaning it is less likely to produce toxic products of incomplete combustion such as particulates and carbon monoxide. This is due to the oxygen content of the fuel. (You can support this claim with correctly balanced equations)
- Although the combustion of ethanol produces CO_2 gas, this is offset by the CO_2 absorbed by the plants used to produce the fuel (through the process of photosynthesis). Hence the use of ethanol has less immediate impact on the greenhouse effect, climate change and hence the environment than fuels derived from petroleum.
- No need for mining/drilling which is harmful to the environment due to pollution and destruction of ecosystems.

Problems of using Ethanol produced from sugars:

- Ethanol is less energy-dense (34% less energy per volume) than octane, meaning that a greater volume of fuel is required to obtain the same amount of energy.
- The use of crops to provide sugar for the fermentation process can reduce the availability of arable land for food production. This can lead to higher prices for grain and food shortages in some countries.
- Destruction of ecosystems due to deforestation/land clearing which may be required to grow crops.
- Most vehicles cannot run on 100% ethanol, so vehicle modification is required if this is to be used as the main source of fuel.
- Fermentation is a slow process, and fractional distillation is required to separate ethanol from water. Time and energy requirements mean that production is relatively expensive.

Question 25 (6 marks

A conductometric titration was carried out using 25.00 mL of barium hydroxide and 0.100 mol^{-1} sulfuric acid. Conductivity measurements were recorded at five different intervals and the results plotted on the graph below.

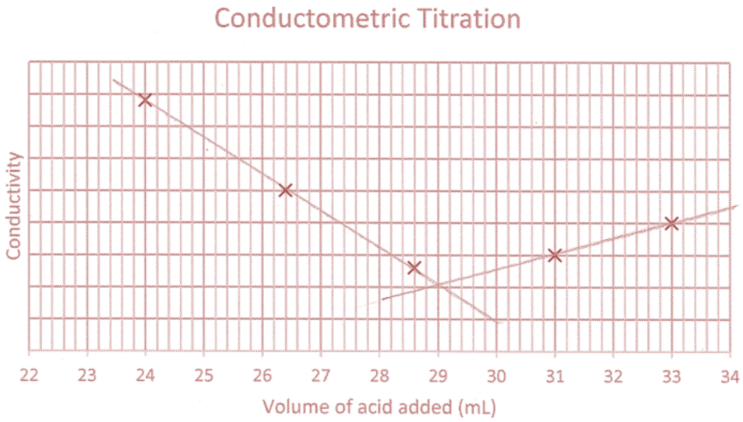


Using information from the graph, calculate the concentration of the barium hydroxide solution. Include a suitable chemical equation in your answer.

25 (a) (3 marks)

Criteria	Marks
- Volume of acid is determined from graph (29 ±0.2 mL) - $Ba(OH)_2$ concentration is calculated correctly - Correct balanced equation (including states) is included	3
- $Ba(OH)_2$ concentration is calculated using value from graph AND - Correct balanced equation (including states) is included	2
- $Ba(OH)_2$ concentration is calculated using value from graph OR - Correct balanced equation (including states) is included	1

Sample answer



Reaction equation:
$H_2SO_4\,(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4\,(s) + 2H_2O(l)$
29.0 mL of acid needed to completely react with $Ba(OH)_2$

$n(H_2SO_4) = c \times V = 0.100 \times 0.029 = 2.9 \times 10^{-3}$mol
$n(Ba(OH)_2) = 2.9 \times 10^{-3}$mol
$c(Ba(OH)_2) = n/V = 2.9 \times 10^{-3}/0.025 = 0.116$ mol L^{-1}

25 (b) (3 marks)

The titration was performed in a thermally insulated vessel. The sulfuric acid and barium hydroxide solutions were 20.2ºC at the start of the titration. The enthalpy of neutralisation is -57.6 kJ mol^{-1}.

Calculate the final temperature of the solution when 40.0mL of the acid is added to 25.00 mL of the base.

