2024
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 at the back of this paper
- Write your student number and/or name at the top of every page

Total marks – 100

Section I – Pages 2–9
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – Pages 10–34
80 marks
- Attempt Questions 21–35
- 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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	A	B	C	D
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20				

1 The discovery of antibiotics in the 20th century reduced infection rates and made many modern medical procedures possible. Today, as bacterial resistance grows, new antibiotics need to be continually synthesised.

What main factor drives scientists to chemically synthesise new antibiotics?

A. Social considerations

B. Political considerations

C. Environmental considerations

D. Technical considerations

2 The cleaning action of soaps and detergents relies on the fact that they can do which of the following?

A. Mechanically remove oils

B. Dissolve oils

C. Emulsify oils

D. Form a protective barrier on fabrics

3 Which of the following is NOT a characteristic of dynamic equilibrium?

A. Requires a closed system

B. Equilibrium position is dependent on temperature

C. Equilibrium may be reached from either direction

D. Requires the concentrations of reactants and products to be the same

4 Which of the following molecules shows the correct positive result of a qualitative test for a particular functional group?

	Functional group	*Positive test result*
A.	Propene	Bromine water is decolourised
B.	Propanol	Turns red litmus blue
C.	Propanone	Potassium dichromate solution turns green
D.	Propanoic acid	Potassium permanganate solution is decolourised

5 What is the concentration of hydroxide ions (in mol L^{-1}) in a solution that has a pH of 9.02?

A. 9.55×10^{-10} mol L^{-1}

B. 1.05×10^{-5} mol L^{-1}

C. 0.95×10^{-1} mol L^{-1}

D. 0.70×10^{-1} mol L^{-1}

6 A sample of methyl butanoate (methyl butyrate) is heated with dilute NaOH.

Which is a product formed?

A. Butyl methanoate

B. 1-butanol

C. Butanoic acid

D. Methanol

7 Which of the following correctly identifies the formula and properties of the compound ammonia?

	Formula	*State at 100 kPa and 25°C*	*Acidic or basic*
A.	NH_2	Gas	Acidic
B.	NH_2	Liquid	Basic
C.	NH_3	Gas	Basic
D.	NH_3	Liquid	Basic

8 Methanol reacts with oxygen gas to form an equilibrium with methanal and water.

$$2CH_3OH(l) + O_2(g) \rightleftharpoons 2HCOH(g) + 2H_2O(g)$$

The equilibrium expression for this reaction would be which of the following?

A. $K_{eq} = [HCOH] \times [H_2O]$

B. $K_{eq} = [HCOH]^2 \times [H_2O]^2$

C. $K_{eq} = \dfrac{[HCOH]^2 \times [H_2O]^2}{[CH_3OH]^2 \times [O_2]}$

D. $K_{eq} = \dfrac{[HCOH]^2 \times [H_2O]^2}{[O_2]}$

9 An organic compound of formula C_4H_8O:

I – could be an alkanal or an alkanone.
II – could be formed by oxidation of an alkanol.
III – could be formed by fermentation of glucose.
IV – could react with an alkanoic acid to form an ester.

Which of the above statements are correct?

A. I, II, III and IV

B. I, II and IV only

C. I and II only

D. III and IV only

10 High yield is an important consideration when designing a chemical synthesis process, but high yield does not always mean high efficiency.

In modern chemistry, an idea called the 'Atom Economy' provides a measure of the efficiency of a chemical reaction.

$$\%\text{ atom economy} = \frac{\text{atomic mass of desired product}}{\text{atomic mass of all reactants}} \times 100$$

Information about the chemical fermentation of glucose, $C_6H_{12}O_6$, in the presence of yeast is shown below.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH(aq) + 2CO_2(g)$$

Reactant or product	*Molecular mass*
$C_6H_{12}O_6$	180.0
C_2H_5OH	46.0
CO_2	44.0

What is the percentage atom economy for the production of ethanol by this reaction?

