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
- A formulae sheet, data sheet and Periodic Table are provided
- Write your student number and/or name at the top of every page

Total marks – 100

Section I – Pages 2–10
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – Pages 11–33
80 marks
- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

This paper MUST NOT be removed from the examination room

STUDENT NUMBER/NAME: .....

STUDENT NUMBER/NAME: .....

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Select the alternative A, B, C or D that best answers the question and indicate your choice with a cross (X) in the appropriate space on the grid below.

	A	B	C	D
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1 What type of chemical reaction occurs when but-2-ene is produced from butan-2-ol using concentrated sulfuric acid?

A. Dehydration

B. Addition

C. Substitution

D. Oxidation

2 At a particular temperature methane gas reacted with oxygen in a closed container until the following equilibrium was achieved.

$$2CH_4(g) + O_2(g) \rightleftharpoons 2CO(g) + 4H_2(g) + 76\ kJ$$

How could the quantity of hydrogen gas in this reaction be increased?

A. Using a suitable catalyst

B. Increasing the temperature of the system

C. Decreasing the pressure of the system

D. Changing the equilibrium constant for the reaction by reducing the methane concentration

3 Ethanol is an alternative fuel to petrol. The statements below relate to the use of ethanol and petrol as fuels.

I. Ethanol releases more energy per gram when completely combusted than petrol.
II. Ethanol releases less CO_2 per mole of fuel combusted than petrol.
III. Ethanol is less likely to undergo incomplete combustion than petrol.
IV. Ethanol can be produced from non-fossil fuel resources.

Which of the above statements correctly compares ethanol to petrol when used as a fuel?

A. All statements are correct

B. I, III and IV only

C. II, III and IV only

D. I and II only

4 Which of the following is an accepted qualitative test for the carboxylic acid functional group?

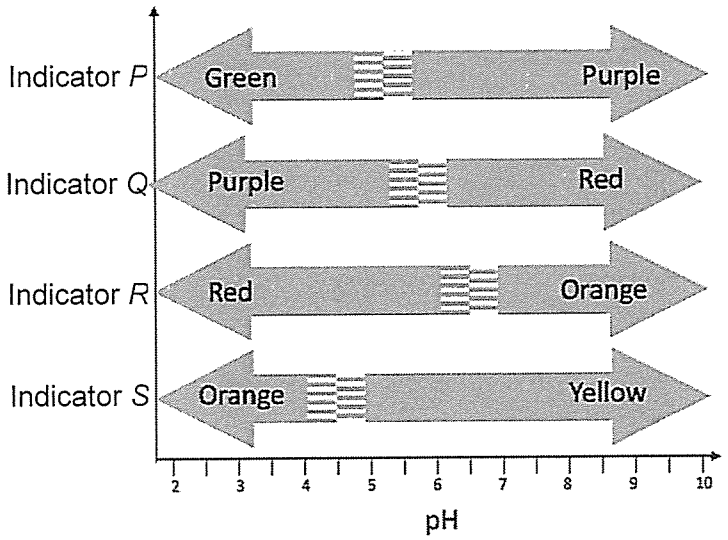
A. Add red litmus

B. Add sodium hydrogen carbonate

C. Dehydration using sulfuric acid

D. Oxidation using potassium permanganate

5 The graph shows the change in colour of four different indicators over a pH range of 2 to 10.



Two samples of an unknown solution *N* are taken. The first sample turns purple when indicator *P* is added. The second sample turns red when indicator *R* is added.

Which of the values below is most likely to be the hydrogen ion concentration in *N*?

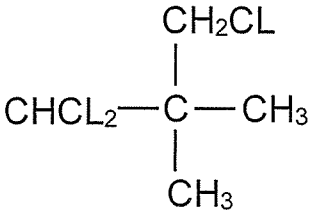
A. 3.2×10^{-3} mol L^{-1}

B. 2.0×10^{-6} mol L^{-1}

C. 7.8×10^{-8} mol L^{-1}

D. 9.1×10^{-10} mol L^{-1}

6 What is the correct IUPAC name for the compound shown below?



A. 1,1,3-trichlorodimethylpropane

B. 2,2-dimethyl-1,1,3-trichloropropane

C. 1,3-trichloro-2-dimethylpropane

D. 2-chloromethyl-1,1-dichloro-2-methylpropane

7 Substances *P*, *Q* and *R* react with a 1.0 mol L^{-1} solution of a strong acid. A salt is produced in all three reactions. Gases are produced when substances *Q* and *R* react with the acid. The gas produced by substance *Q* is flammable.

Which row in the table below best matches the above information?

	Base	*Carbonate*	*Metal*
A.	*P*	*Q*	*R*
B.	*P*	*R*	*Q*
C.	*R*	*P*	*Q*
D.	*R*	*Q*	*P*

8 Consider the formulae of compounds *A* and *B* shown below.

$CH_3CH_2CONH_2$	$CH_3CH_2CH_2NH_2$
compound *A*	compound *B*

Which of the following correctly names and describes compound *A*?

A. Propyl amine, which is more basic than compound *B*

B. Propyl amine, which is less basic than compound *B*

C. Propyl amide, which is more basic than compound *B*

D. Propyl amide, which is less basic than compound *B*

9 Which of the following provides a visible characteristic indicating that a chemical reaction has achieved equilibrium?

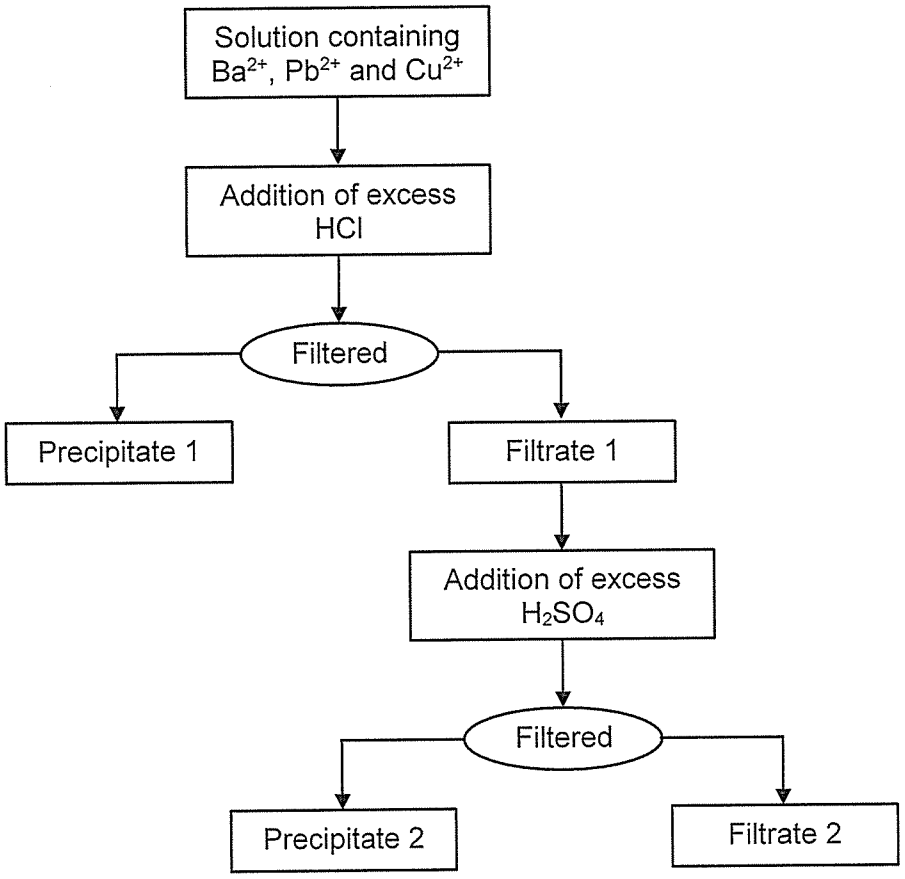
A. The rate of the forward and reverse reactions become equal.

B. The concentration of the reactants and the products remain the same.

C. The gas produced by the reaction is allowed to escape from the reaction.

D. The macroscopic properties remain constant.

10 A solution contains three cations barium, Ba^{2+}, lead Pb^{2+} and copper Cu^{2+}. The flow chart indicates steps to confirm the identity of these cations.



Which of the following is correct?

A. Precipitate 1 is $PbCl_2$ and filtrate 2 contains $CuSO_4$.

B. Precipitate 1 is $PbCl_2$ and filtrate 2 contains $BaSO_4$.

C. Precipitate 1 is $BaCl_2$ and filtrate 2 contains $CuSO_4$.

D. Precipitate 1 is $BaCl_2$ and filtrate 2 contains $PbSO_4$.

11 Under the right conditions, ethane and ethene (ethylene) are both capable of reacting with bromine.

Which of the following correctly identifies the organic product formed when 1 mole of bromine Br_2 reacts with 1 mole of ethane and when 1 mole of bromine Br_2 reacts with 1 mole of ethene?

	Ethane reaction product	*Ethene reaction product*
A.	$C_2H_4Br_2$	$C_2H_4Br_2$
B.	C_2H_5Br	$C_2H_4Br_2$
C.	$C_2H_4Br_2$	C_2H_5Br
D.	C_2H_5Br	C_2H_5Br

12 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, Ksp, for magnesium chloride?