Criteria	Marks
• Correctly calculates the final temperature	3
• Calculates a final temperature using more than one correct process or calculation	2
• Calculates a final temperature using a correct process or calculation	1

Sample answer

Mol H_2SO_4 reacted at endpoint = 2.9×10^{-3}mol (from part (a))
Mol water formed = $2 \times 2.9 \times 10^{-3}$mol = 0.0058 mol
∴ energy released = $0.0058 \times 57.6 = 0.33408$ kJ = 334.08 J
Total volume of mixture = 25 + 40 = 65 mL =65 g
$\Delta H = mC\Delta T$
$334.08 = 65 \times 4.18 \times \Delta T$
$\Delta T = 334.08/271.7 = 1.23$ºC
∴ final temperature = 21.4 ºC

Question 26 (3 marks)

A sample of an unknown metal salt is to be analysed. The cation in the metal salt is known to be one of Ba^{2+}, Ca^{2+}, Mg^{2+} or Cu^{2+} and the anion is known to be one of Cl^-, OH^-, CO_3^{2-} or SO_4^{2-}

The metal salt is dissolved in water and the resulting colourless solution is divided into four equal samples to be tested, labelled A, B, C and D. The results of the tests are shown in the table. Note: silver sulfate is soluble in dilute acid.

A sample of an unknown metal salt is to be analysed. The cation in the metal salt is known to be one of Ba^{2+}, Ca^{2+}, Mg^{2+} or Cu^{2+} and the anion is known to be one of Cl^-, OH^-, CO_3^{2-} or SO_4^{2-}

	Test(s) conducted	*Result*
Sample A	A solution of NaOH is added.	A white precipitate forms.
Sample B	Test 1: A dilute solution of HNO_3 is added.	There is no visible reaction.
	Test 2: A solution of $AgNO_3$ is added.	There is no visible reaction.
Sample C	Test 1: A solution of $BaCl_2$ is added.	A white precipitate forms.
	Test 2: A solution of HCl is added.	There is no visible reaction.
Sample D	A small sample of the solution was heated in the flame of a Bunsen burner.	The flame of the Bunsen burner does not change colour.

Criteria	**Marks**
• Identifies the metal salt AND • Includes ONE relevant net ionic equation	3
• Identifies either the anion OR cation in the metal salt AND • Includes ONE relevant net ionic equation	2
• Provides some relevant information	1

Sample answer

The metal salt is magnesium sulfate. The metal salt is colourless and, therefore, cannot be a copper salt. Calcium salts will give a positive red flame test and barium compounds will give a positive green flame test. Therefore, the flame test eliminates these two cations, leaving magnesium as the only remaining option. Magnesium hydroxide is insoluble; therefore, as the metal salt is soluble, it cannot be magnesium hydroxide. The failure of sample B to give a precipitate eliminates magnesium chloride as a possibility.

The precipitate formed by sample A is magnesium hydroxide:

$Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$

The precipitate formed by sample C is barium sulfate:

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

The compound is not a carbonate as sample C does not produce bubbles of gas when HCl is added. Therefore, the metal salt must be magnesium sulfate.

Question 27 (5 marks)

Some properties of but-1-ene, 1-fluoropropane, propan-1-ol and ethanamide are shown in the table

Compound	*Molar mass (g mol^{-1})*	*Solubility in water*
but-1-ene	56	insoluble
1-fluoropropane	62	slightly soluble
propan-1-ol	60	soluble
ethanamide	59	soluble

Explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram.