A. 25.6%

B. 50.0%

C. 51.1%

D. 100%

11 Which of the following is an Arrhenius base?

A. $Mg(OH)_2$

B. MgO

C. Mg

D. $MgCO_3$

12 Which of the following contains molecules best described as tetrahedral in shape around the carbon atom?

A. Methanol

B. Methanal

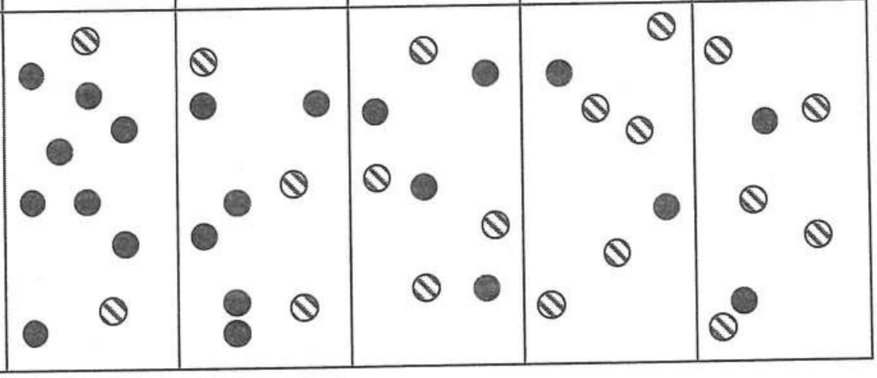
C. Methanoic acid

D. None of the above

13 A teacher designs a model to represent the equilibrium reaction: $2X(g) \rightleftharpoons Y(g)$.

The series of diagrams below show the number of molecules of gas *X* and gas *Y* over five successive time intervals.

Time interval	*10–15*	*16–20*	*21–25*	*26–30*	*31–35*
Concentration of gas molecules *X* ● *Y* ⊘					



During which time interval was equilibrium achieved?

A. 16–20

B. 21–25

C. 26–30

D. 31–35

14 Which of the following ions is the most common ion used in precipitation titrations to determine the concentration of an anion?

A. Ag^+

B. Mg^{2+}

C. Na^+

D. NH_4^+

15 The following equilibrium occurs in human blood when cells release carbon dioxide gas.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \quad \Delta H = -19.4 \text{ kJ mol}^{-1}$$

Which of the following would cause a decrease in the gas pressure of this system?

A. The release of more carbon dioxide by the cells

B. The addition of a base to the system

C. An increase in the blood's temperature

D. Reducing the volume of the vessels occupied by the blood

16 The acid ionisation constants for hydrofluoric acid, nitrous acid and hydrogen cyanide are shown in the table below.

Acid	*Acid ionisation constant, K_a*
HF	7.2×10^{-4}
HNO_2	4.5×10^{-4}
HCN	6.2×10^{-10}

Which of the following shows the conjugate bases arranged in correct order of decreasing base strength?

A. $NO_2^- > F^- > CN^-$

B. $F^- > CN^- > NO_2^-$

C. $F^- > NO_2^- > CN^-$

D. $CN^- > NO_2^- > F^-$

17 What is the molar solubility of silver carbonate at 25°C?

A. 1.56×10^{-3} mol L^{-1}

B. 1.28×10^{-4} mol L^{-1}

C. 2.04×10^{-4} mol L^{-1}

D. 8.46×10^{-12} mol L^{-1}

18 A student used the following procedure to titrate an acetic acid solution of unknown concentration with a standardised solution of dilute sodium hydroxide.

- Rinse and fill the burette with the sodium hydroxide solution.
- Rinse a 25.00 mL pipette and a 250.00 mL conical flask with deionised water.
- Pipette 25.00 mL of the unknown acetic acid solution into the conical flask, before adding 3 drops of the phenolphthalein indicator.
- Titrate to the endpoint and record the volume of sodium hydroxide used.
- Repeat method two additional times.

Compared to the actual concentration of acetic acid, what will the calculated concentration be?

A. The same

B. Lower

C. Higher

D. Different, but cannot be predicted to be higher or lower

19 Which of the following identifies only properties of polyesters?

A. Strong, durable and waterproof

B. Strong, heavy and easily moulded

C. Strong, non-flexible and resistant to chemical attack

D. Rigid, good electrical conduction and good heat conduction

20 Ions formed in a mass spectrometer are separated by magnetic deflection based on their mass (*m*) to charge (*z*) ratio.