A. X

B. X^2

C. $3X^2$

D. $4X^3$

13 A sample of 0.50 grams of methanol was burned in a spirit burner placed under an open flask which contained 100 g of water initially at 25°C. When heating was finished it was determined that 40% of the heat produced was lost to the environment. The enthalpy of combustion of methanol is
-726 kJ mol^{-1}.

What was the final temperature of the water?

A. 16°C

B. 41°C

C. 52°C

D. 64°C

Questions 14 and 15 refer to the following information.

Hypochlorous acid (HOCl) reacts with water to form hypochlorite ions and hydronium ions.

$$HOCl(aq) + H_2O(l) \rightleftharpoons OCl^-(aq) + H_3O^+(aq) \qquad K_{eq} = 3.0 \times 10^{-8}$$

Sodium hypochlorite dissociates completely in water forming $Na^+(aq)$ and $OCl^-(aq)$. 100 mL of a 1.0 mol L^{-1} HOCl solution is mixed with 100 mL of a 1.0 mol L^{-1} NaOCl solution.

14 Which term is the most appropriate label for this mixture?

A. Acidic

B. Basic

C. Buffer

D. Amphiprotic

15 Which of the values below is closest to the pH of this mixture?

A. 8.5

B. 7.5

C. 6.5

D. 5.5

16 The data sheet lists the K_{sp} value for lead iodide, PbI_2 as 9.8×10^{-9}.

If the concentration of lead ions in a sample solution is 5.0×10^{-5} mol L^{-1}, then what is the maximum concentration of iodide ions in the same solution?

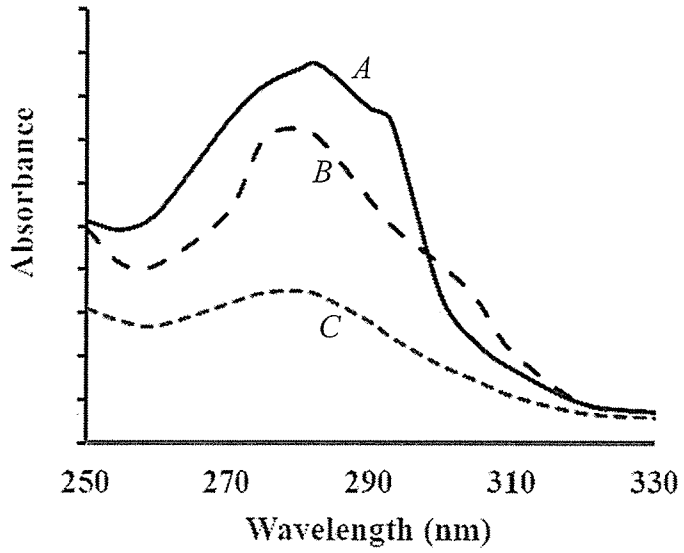
A. 1.1×10^{-2} mol L^{-1}

B. 1.4×10^{-2} mol L^{-1}

C. 2.3×10^{-1} mol L^{-1}

D. $1.5 \times 10^{+2}$ mol L^{-1}

17 An ultraviolet spectrum of three compounds *A*, *B* and *C* is shown.



The peak absorbance of UV light for each compound is at a wavelength of approximately 280 nm.

What does this indicate about these three compounds?

A. They have a similar bonding structure.

B. They have a similar molecular mass.

C. They have the same concentration.

D. They have the same colour.

18 Consider the following equilibrium.

$$HA(aq) + B^-(aq) \rightleftharpoons A^-(aq) + HB(aq) \quad K_{eq} = 2.5$$

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^-

19 The organic compound ethylene (C_2H_2) can be reacted with water to make ethanol. The equation for this reaction is:

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

A reaction uses 18.4 g of ethylene but only produces 27.6 g of ethanol at the end of the reaction pathway.

What is the percentage yield for this reaction?

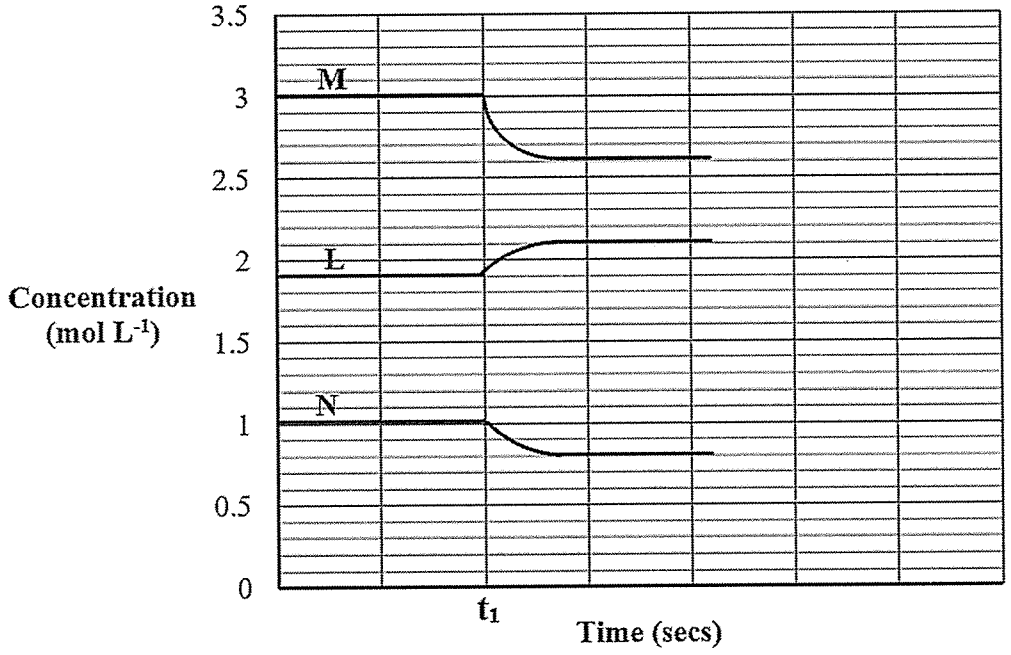
A. 43%

B. 61%

C. 67%

D. 91%

20 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 of 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

Section II

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (5 marks) **Marks**

Ethanol is often produced by the fermentation of glucose.

(a) Write an equation to represent the fermentation of glucose and account for the conditions required for the production of ethanol using this method. **3**

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(b) Ethanol is a member of the homologous series of alcohols. **2**

Compare the physical properties of different members of this homologous series.

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Question 22 (4 marks) **Marks**

(a) Barium sulfate ($BaSO_4$) is a sparingly soluble compound that is used as a coating for paper to make it brighter and as a filler for plastics to make them denser. **2**

Outline how a suspension of barium sulfate could be prepared in a school laboratory by mixing two salts.

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(b) At 25°C, 250.0 mL of a 2.0×10^{-2} mol L^{-1} aqueous solution of barium ions is mixed with 250.0 mL of a 4.0×10^{-4} mol L^{-1} aqueous solution of sulfate ions. **2**

Determine whether a precipitate would form. Show all relevant calculations.

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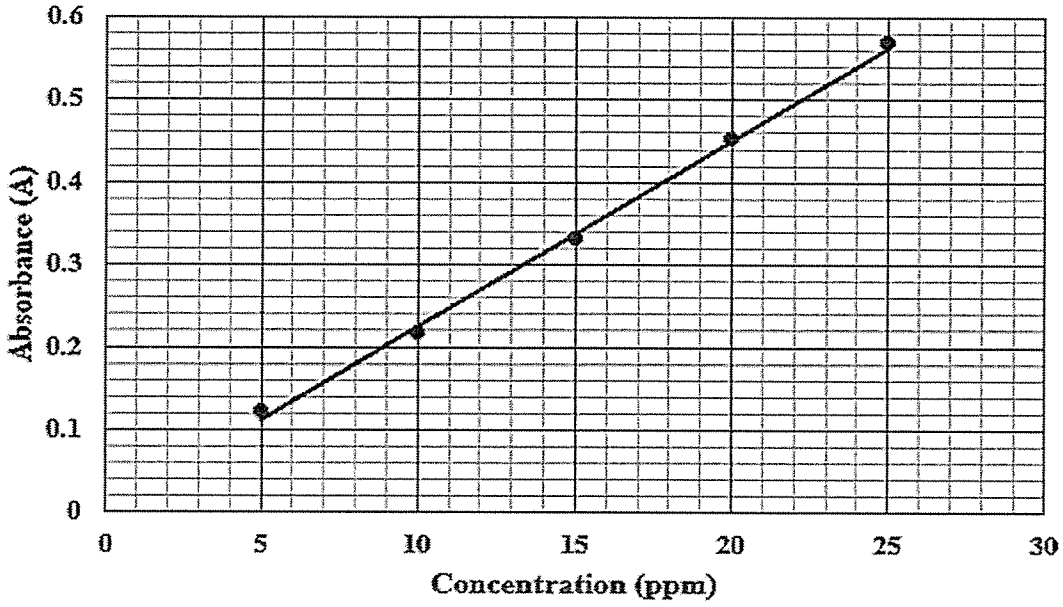
Question 23 (5 marks) **Marks**

The concentration of copper ions in one sample of river water was determined by colourimetry. An almost colourless sample of the river water was complexed with excess ammonia to form a deep blue solution:

$$\underset{\text{copper ions}}{Cu^{2+}(aq)} + \underset{\text{ammonia}}{4NH_3(aq)} \rightarrow \underset{\text{tetraamine copper (II) ion}}{[Cu(NH_3)_4]^{2+}}$$

The following calibration curve was determined.