Criteria	**Marks**
• Demonstrates extensive knowledge and understanding of water solubility in terms of all solvent/solute interactions. • Explains different solubilities of all compounds • Includes complete and correctly labelled diagram showing solute/solvent interactions	5
• Demonstrates knowledge and understanding of water solubility in terms of solvent/solute interactions. • Explains different solubilities of all compounds • Includes complete and correctly labelled diagram showing solute/solvent interactions	4
• Explains different solubilities of all or most compounds with some understanding of solvent/solute interactions. • Includes a diagram	3-2
• Provides some relevant information	1

Sample answer

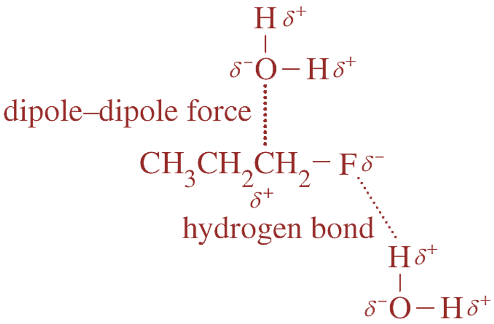
For a compound to be soluble in water, the attractive forces between the compound molecule and water molecules must be strong enough to overcome the strong hydrogen bonding between water molecules. The molecule must be able to form significant attractive interactions (hydrogen bonds) with water molecules.

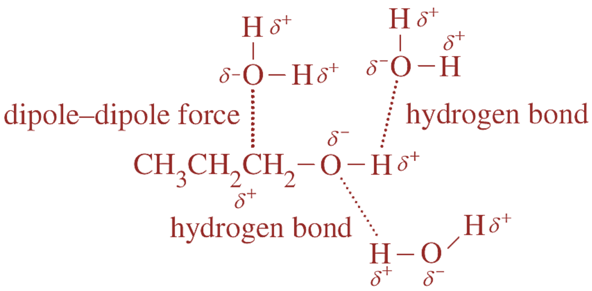
As all of these compounds are have a similar molar mass, the size of their dispersion forces is similar, and this will not determine the different solubilities.

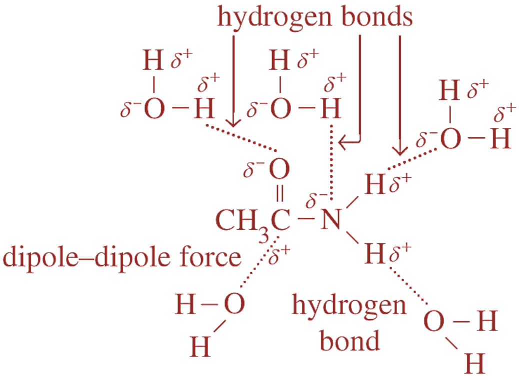
But-1-ene, being non-polar, can only form dispersion forces between molecules. These dispersion forces are not strong enough to overcome the strong hydrogen bonds between water molecules, nor is it able to form hydrogen bonds with water. Therefore, but-1-ene is insoluble in water.

1-fluoropropane contains a polar C-F bond due to the electronegativity of F. This enables the molecule to form only weak dipole-dipole forces with water molecules. These are not sufficiently strong enough to overcome hydrogen bonds between water molecules, so the compound is only slightly soluble in water.

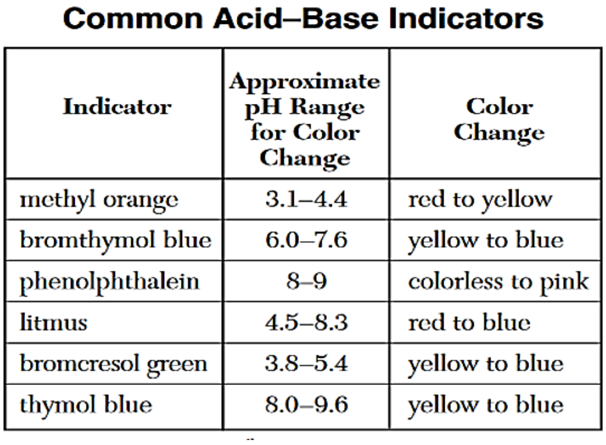
Due to the presence of polar O-H bonds, propan-1-ol can form dipole–dipole forces as well as strong hydrogen bonds with water. Ethanamide contains the polar carbonyl group as well as polar N-H bonds, meaning that it too can form both dipole-dipole forces and hydrogen bonds with water. Both molecules can act as both hydrogen bond-donors and acceptors, meaning that they can form a large number of hydrogen bonds with water molecules, making them soluble.