Which of the following ions will bend the most when deflected?

	Mass of ion	*Charge on ion*
A.	10	+1
B.	20	+1
C.	10	+2
D.	20	+2

STUDENT NUMBER/NAME: ……………………..

Section II

80 marks
Attempt Questions 21–35
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 (3 marks)

Explain how Aboriginal and Torres Strait Islander Peoples have used the principles of solubility equilibria when removing toxic compounds from foods. **3**

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Question 22 (8 marks)

(a) In a beaker, sodium hydroxide of concentration 0.0273 mol L^{-1} is added to 21.7 mL of 0.0355 mol L^{-1} of nitric acid to make a total volume of 50.0 mL. **5**

Identify TWO practical methods to determine if enough sodium hydroxide was used to neutralise the acid and calculate the pH of the remaining mixture to two significant figures.

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(b) In another reaction between sodium hydroxide and nitric acid, 30.0 mL of 0.600 mol L^{-1} NaOH was mixed with 20.0 mL of 0.900 mol L^{-1} HNO_3, both initially at a temperature of 21.5°C. The measured change in molar enthalpy of neutralisation for this reaction was –52.8 kJ mol^{-1}. **3**

Assuming the mass of reactants is negligible, calculate the maximum temperature reached.

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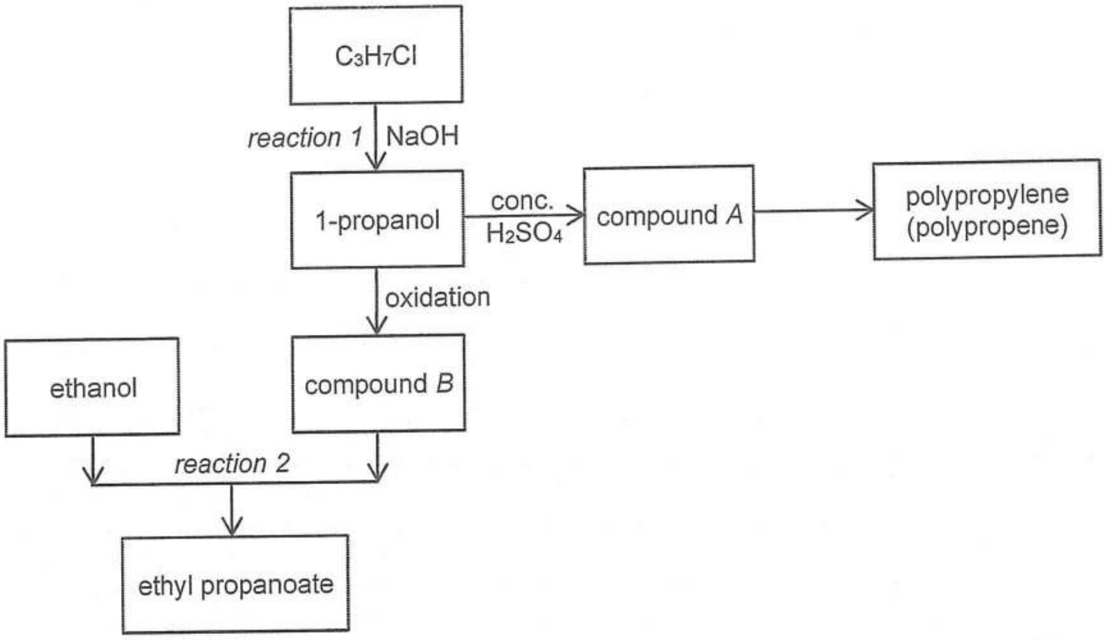
Question 23 (9 marks)

Consider the flow diagram below which outlines a series of chemical reactions.



(a) Name the compound with the formula C_3H_7Cl and identify the type of reaction labelled as reaction 1. **2**

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(b) Draw the structural formulae for compounds *A* and *B*. **2**

Compound *A*:

Compound *B*:

(c) Draw the structure of polypropylene by showing at least THREE monomer units joined together. **1**

Question 23 continues on page 13

Question 23 (continued)

(d) Identify the apparatus used and describe the conditions that would allow *reaction 2* to be performed efficiently and safely in the school laboratory. **4**

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End of Question 23

Question 24 (5 marks)

Nitric oxide gas (NO) reacts with oxygen gas in a sealed 1 L container to produce nitrogen dioxide gas (NO_2).