$A = \log_{10} \frac{I_0}{I}$ I_0 = intensity of the light before passing through the sample
I = intensity of the light after passing through the sample

(a) Use the graph to determine the absorbance of the sample solution and hence calculate the concentration of copper ions in the original solution in mol L^{-1}. **3**

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Question 23 continues on the next page

Question 23 (continued) **Marks**

(b) Describe an alternative technique to colourimetry that could be used to accurately determine the concentration of copper ions if ammonia was not available. **2**

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End of Question 23

Question 24 (3 marks) **Marks**

The Gunwinggu people of Arnhem Land eat the roots of a bitter yam plant, which they call mangindjeg. These roots contain salts (oxalates) that would be toxic if consumed. **3**

Using this example or another food prepared by Indigenous peoples, identify at least THREE steps in the preparation and analyse how solution equilibria or another chemical principle is used to remove toxins.

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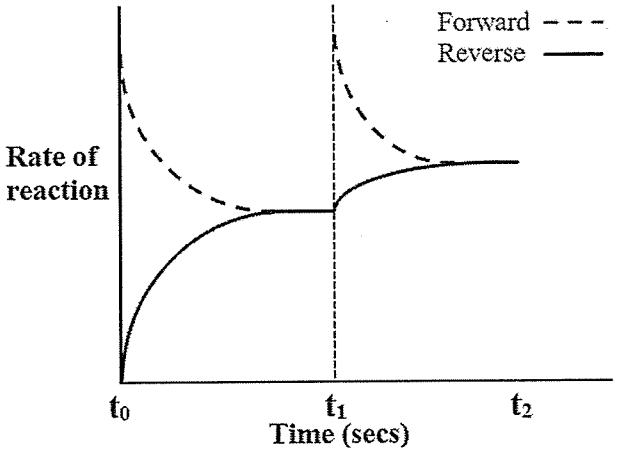
Question 25 (3 marks) **Marks**

A graph of the rate of reaction versus time for a particular chemical reaction is shown. At time t_1 the reactant concentration is increased. **3**



Account for the shape of the graphs between t_0 and t_1 and between t_1 and t_2 in terms of collision theory.

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Question 26 (8 marks) **Marks**

Compounds *A* and *B* are isomers with a molecular formula C_3H_7Cl. Samples of compounds *A* and *B* are heated separately with sodium hydroxide to produce compounds *C* and *D* respectively. A student used samples of compound *C* in a series of reactions to produce propyl propanoate, a volatile compound with a strong, pungent but sweet pineapple-like smell.

(a) Identify all compounds and construct a flow chart to outline a series of reactions that the student could use to produce propyl propanoate using compound *C*. In your flow chart identify the types of reactions that are carried out and the reagents required for each step. **4**

Question 26 continues on the next page

Question 26 (continued) **Marks**

(b) Explain in terms of molecular structure why propyl propanoate is a volatile compound with a strong smell. **1**

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(c) Describe TWO significant differences between compound *A* and the monomer used to produce polyvinyl chloride (PVC). **3**

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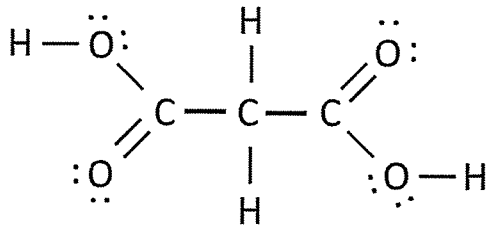
End of Question 26

Question 27 (5 marks) **Marks**

Malonic acid is a diprotic acid with the following molecular structure:



(a) In the space below, draw the structural formulas of the anions that form in the first and second ionisation of malonic acid in water. Label each structure as ionisation 1 and ionisation 2. **2**

(b) The pK_a value for the first ionisation of malonic acid is 2.83. Based on this value, calculate the pH of a 2.5 mol L^{-1} solution of malonic acid. **3**

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Question 28 (3 marks) **Marks**

With the use of at least ONE diagram, explain the action of soaps in emulsifying oils. **3**

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Question 29 (3 marks)

Initially a 2.00 litre glass vessel contains a mixture of 1.00 mole of hydrogen gas and 1.00 mole of iodine gas. The gases react as follows: **3**

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

At 400°C equilibrium is achieved and the concentration of hydrogen iodide gas is 0.760 mol L^{-1}.

Calculate the equilibrium constant for this reaction and discuss what the value indicates about the reaction. Show all working.

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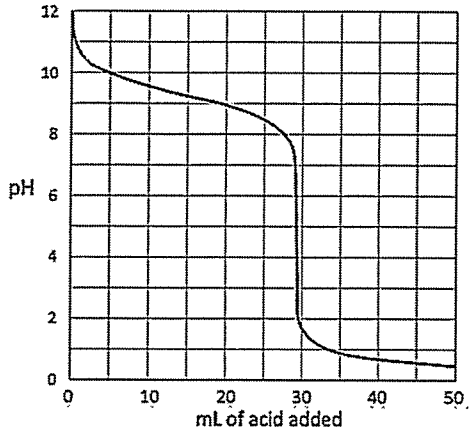
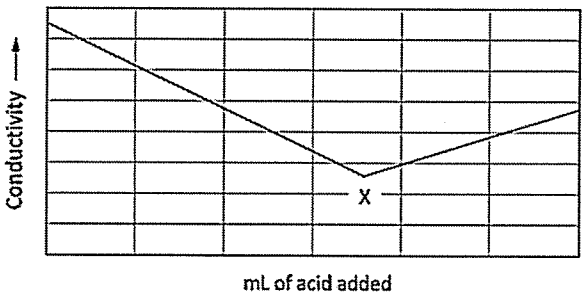
Question 30 (8 marks) **Marks**

Two titrations, one volumetric and the other conductometric, were performed both using 25.00 mL of the barium hydroxide, $Ba(OH)_2$ and 0.100 mol L^{-1} sulfuric acid, H_2SO_4. The results from each titration are graphed below.

Graph 1



Graph 2



(a) Using information from graph 1, calculate the concentration of barium hydroxide solution and explain the changes in conductivity on either side of point *X* on graph 2. Include a suitable chemical equation in your answer. **5**

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Question 30 continues on the next page

Question 30 (continued) **Marks**

(b) The titration was performed in a thermally insulated vessel. The H_2SO_4 solution and the $Ba(OH)_2$ solution were at 20.2°C at the start of the titration. The enthalpy of neutralisation = –57.6 kJ mol^{-1}. **3**

Calculate the final temperature of the mixture if 40.0 mL of the acid is added to 25.0 mL of the base.

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End of Question 30

Question 31 (3 marks) **Marks**

Contrast the shapes of the following three carbon molecules – ethane (C_2H_6), ethene (C_2H_4) and ethyne (C_2H_2) and outline reasons for any differences. **3**

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Question 32 (5 marks) **Marks**

An equilibrium system is set up between yellow chromate ions (CrO_4^{2-}) and orange dichromate ions ($Cr_2O_7^{2-}$) in an aqueous solution according to the following equation:

chromate ions + hydronium ions ⇌ dichromate ions + water
(yellow) (orange)

(a) Write a balanced equation for this reaction. **1**

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(b) Design a suitable method involving this equilibrium to provide qualitative data about Le Chatelier's principle. Identify the equipment that would be used for the investigation and describe any risks involved. **4**

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Question 33 (4 marks) **Marks**

A sample of 20.0 mL of 0.320 mol L^{-1} ammonia NH_3 is titrated with a hydrochloric acid solution. The equation for the reaction is given as:

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$

Five titrations were performed under the same conditions and the following results were obtained.

Titration	*Volume HCL (mL)*
1	22.1
2	18.9
3	18.7
4	19.0
5	18.7

(a) Calculate the concentration of the hydrochloric acid solution. **2**

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(b) Explain why the final solution in the titration has a pH less than 7.0. Provide an equation to support your answer. **2**

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Question 34 (4 marks) **Marks**

A solution of 25 ml of sodium chloride NaCl is analysed by precipitation titration. The sample is titrated using a chromate ion indicator to the Ag_2CrO_4 end point and requires 24.5 mL of 0.120 mol L^{-1} $AgNO_3$. A blank titration required 0.610 mL of $AgNO_3$ to reach the same end point. **4**

Calculate the concentration of the NaCl sample in g L^{-1} and explain the purpose of using a blank titration.