Question 28 (8 marks)
28(a) (2 marks)



Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.1–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8–9	colorless to pink
litmus	4.5–8.3	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

Which of the above indicators could be used to distinguish between solutions of 0.1 mol L^{-1} sodium hydroxide and 0.1 mol L^{-1} hydrochloric acid? Justify your answer.

Criteria	Marks
- Identifies that all 6 indicators can be used to distinguish between 0.1 M solutions of sodium hydroxide and hydrochloric acid AND	2

- Justifies this on the basis of the pH values of 13 and 1 for NaOH and HCl respectively	
- Identifies that all 6 indicators can be used to distinguish between 0.1 M solutions of sodium hydroxide and hydrochloric acid OR - Correctly identifies the pH values of 13 and 1 for NaOH and HCl respectively	1

Sample answer

All 6 indicators would distinguish between hydrochloric acid (pH = 1) and sodium hydroxide (pH = 13) solutions.
Methyl orange would be red at pH = 1 and yellow at pH = 13
Bromothymol blue would be yellow at pH = 1 and blue at pH = 13
Phenolphthalein would be colourless at pH = 1 and pink at pH = 13
Litmus would be red at pH = 1 and blue at pH = 13
Bromocresol green would be yellow at pH = 1 and blue at pH = 13
Thymol blue would be yellow at pH = 1 and blue at pH = 13

28 (b) (2 marks)

Criteria	Marks
- Indicates that thymol blue can only distinguish between solutions with pH < 8.0 and > 9.6 and can indicate that a solution is within the 8.0 – 9.6 pH range AND - Indicates that thymol blue cannot distinguish between weak and strong bases unless the concentration of the solution is known	2
- Indicates that thymol blue can only distinguish between solutions with pH < 8.0 and > 9.6 and can indicate that a solution is within the 8.0 – 9.6 pH range OR - Indicates that thymol blue cannot distinguish between weak and strong bases unless the concentration of the solution is known	1

Sample answer

The claim is not correct. The concentrations of the 2 bases to be distinguished need to be known. A concentrated strong base such as sodium hydroxide (at pH = 10) would be blue using thymol blue indicator. It could be distinguished from a dilute solution of a weak base (between pH values of 7.2 and 8.0) as the indicator would be yellow in this range. However, if the weak base had a pH above 9.6 (such as ammonia solution) it could not be distinguished from sodium hydroxide using this indicator. If the 2 bases are known to have the same concentration, then thymol blue could be used to distinguish between them as long as one had a pH < 8.0 and the other had pH > 9.6.

28 (c) (3 marks)

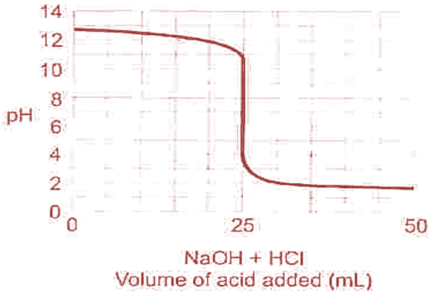
Criteria	Marks
- Explains that an indicator must be chosen so that its colour change occurs at the equivalence point of the titration (i.e. when the end-point = equivalence point) - Gives examples of at least 2 titrations with different equivalence points and explains which indicator should be used for each example	4

- Explains why the pH at the equivalence point differs for each of these titrations in terms of the pH of the salt solution at the equivalence point - Includes appropriate sketch of titration curve	
- THREE of the above	3
- TWO of the above	2
- ONE of the above	1

Sample answer

An indicator used in an acid-base titration must be chosen so that its colour change occurs at the equivalence point of the titration. This means that the end-point (when one stops titrating) and the equivalence point (when the same number of moles of acid has been added to base as is shown in the balanced equation) occur at the same point in the titration. A valid result from the quantitative technique is then possible.