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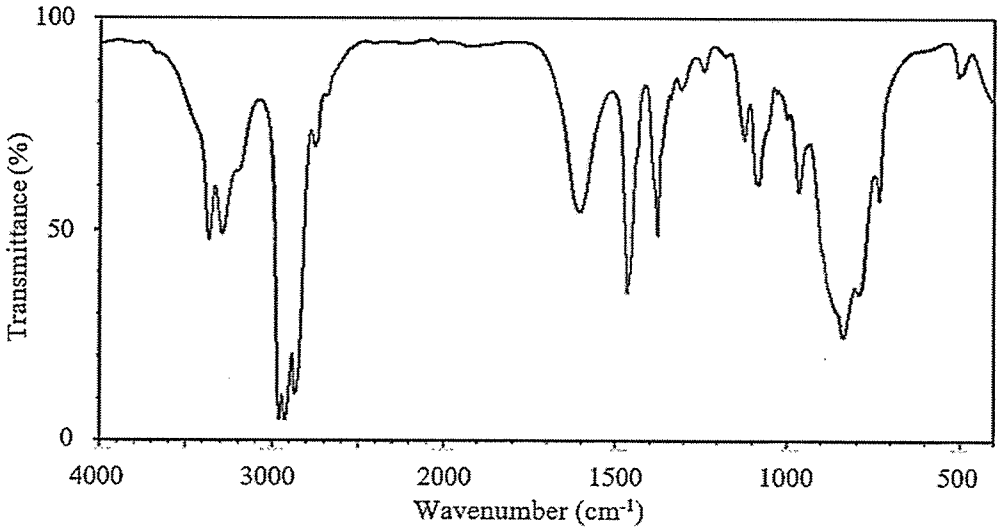
Question 35 (8 marks) **Marks**

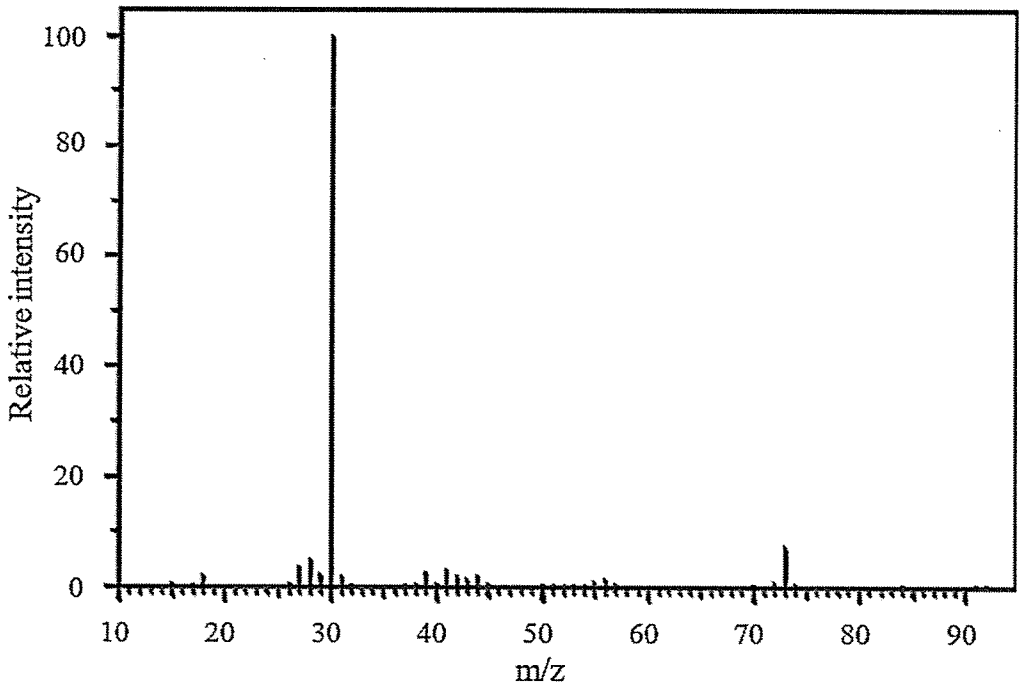
Information on the reactivity and four spectra of an organic compound are provided. **8**

Test	*Result*
Acidified potassium permanganate was added to a sample	Purple colour remains
Bromine water was added to a sample	Orange colour remains
Sodium carbonate was added to a sample	No bubbles

Graph 1 Infrared Spectrum



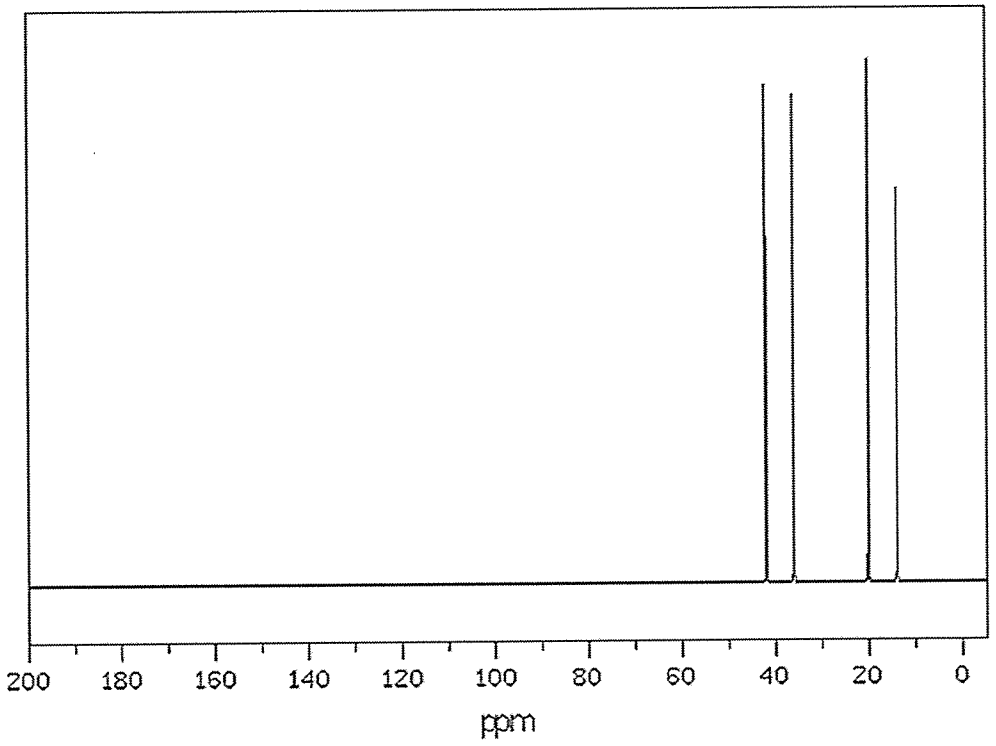
Graph 2 Mass Spectrum



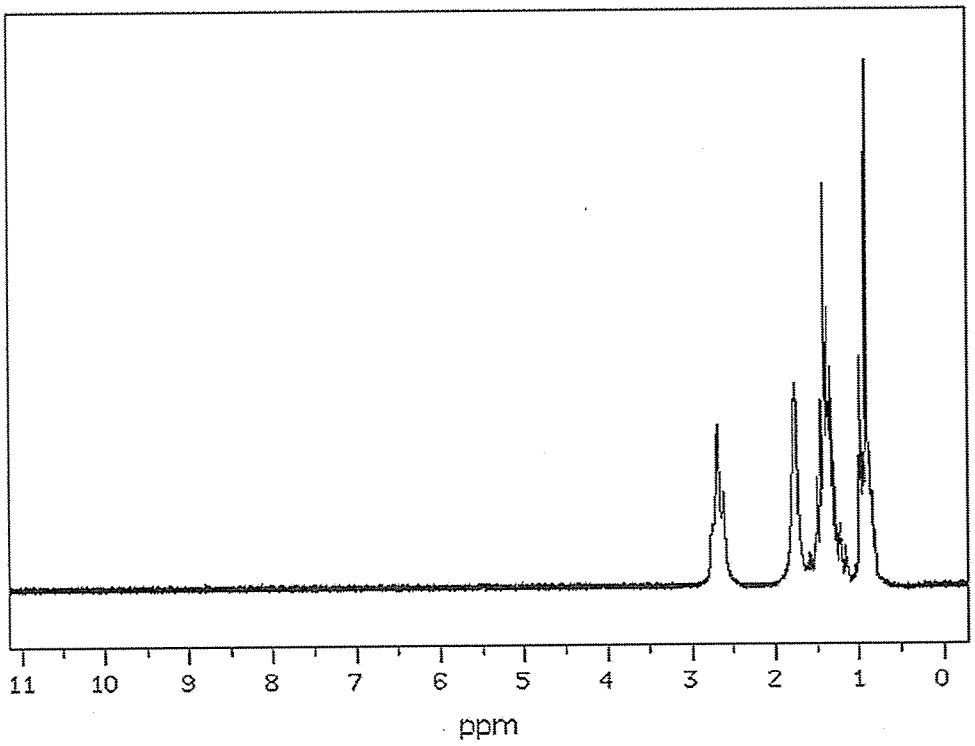
Question 35 continues on the next page

Question 35 (continued) **Marks**

Graph 3 Carbon-13 NMR



Graph 4 Proton NMR



Question 35 continues on the next page

Question 35 (continued) **Marks**

Identify and draw the structural formula of this compound and justify your identification by referring to the reaction data and spectra provided.

Question 36 (9 marks) **Marks**

Diesel is a common fuel used in vehicles. Biodiesel, first commercially developed in 1991, is now readily available as an alternative fuel. A biofuels manufacturing facility, Shoalhaven Pty Ltd, in Nowra NSW, uses waste plant products from sugar and wheat processing and canola oil to produce biodiesel. **9**

Discuss advantages and disadvantages of producing and using biodiesel as a sustainable fuel for transport and critically analyse THREE significant factors that may have been considered when building the Shoalhaven biofuels facility.

More space to answer this question is provided on the next page

Question 36 (continued)

End of paper

Section II extra writing space

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Section II extra writing space

If you use this space, clearly indicate which question you are answering.

NSW INDEPENDENT TRIAL EXAMS – 2022
CHEMISTRY TRIAL HSC EXAMINATION
MARKING GUIDELINES

Section I

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

Section II

Question 21(a)

Criteria	Mark
• Writes a correctly balanced equation for fermentation • Gives reasons for at least THREE conditions required for fermentation	3
• Writes a correctly balanced equation for fermentation AND • Gives reasons for at least TWO conditions required for fermentation OR • Identifies at least THREE conditions required for fermentation	2
• Provides a correct formula equation or some correct information about the conditions required for fermentation	1

Sample answer: $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Fermentation requires:

- The presence of yeast to provide the enzymes required to catalyse the reaction.
- Warmth/room temperature. Yeast is a living organism that requires a particular temperature range in which to function.
- The absence of oxygen. If oxygen was present the ethanol produced would be further oxidised to other products.
- The glucose to be dissolved in water. Yeast requires the glucose to be dissolved in water for it to be able to catalyse the reaction and maintain an ethanol concentration below about 15%.

Question 21(b)

Criteria	Mark
• Explains at least TWO similarities and TWO differences in physical properties between members of the alcohol homologous series	2
• Explains at least ONE similarity and ONE difference in physical properties between members of the alcohol homologous series	1

Sample answer: All members of the alcohol homologous group contain the polar hydroxyl (-OH) functional group in their molecular structure. This results in strong hydrogen bonding occurring between molecules; hence they all have relatively high boiling points, higher than the corresponding alkanes.

The polar hydroxyl group also allows the alcohols to establish hydrogen bonding with water molecules, hence the smaller-chained alcohols are all soluble in water.

The longer the carbon chain in the homologous series, the higher the molar mass, hence the stronger the dispersion forces between the molecules. Therefore, the boiling points increase as the length of the carbon chain increases. As the carbon chains are non-polar, the longer they are the more they interfere with the ability of the molecules to establish hydrogen bonds with water. Hence the solubility in water of the homologous series members decreases as the carbon chain length increases.

Question 22(a)

Criteria	Mark
• Identifies the names or formulas of TWO soluble salts that could form a barium sulfate suspension • Indicates the main features of the procedure in a school laboratory	2
• Identifies the names or formulas of TWO soluble salts that could form a barium sulfate suspension	1

Sample answer: A small mass of barium nitrate (e.g., 5.0 g) is added to a suitable volume (e.g., 50.0 mL) of distilled water in a beaker and stirred until the salt is completely dissolved. A small mass of sodium sulfate (e.g., 5.0 g) is added to a suitable volume (e.g., 50.0 mL) of distilled water in a separate beaker and stirred until the salt is completely dissolved. The two solutions are mixed until a fine precipitate of barium sulfate is produced in suspension.

Question 22(b)

Criteria	Mark
• Shows relevant working to calculate the correct ionic product • Compares the ionic product with the correct K_{sp} to determine a precipitate formation	2
• Provides a relevant process or working to calculate an ionic product	1

Sample answer:

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

$[Ba^{2+}] = c \times V = 2.0 \times 10^{-2} \times (0.25 \times 2) = 1.0 \times 10^{-2}$

$[SO_4^{2-}] = c \times V = 4.0 \times 10^{-4} \times (0.25 \times 2) = 2.0 \times 10^{-4}$

$Q_{sp} = [Ba^{2+}][SO_4^{2-}] = (1.0 \times 10^{-2}) \times (2.0 \times 10^{-4}) = 2.0 \times 10^{-6}$

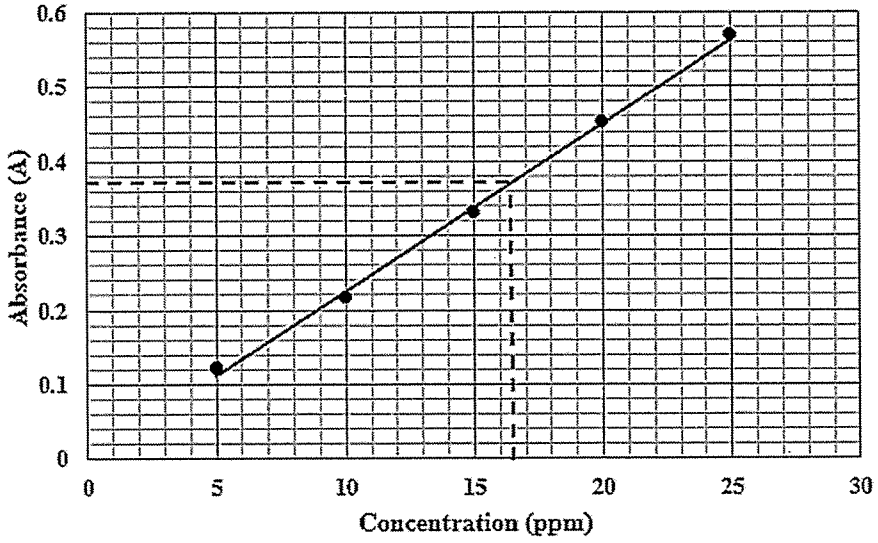
From the data sheet, $K_{sp}\ BaSO_4 = 1.08 \times 10^{-10}$

$Q_{sp} > K_{sp}$, therefore a precipitate will form.

Question 23(a)

Criteria	Mark
• Correctly calculates the absorbance of the sample solution • Uses data from the graph to calculate the correct concentration of the original solution in mol L^{-1}	3
• Correctly calculates the absorbance of the sample solution AND • Uses data from the graph to calculate a concentration of the original solution in mol L^{-1} using a correct process	2
• Calculates a concentration of the original solution in mol L^{-1} using a correct process	1

Sample answer:



$A = \log_{10}\frac{I_0}{I} = \log(1/0.426) = 0.3706$

Absorbance of 0.3706 = $[Cu^{2+}]$ of 16.5 ppm

16.5 ppm = 16.5 mg L^{-1} = 0.0165 g L^{-1}

$n = m/M = 0.0165/63.55 = 2.60 \times 10^{-4}$

$\therefore [Cu^{2+}] = 2.60 \times 10^{-4}$ mol L^{-1}

Question 23(b)

Criteria	Mark
• Outlines a minimum of TWO features of a named suitable alternative to colourimetry	2
• Outlines ONE feature of a named suitable alternative to colourimetry	1

Sample answer: Using atomic absorption spectrometry (AAS) a sample solution containing an element is vaporised in a hot flame. Radiation from a cathode lamp of a particular wavelength is absorbed by the atom's electrons. Unabsorbed light is passed through a wavelength selector and a detector. A computer determines the amount of absorbance as a measure of the concentration of the metal ions present in the sample.

Question 24

Criteria	Mark
• Identifies a minimum of THREE steps in how an Indigenous food is prepared • Explains how solution equilibria is able to remove toxins from food	3
• Identifies a minimum of TWO steps in how an Indigenous food is prepared • Outlines how solution equilibria is able to remove toxins from food	2
• Provides some relevant information about food preparation to remove toxins	1

Sample answer: Steps in how mangindjeg is prepared. Food (yam roots):

1. are cut up or ground
2. cooked in hot ashes
3. peeled and soaked in a paperbark straining basket

Solution equilibria – Yam roots are ground up to increase their surface area and allowed to soak in water for a period of time. The toxins (e.g., oxalates) are more soluble than the starch food and so they are leached out. Removing the toxins by water leaching drives any equilibria reached to the water side of the reaction. When repeated, very little toxin remains.

Question 25

Criteria	Mark
• Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_0 and t_1 in terms of collision theory • Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_1 and t_2 in terms of collision theory	3
• Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_0 and t_1 in terms of collision theory OR • Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_1 and t_2 in terms of collision theory	2
• Provides some correct information about the shape of a graph in terms of collision theory	1

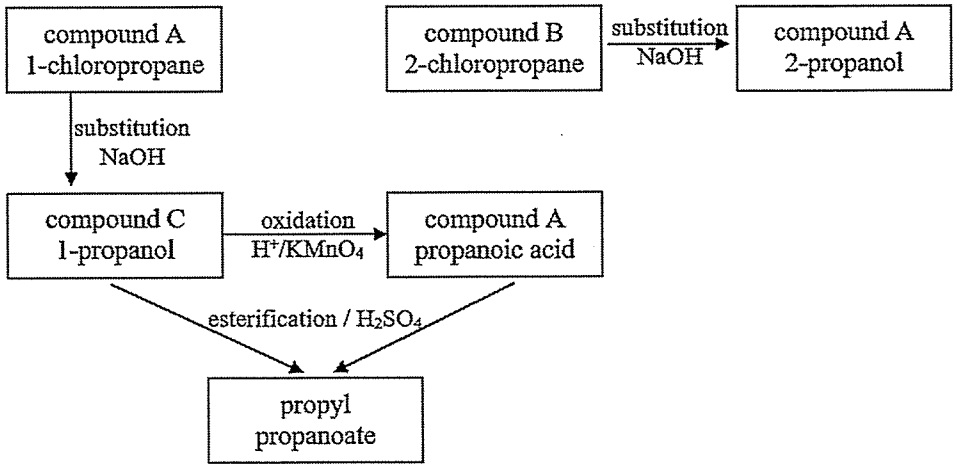
Sample answer: At the start of the reaction (t_0) the reactants are at their highest concentration and no products have formed. When a chemical reaction first occurs the chances of more successful collisions is therefore greater, and the forward reaction is relatively fast. As the reaction proceeds, the reactants become less concentrated, and the chances of successful collisions decreases. As the products become more concentrated, collisions become more successful, and the rate of the reverse reaction now increases. This continues until the forward reaction rate equals the reverse reaction rate and the system is now said to be in equilibrium.