For strong acid – strong base titrations, such as sodium hydroxide against hydrochloric acid, the pH at the equivalence point is 7. The salt formed in this titration is sodium chloride. As neither the sodium ion nor the chloride ion can act as an acid or base with water, the solution remains neutral. So an indicator such as litmus solution or bromothymol blue must be chosen, as these indicators change colour at pH = 7.

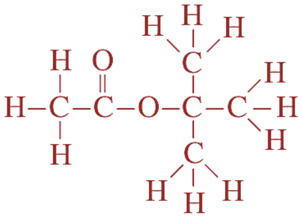


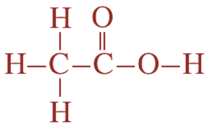
For a strong base – weak acid titration, such as sodium hydroxide against acetic acid, the pH at the equivalence point is close to 9. The indicator which changes colour in this range is phenolphthalein (in the range pH 8.3 – 10.0). An indicator which changes colour outside this range would not give a true indication of the equivalence point. The equivalence point in this titration is at pH 9 because the salt, sodium acetate, produces an alkaline solution.

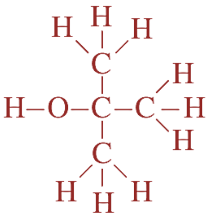
Question 29 (7 marks)

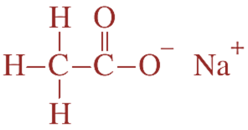
Criteria	Marks
• Draws the structural formulae for all SIX compounds AND • Provides a justification for all SIX compounds	7
• Draws the structural formulae for most compounds with relevant justifications	6
• Draws the structural formulae for some compounds with relevant justifications OR • Draws the structural formulae for all SIX compounds without relevant justification	5-4
• Identifies some of the compounds OR • Draws the structural formulae for some compounds	3-2
• Provides some relevant information	1

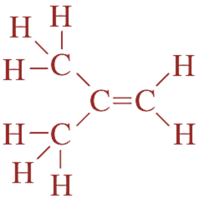
Sample answer

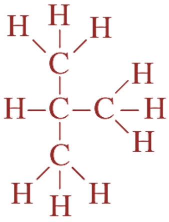
Compound A	
Structural formula	*Justification*
	Compound A is the ester 2-methyl-2-propyl ethanoate, as this will hydrolyse to yield ethanoic acid and 2-methylpropan-2-ol.

Compound B	
Structural formula	*Justification*
 CH_3COOH	Compound B reacts with Na_2CO_3 to give a sodium salt plus carbon dioxide gas. This is consistent with the compound being ethanoic acid.

Compound C	
Structural formula	*Justification*
	Alkene E was formed from the dehydration of compound C, suggesting that compound C is an alkanol. Compound C resists oxidation with an acidified permanganate solution, indicating that compound C is a four-carbon tertiary alkanol. The only possible four-carbon tertiary alkanol is 2-methylpropan-2-ol.

Compound D	
Structural formula	*Justification*
 $CH_3COO^- \ Na^+$	Compound D, sodium ethanoate, is the sodium salt of compound B, ethanoic acid.

Compound E	
Structural formula	*Justification*
	Alkene E was formed from the dehydration of compound C, so it must have the same branched carbon backbone as the tertiary alkanol.

Compound F	
Structural formula	*Justification*
	Compound F is an alkane that results from the hydrogenation of alkene E.

Marker's Comment

Structure needed to be correct for the justification to be correct.

Compound D: the bond between the Na+ and the acetate is an ionic bond so drawing a covalent bond (many did this) is incorrect.

Compound C had to be correct tertiary alcohol structure due to the lack of oxidation shown. However, if Compound E and F were wrong because C was wrong, it could be marked correct (similar to a carry error).