At t_1 more reactant(s) are added. This increases the reactant concentration and causes an immediate spike in the rate of the forward reaction. However, as before, as the reaction proceeds, the reactants become less concentrated, and the chances of successful collisions decreases. The forward reaction rate therefore decreases gradually until equilibrium is again re-established just before t_2. At the same time the reverse reaction rate will gradually increase because reactant particles have become product particles. An increase in concentration of either the reactants or the products will result in both the forward and reverse reaction rates being higher once equilibrium is re-established as more particles are present after t_1.

Question 26(a)

Criteria	Mark
• Constructs a suitable flow diagram to show the steps required to produce propyl propanoate from propanol • Correctly identifies all relevant organic compounds, types of reactions and other reagents required	4
• Constructs a suitable flow diagram to show the steps required to produce propyl propanoate from propanol • Correctly identifies all relevant organic compounds	2–3
• Constructs a suitable and relevant flow diagram that identifies some relevant organic compounds, types of reaction and/or other reagents required	1

Sample answer:



Question 26(b)

Criteria	Mark
• Explains the volatile nature of propyl propanoate in terms of intermolecular forces	1

Sample answer: Propyl propanoate is an ester. Esters are substances of low polarity and so only have relatively weak forces of attraction between molecules. This allows molecules to easily separate from each other, forming vapours which can be inhaled through one's nose.

Question 26(c)

Criteria	Mark
• Identifies compound A and the monomer used to produce PVC • Describes TWO significant differences between the identified compounds	3
• Identifies compound A and the monomer used to produce PVC • Describes ONE significant difference between the identified compounds	2
• Identifies compound A and the monomer used to produce PVC OR • Describes ONE significant difference between the above compounds	1

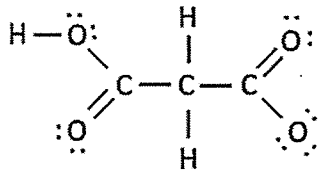
Sample answer: PVC is a polymer made by joining many monomer units together to form a long-chained molecule. The monomer used to produce PVC is chloroethene C_2H_3Cl. Chloroethene has a double covalent bond between two carbon atoms in its molecules. The polymer is formed when the double bond "opens up" allowing monomer units to join together.

Compound A, C_3H_7Cl, is 1-chloropropane containing a chain of 3 carbon atoms with only single covalent bonds between them. The absence of any double bonds means that these molecules cannot be joined together to form a long-chained polymer.

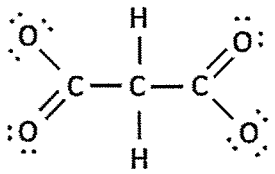
Question 27(a)

Criteria	Mark
• Draws TWO correct structures with correct labels	2
• Draws ONE correct structure and correct label	1

Sample answer:



Ionisation 1



Ionisation 2

Question 27(b)

Criteria	Mark
• Calculates the correct pH value	3
• Uses at least TWO correct processes or calculations to obtain a logical pH value	2
• Uses a correct process or calculation to obtain a logical pH value	1

Sample answer: The first ionisation of malonic acid can be represented as: $HA \rightleftharpoons H^+ + A^-$.

If $pK_a = 2.83$, then $K_a = 10^{-2.83} = 1.4791 \times 10^{-3}$.

$$K_a = \frac{[H^+][A^-]}{[HA]} \text{ becomes } \frac{[x][x]}{[2.5 - x]}$$

Assuming x is very small, $2.5 - x$ can be approximated to 2.5.

$$\therefore 1.4791 \times 10^{-3} = \frac{x^2}{2.5}$$

$$\therefore x^2 = 1.4791 - 10^{-3} - 2.5 = 3.69775 \times 10^{-3}$$

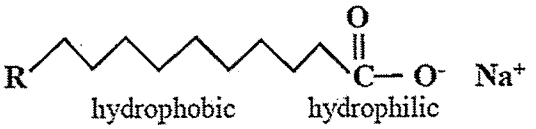
$$\therefore x = 0.060809$$

$pH = -\log(0.060809) = 1.22$ *(NB: this value has 2 significant figures)*

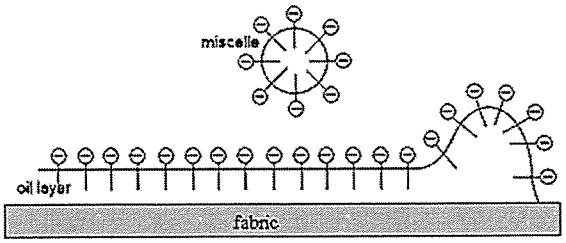
Question 28

Criteria	Mark
• Thoroughly explains, with the use of a suitable diagram(s), the action of soaps in emulsifying oils in terms of the structure of the soap anions	3
• Explains, with the use of a suitable diagram, the action of soaps in interacting with oils in terms of the structure of the soap anions	2
• Describes the structure of the soap anions OR • Describes the interaction of soaps with water and oils (in words OR as a diagram)	1

Sample answer: Soaps are soluble salts of long chain fatty acids with a typical formula $CH_3(CH_2)_{16}COO^-Na^+$. When dissolved in water the soap loses its cation leaving an anion that has a negatively charged carboxylate "head" at one end and a non-polar hydrocarbon "tail" at the other. The charged head is hydrophilic and so is soluble in water, while the non-polar tail is hydrophobic, so it is insoluble in water but soluble in oils. In a water and oil mixture, the soap anions will line up along the water/oil interface with the charged head end in water and the non-polar tail in the oil, as shown in the diagram.



Agitation will cause droplets of oil to break off and become completely surrounded by soap anions forming micelles. The charge surrounding each micelle repels other micelles, keeping them separated. The oil broken up into droplets in this way is said to be emulsified in the water.



Question 29

Criteria	Mark
• Shows working to calculate the value of the equilibrium constant, K_{eq} • Makes a correct statement(s) about what the K_{eq} indicates	3
• Shows working to calculate the value of the equilibrium constant, K_{eq}	2
• Provides a correct calculation process or some correct information about K_{eq}	1

Sample answer: Initial concentrations: $[H_2] = 0.5$ mol L^{-1} $[I_2] = 0.5$ mol L^{-1} $[HI] = 0.0$ mol L^{-1}

	$[H_2]$	$[I_2]$	$[HI]$
Initial	0.5	0.5	0.0
Change	−0.38	−0.38	+0.76
Equilibrium	0.12	0.12	0.76

$$\text{Now } K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = (0.76)^2/(0.12) \times (0.12) = 40.1$$

This moderately large number indicates that the equilibrium position is on the right side. The products are favoured in this equilibrium reaction.

Question 30(a)

Criteria	Mark
• Writes a correct reaction equation • Calculates the correct concentration of barium hydroxide • Explains the effect on conductivity of the concentration of Ba^{2+} and OH^- • Explains the effect on conductivity of the concentration of H^+ and SO_4^{2-}	5
• Writes a correct reaction equation • Calculates the correct concentration of barium hydroxide OR • Gives correct reasons to explain the changes in conductivity on either side of point X	3–4
• Calculates a concentration of barium hydroxide using a correct process OR • Relates the change in conductivity in graph 2 to the changes in the concentrations of ions during the titration	1–2

Sample answer: Reaction equation: $H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4(s) + 2H_2O$

The midpoint of the steepest part of the curve in graph 1 (the end point) corresponds to a volume of 29 mL of acid.

$\therefore$ n $H_2SO_4 = c \times V = 0.1 \times 0.029 = 0.0029$

$\therefore$ n $Ba(OH)_2 = 0.0029$

$\therefore$ $[Ba(OH)_2] = n/V = 0.0029/0.025 = 0.116$ mol L^{-1}

The end point in the titration corresponds to the point in the reaction where the acid and base have both completely reacted to form solid barium sulfate and water. With very few ions present, this corresponds to the electrical conductivity of the solution at its lowest value, that is, at point X in graph 2. When less than 29 mL of acid has been added the extra Ba^{2+} and OH^- ions raise the conductivity. When more than 29 mL of acid has been added the extra H^+ and SO_4^{2-} ions also raise the conductivity.