Question 30 (12 marks)

30 (a) (2 marks)

Criteria	Marks
• Writes correct equilibrium equation • Includes states	2
• Writes correct equation without double arrow or does not include states	1

Sample answer

$$H_3C_6H_5O_7(aq) + H_2O(\ell) \rightleftharpoons H_2C_6H_5O_7^-(aq) + H_3O^+(aq)$$

or

$$H_2C_6H_5O_7^-(aq) + H_2O(\ell) \rightleftharpoons H_3C_6H_5O_7(aq) + OH^-(aq)$$

30 (b) (3 marks)

Criteria	Marks
• Identifies that effective buffer has equimolar concs of both components (i.e $c(NaH_2C_6H_5O_7) = 0.200M$) • Calculates mol of $NaH_2C_6H_5O_7$ required • Calculates mass of $NaH_2C_6H_5O_7$ required	3
• TWO of the above	2
• ONE of the above	1

Sample answer

To form most effective buffer

$c(H_3C_6H_5O_7) = c(H_2C_6H_5O_7^-) = 0.200\ mol\ L^{-1}$

$V(H_2C_6H_5O_7^-) = 100.0\ mL$

$c(H_2C_6H_5O_7^-) = 0.200\ mol\ L^{1-}$

$n(H_2C_6H_5O_7^-) = c.V = 0.200 \times 0.100$

$= 0.0200\ mol$

$m(NaH_2C_6H_5O_7) = n.M = 0.0200 \times 214.106$

$= 4.28\ g$

30 (c) (3 marks)

Criteria	Marks
• Calculates $[H^+]$ from pH • Calculates $[OH^-]$ using K_w • Expresses answer in $mol\ L^{-1}$ to 1 sig fig	3
• TWO of the above	2
• ONE of the above	1

Sample answer

pH = -log $[H^+]$

-3.5 = log $[H^+]$

$[H^+]$ = 3.1622777 x 10^{-4} (or $10^{-3.5}$)

So $[OH^-]$ = 1 x10^{-14}/3.16 x 10^{-4}

= 3.16 x 10^{-11} mol L^{-1}

Note: alternative answer

pOH = 14 – 3.5 (1 mark)

= 10.5

$[OH^-]$ = $10^{-10.5}$ (1 mark)

= 3.16 x 10^{-11} mol L^{-1} (1 mark)

Marker's comment

1 sf due to pH – sig fig from any log (including pH) is determined by the number of decimal places.

30 (d) (4 marks)

Criteria	Marks
• Correct explanation of how buffer system resists change in pH when base is added • Refers to equilibrium system identified in part (a) • Compares with pH change when NaOH is added to water • Includes at least one equation	4
• Mostly correct explanation of how buffer system resists change in pH when base is added • Compares with pH change when NaOH is added to water • Includes at least one equation	3
• TWO of the above	2
• Any relevant information	1

Sample answer

The added OH^- ions are removed by reaction with citric acid ($H_3C_6H_5O_7(aq) + OH^-(aq) \rightarrow H_2C_6H_5O_7^-(aq) + H_2O(\ell)$)

This increases the concentration of citrate ion ($H_2C_6H_5O_7^-$) and decreases concentration of citric acid ($H_3C_6H_5O_7$) so the buffer equilibrium favours production of citric acid

This in turn reduces the concentration of H_3O^+ ions (This in turn increases concentration of OH^-)

Recognition that when OH^- is added to a non-buffer solution, there is no weak acid/species for it to react with and so contributes fully to pH change

Alternative explanation

$H_3C_6H_5O_7(aq) + H_2O(\ell) \rightleftharpoons H_2C_6H_5O_7^-(aq) + H_3O^+(aq)$

The OH- reacts with the H_3O^+ and reduces its concentration

The reduction in H_3O^+ causes the equilibrium to shift to the right

or

The reduction of the H_3O^+ reduces the rate of the reverse reaction more than the forward reaction resulting in increase in the amount of H_3O^+ present when equilibrium is re-established.

or

Therefore, the forward reaction rate is greater relative to the reverse until equilibrium is re-established and the $[H_3O^+]$ increases again as the system adjusts.

As the concentration of H_3O^+ increases to close to before the addition of OH^-, there is minimal change in pH

Recognition that when OH^- is added to a non-buffer solution, there is no weak acid/species for it to react with and so contributes fully to pH change