Question 30(b)

Criteria	Mark
• Calculates the final temperature to three significant figures	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 $= c \times V = 0.100 \times 0.029 = 2.9 \times 10^{-3}$

Mol water formed $= 2 \times 2.9 \times 10^{-3} = 0.0058$

$\therefore$ energy released $= 0.0058 \times 57.6 = 0.33408$ kJ $= 334.08$ J

Total volume mixture = 65.0 mL = 65.0 g

$\Delta H = mC\Delta T$

$\therefore 334.08 = 65 \times 4.18 \times \Delta T$

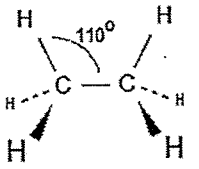
$\Delta T = 334.08/271.7 = 1.23°C$

$\therefore$ final temperature = 21.4°C

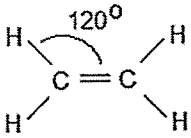
Question 31

Criteria	Mark
• Describes differences in the shapes of the THREE molecules and outlines a reason(s) to explain these differences	3
• Describes differences in the shapes of TWO molecules and outlines a reason(s) to explain these differences	2
• Describes and explains the shape of ONE of the molecules OR • Describes the shapes of TWO of the molecules	1

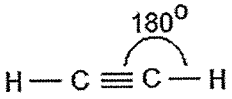
Sample answer: The shape of a molecule is mainly dependent on the number of valence electron pairs around the central atoms, all of which repel each other due to their negative charge.



In C_2H_6 each C atom has 4 separate valence electron pairs, one shared with another C atom and 3 shared with H atoms. The repulsion of these 4 electron pairs results in a 3-dimensional molecule with two overlapping tetrahedrons. (The angle between each electron pair is approximately 110°).



In C_2H_4 the double bond between the carbon atoms allows for only 2 H atoms sharing electron pairs with each C atom. This results in a flat, 2-dimensional planar molecule. (The angle between each bond is about 120°)



In C_2H_2 the triple bond between the carbon atoms allows for only one H atom sharing an electron pair with each C atom. This results in a linear molecule. (The angle between each bond is 180°).

Question 32(a)

Criteria	Mark
• Provides a correctly balanced chemical equation	1

Sample answer:

$2CrO_4^{2-}(aq) + 2H_3O^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + 3H_2O(l)$

OR

$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$

Question 32(b)

Criteria	Mark
• Designs a thorough method to provide qualitative data about Le Chatelier's principle • Identifies equipment that would be used in the investigation • Describes at least TWO risks involved in the procedure	4
• Designs a sound method to provide qualitative data about Le Chatelier's principle • Identifies some equipment that would be used in the investigation • Describe ONE risk involved in the procedure	2–3
• Provides some correct information about the reaction related to observing Le Chatelier's principle	1

Sample answer: Method may include:

- Prepare suitable volumes of solutions of potassium chromate (K_2CrO_4) and potassium dichromate ($K_2Cr_2O_7$) – e.g., 50.0 mL of 0.1 mol L^{-1} of each in reagent bottles or beakers.
- Collect separate small vials of 0.1 mol L^{-1} HCl and 0.1 mol L^{-1} NaOH solutions.
- Label three small evaporating dishes 1, 2 and 3.
- Place 20.0 mL of chromate solution in dish 1 and 20.0 mL of dichromate solution in dish 2.
- Place 10.0 mL of each solution into dish 3.
- Use a plastic dropper to place several drops of acid into dish 3 and record colour changes.
- Use a plastic dropper to place several drops of alkali into dish 3 and record colour changes.
- Repeat the process of alternately adding acid and alkali drops to represent visible colour changes occurring to the equilibrium as a consequence of Le Chatelier's principle.

Risk assessment may include:

- Care must be taken with the acid and alkali solutions as they can be toxic and/or corrosive.
- Chromates can also be toxic and cause skin irritations and allergic reactions.
- Inhalation should be avoided. Gloves, a laboratory coat and safety glasses must be worn.
- Chromate and dichromate solutions contain the heavy metal chromium and must be placed into a suitable container for specialist disposal and not washed down the sink.

Question 33(a)

Criteria	Mark
• Calculates the correct concentration of the hydrochloric acid solution	2
• Calculates a concentration of the hydrochloric acid solution using a correct process or calculation	1

Sample answer:

Average titre = (18.9 + 18.7 + 19.0 + 18.7)/4 = 18.8 mL

n NH_3 = c × V = 0.32 × 0.02 = 6.4×10^{-3}

∴ n HCl = 6.4×10^{-3}

∴ [HCl] = n/V = $6.4 \times 10^{-3}/0.0188$ = 0.340 mol L^{-1}

Question 33(b)

Criteria	Mark
• Gives a logical reason why the pH of the final solution is less than 7.0 • Provides an appropriate equation	2
• Gives a logical reason why the pH of the final solution is less than 7.0	1

Sample answer: The salt ammonium chloride is an acidic salt because in solution the ammonium ion ionises to form ammonia and hydrogen ions. $NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$
The formation of H^+ ions in equilibrium lowers the pH of the solution.

Question 34

Criteria	Mark
• Calculates the correct concentration of the NaCl sample in g L^{-1} • Provides a significant reason for the use of a blank titration	4
• Calculates a concentration of the NaCl sample in g L^{-1} using TWO correct processes • Provides a relevant reason for the use of a blank titration	2–3
• Calculates a concentration of the NaCl sample in g L^{-1} using ONE correct process OR • Provides a relevant reason for the use of a blank titration	1

Sample answer:

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Vol $AgNO_3$ reacted = 24.5 – 0.61 = 23.89 mL

n $AgNO_3$ reacted = c × V = 0.12 × 0.02389 = 0.0028668

∴ n Cl^- precipitated = 0.0028668 in 25 mL

∴ [NaCl] = n/V = 0.002866/0.025 = 0.114672 mol L^{-1}

= 0.114672 × (22.99 + 35.45) = 6.70 g L^{-1}

The precipitation titration causes an error because the end point is identified by the addition of extra $AgNO_3$. A blank titration is performed where $AgNO_3$ is added to a solution containing only the indicator and not the chloride ion, to determine and remove this error.

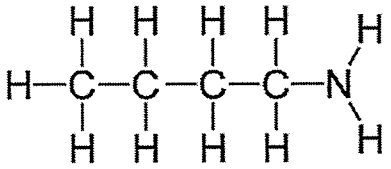
Question 35

Criteria	Mark
• Correctly identifies the compound • Draws the correct structural formula of the compound • Gives thorough reasons for the identity by referring to the table of reactivity • Gives thorough reasons for the identity by referring to each of the four spectra provided	**8**
• Correctly identifies the compound • Draws the correct structural formula of the compound • Gives sound reasons for the identity by referring to the table of reactivity • Gives sound reasons for the identity by referring to each of the four spectra provided	**6–7**
• Correctly identifies the compound • Draws the correct structural formula of the compound • Gives reasons for the identity by referring to the table of reactivity • Gives reasons for the identity by referring to each of the four spectra provided	**4–5**
• Correctly identifies a compound OR • Draws the correct structural formula of a compound • Gives logical reasons for the identity by referring to the table of reactivity and/or a minimum of TWO of the spectra provided	**2–3**
• Provides some correct information about a compound based on some of the data supplied including at least ONE spectrum	**1**

Question 35 continues on the next page

Question 35 continued

Sample answer: The compound is butan-1-amine (1-butanamine).



Justification based on reactivity data:

- Adding $KMnO_4$ is an oxidation test. The purple colour remaining is a negative result and indicates that this compound does not contain an alcohol or an aldehyde functional group.
- Adding bromine water is a test for saturation. The orange colour remaining is a negative result and indicates that this compound does not contain carbon double or triple bonds.
- The absence of bubbles of carbon dioxide in the sodium carbonate test indicates that a carboxylic acid functional group is absent.

Conclusion – the compound is not a primary or secondary alcohol or an aldehyde or an acid.

Justification based on spectra:

- Graph 1 Infrared spectrum
  The narrowness and position of the strong peak below 3000 cm^{-1} indicates the 'absence' of both a carboxylic acid and a hydroxyl group. The band at 3300 to 3500 cm^{-1} indicates the presence of an amine functional group and the two peaks on this absorbance band indicate a 'primary' amine. The peak at approximately 800 cm^{-1} simply indicates the presence of C-C bonds.

- Graph 2 Mass spectrum
  The mass spectrum gives the molecular ion peak at m/z = 73 so it can be determined that the compound has a molecular weight of 73. Butanamine has a molecular mass of 73.1 g mol^{-1}. The base peak is at m/z = 30 which is consistent with the fragment $CH_2NH_2^+$.

- Graph 3 C-13 NMR spectrum
  The carbon-13 NMR spectrum contains four peaks and this indicates that there are at least four carbons in the compound. Based on the reference table, the two peaks around 20 ppm correspond to a hydrocarbon chain and the two peaks around 40 ppm could indicate an amine group.

- Graph 4 Proton NMR spectrum
  The Proton NMR spectrum contains four peaks which indicates the existence of four unique hydrogen environments. This would correspond with the four different hydrogen environments in butanamine.

Question 36

Criteria	Mark
• Indicates a significant difference between the production of petrol or diesel and the production of biodiesel • Thoroughly discusses a minimum of TWO significant advantages and TWO significant disadvantages of using biodiesel as a sustainable fuel • Identifies a minimum of THREE significant factors that would have been considered when building the biofuels plant • Describes in some depth and understanding the characteristics of EACH of these factors that would make them relevant to building the biofuels plant	**9**
• Indicates a difference between the production of petrol or diesel and the production of biodiesel • Soundly discusses a minimum of TWO significant advantages and TWO significant disadvantages of using biodiesel as a sustainable fuel • Identifies a minimum of TWO significant factors that would have been considered when building the biofuels plant • Describes in some depth the characteristics of EACH of these factors that would make them relevant to building the biofuels plant	**7–8**
• Indicates how petrol or diesel is produced • Discusses a minimum of TWO significant advantages and TWO significant disadvantages of using biodiesel as a sustainable fuel • Identifies a minimum of TWO significant factors that would have been considered when building the biofuels plant • Describes the characteristics of EACH of these factors that would make them relevant to building the biofuels plant	**5–6**
• Indicates how petrol or diesel is produced • Discusses ONE significant advantage and ONE significant disadvantage of using biodiesel as a sustainable fuel • Identifies a minimum of TWO factors that would have been considered when building the biofuels plant • Indicates a characteristic of EACH of these factors that would make them relevant to building the biofuels plant	**3–4**
• Provides some relevant information about using biodiesel as a sustainable fuel OR • Provides some relevant information about the reasons for building the biofuels plant	**1–2**

Sample answer: Petrol and diesel fossil fuels are mainly produced from the refining of crude oil at petroleum refineries using fractional distillation. Biodiesel is a liquid fuel obtained by the esterification of oils (called triglycerides) obtained from plant and animal matter such as sunflower, soybean and waste vegetable oils and from commercial cooking waste oils. It can also be produced by the fermentation of sugars produced from cellulose.

The table lists some significant advantages and disadvantages of using biodiesel as a sustainable fuel.

Marks should be awarded for a relevant discussion of items from this list or other valid items.

Question 36 continues on the next page

Advantages	**Disadvantages**
Biodiesel has a renewable, carbon-neutral component	Relatively expensive to produce
100% biodiesel is biodegradable, non-toxic and can be produced from waste materials	Its production could replace food crops and use large quantities of water
Fewer harmful emissions than diesel especially greenhouse gases (e.g., NO_x, CO, CO_2),	Produces harmful emissions and more nitrogen emissions than other petroleum products
Relatively safer to use *(has a high flashpoint)*	Not suitable for transport in low temperatures
Lower blends can be used in existing diesel engines	Causes corrosion of some metals (zinc and tin)
Can improve engine life as it does not contain sulfur	Can cause engine filters to clog
Biodiesel has a greater efficiency than petrol	

The main factors considered when building the biofuel plant would be:

- Availability of raw materials and reagents
- Reaction conditions
- Yield and purity
- Markets and their location
- Availability of cheap energy
- Availability of a workforce
- Suitability of waste disposal sites and environmental controls

The Shoalhaven biofuel plant is conveniently located where its main raw material is located, that is, wheat for starch and canola crops for canola oil. The main reaction involved in producing biodiesel is an equilibrium and the conditions of temperature, pressure, concentration and the use of a catalyst would need to be considered in order to maximise the yield of biodiesel and in a realistic time frame.

Purity would need to be monitored so that contaminants did not affect the reaction process. Regulations need to be enforced for waste treatment. Wastes would need to be properly disposed of, recycled and/or sold for reprocessing for other uses such as fertilisers or added to road base.

The market for biofuels is increasing internationally and recent government policy has required that the fuel industry meets targets for the sale of bio-based fuels. A by-product of the production of biodiesel is glycerol which is sold for use in other industries like soap making and solvents.

The town of Shoalhaven is found near a large city (Nowra) and in an area that has access to relatively cheap energy to power the plant, a large local workforce for the production process and good transport options (rail, road, shipping and airport) to distribute the fuel to markets.

The production of biodiesel has impacts on the environment. A large amount of land and water is required and the use of monocultures (e.g., wheat and canola) affects biodiversity. The combustion of biodiesel produces significant greenhouse gases. Many believe that growing crops for biofuels will offset greenhouse gas emissions from their combustion but this depends on the methods used to produce the feedstock and process the fuel. Some studies have shown significant emissions reductions compared to fossil fuels plants that base their main energy source on non-renewables.

(NB: only 3 factors required)

NSW INDEPENDENT TRIAL EXAMS – 2022
CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section I				
1	1	Mod 7 Alcohols	12-14	2-3
2	1	Mod 5 Factors that affect equilibrium	12-12	2-3
3	1	Mod 7 Alcohols	12-5, 12-14	3
4	1	Mod 8 Analysis of organic substances	12-15	2-3
5	1	Mod 6 Properties of acids and bases Mod 6 Quantitative analysis	12-5, 12-6, 12-13	2-4
6	1	Mod 7 Nomenclature	12-7, 12-14	3-4
7	1	Mod 6 Properties of acids and bases	12-5, 12-13	3-4
8	1	Mod 7 Nomenclature Mod 7 Reactions of organic acids and bases	12-7, 12-14	4
9	1	Mod 5 Static and dynamic equilibrium	12-12	4
10	1	Mod 8 Analysis of inorganic substances	12-4, 12-6, 12-15	4
11	1	Mod 7 Products of reactions involving hydrocarbons	12-6, 12-14	3-4
12	1	Mod 5 Solution equilibria	12-5, 12-6, 12-12	4-5
13	1	Mod 7 Alcohols	12-5, 12-6, 12-14	4-5
14	1	Mod 6 Quantitative analysis	12-5, 12-12, 12-13	4
15	1	Mod 6 Using Brønsted–Lowry theory	12-5, 12-6, 12-12, 12-13	5
16	1	Mod 5 Solution equilibria	12-5, 12-6, 12-12	5-6
17	1	Mod 8 Analysis of inorganic substances	12-5, 12-15	5
18	1	Mod 5 Calculating the equilibrium constant Mod 6 Using Brønsted–Lowry theory	12-4, 12-5, 12-6, 12-12	5-6
19	1	Mod 8 Chemical synthesis and design	12-4, 12-6, 12-15	5-6
20	1	Mod 5 Factors that affect equilibrium	12-4, 12-5, 12-12	5-6

NSW INDEPENDENT TRIAL EXAMS – 2022
CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section II				
21(a)	3	Mod 7 Alcohols	12-2, 12-7, 12-14	2-4
21(b)	2	Mod 7 Alcohols	12-7, 12-14	3-5
22(a)	2	Mod 5 Solution equilibria	12-2, 12-12	3-4
22(b)	2	Mod 5 Solution equilibria	12-6, 12-12	4-5
23(a)	3	Mod 8 Applying chemical ideas	12-4, 12-6, 12-15	4-6
23(b)	2	Mod 8 Applying chemical ideas	12-7, 12-15	3-4
24	3	Mod 5 Solution equilibria	12-7, 12-12	4-5
25	3	Mod 5 Static and dynamic equilibrium	12-5, 12-7, 12-12	3-5
26(a)	4	Mod 7 Alcohols Mod 7 Reactions of organic acids and bases	12-2, 12-6, 12-7, 12-14	4-6
26(b)	1	Mod 7 Reactions of organic acids and bases	12-7, 12-14	3-5
26(c)	3	Mod 7 Polymers	12-7, 12-14	3-5
27(a)	2	Mod 6 Using Brønsted–Lowry theory Mod 7 Reactions of organic acids and bases	12-4, 12-13, 12-14	3-4
27(b)	3	Mod 6 Quantitative analysis Mod 6 Using Bronsted-Lowry theory	12-6, 12-13	5-6
28	3	Mod 7 Reactions of organic acids and bases	12-7, 12-14	3-5
29	3	Mod 5 Calculating the equilibrium constant	12-4, 12-6, 12-12	4-5
30(a)	5	Mod 6 Quantitative analysis	12-4, 12-7, 12-13	4
30(b)	3	Mod 6 Properties of acids and bases	12-6, 12-13	5-6
31	3	Mod 7 Hydrocarbons	12-7, 12-14	3-6
32(a)	1	Mod 5 Static and dynamic equilibrium	12-12	3-4
32(b)	4	WS Planning investigations WS Conducting investigations Mod 5 Factors that affect equilibrium	12-2, 12-3, 12-12	5-6
33(a)	2	Mod 6 Quantitative analysis	12-4, 12-6, 12-13	3-4
33(b)	2	Mod 6 Using Bronsted-Lowry theory	12-7, 12-13	5-6
34	4	Mod 8 Applying chemical ideas	12-6, 12-7, 12-15	5-6
35	8	Mod 8 Analysis of organic substances	12-5, 12-6, 12-7, 12-15	4-6
36	9	Mod 7 Alcohols Mod 8 Chemical synthesis and design	12-7, 12-15	4-6

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{V} \qquad PV = nRT$$

$$q = mc\Delta T \qquad \Delta G° = \Delta H° - T\Delta S° \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

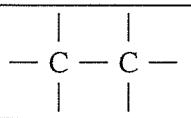
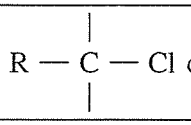
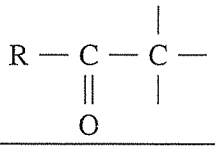
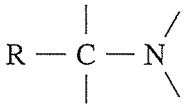
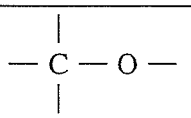
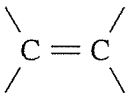
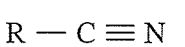
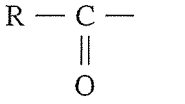
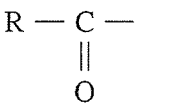
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for the standard potentials. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.