The table below provides data about the equilibrium constants for this reaction at different temperatures.

Temperature (°C)	*Equilibrium constant*
480	110
750	1.50
1200	2.0×10^{-2}
1750	6.0×10^{-4}

(a) Write a balanced equation for this reaction to show the formation of TWO moles of nitrogen dioxide gas and justify whether this reaction is endothermic or exothermic. **3**

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(b) When the mixture of gases reaches equilibrium at 750°C, there is 0.16 mol L^{-1} of oxygen gas and 0.65 mol L^{-1} of nitrogen dioxide gas in the container. **2**

Calculate the concentration of nitric oxide in the container at equilibrium.

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Question 25 (4 marks)

Give the names and structural formulae of a primary alkanol and a tertiary alkanol that are isomers of each other and outline a chemical test that could be used in the school laboratory to distinguish between these two isomers. **4**

Structural formulae and names:

Chemical test:

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Question 26 (5 marks)

The following method was performed under standard laboratory conditions to measure the amount of carbon dioxide dissolved in a bottle of soda water.

- The total weight of a full unopened bottle of soda water, 500 mL beaker and stirring rod were determined to be 1500 g.
- The soda water was poured into the 500 mL beaker to which 8.00 g of salt, which reduces the solubility of carbon dioxide, was added.
- The mixture was left at 25°C for 60.0 minutes to decarbonate the soda water.
- After the elapsed time, the weight of the empty soda water bottle, 500 mL beaker containing the soda water and salt mixture, and stirring rod, was determined to be 1496 g.

(a) Write a suitable equilibrium equation that represents the dissolution of carbon dioxide in water and explain why carbon dioxide is released into the atmosphere when the soda water bottle is opened. **3**

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(b) Determine the volume of carbon dioxide released from soda water assuming the net loss of mass was due to carbon dioxide only. **2**

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Question 27 (3 marks)

Account for the amphiprotic nature of sodium hydrogen carbonate and use chemical equations to support your response. **3**

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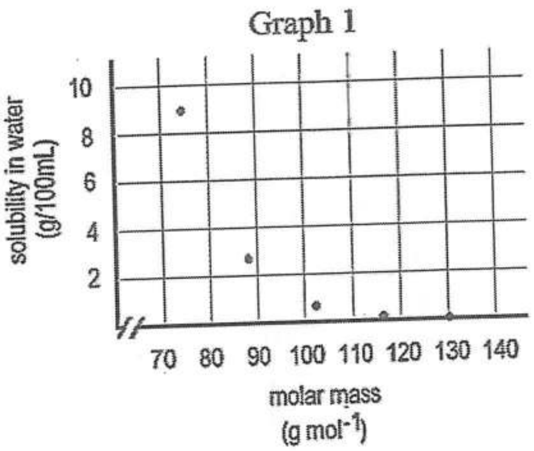
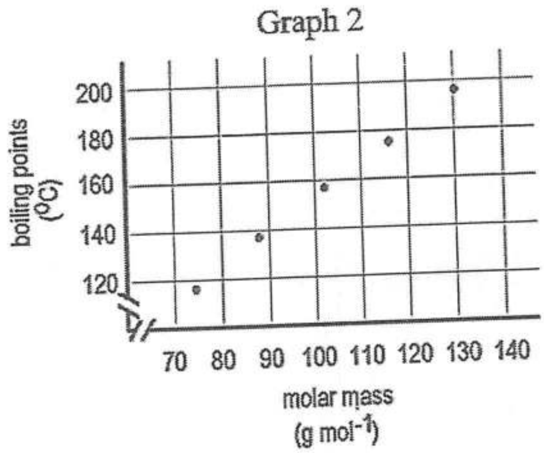
Question 28 (4 marks) 4

The following graphs show the solubility and boiling points of some members of a homologous series of alkanols.





Define the term *homologous series* and explain the difference in the trends shown in the two graphs in terms of intermolecular forces.

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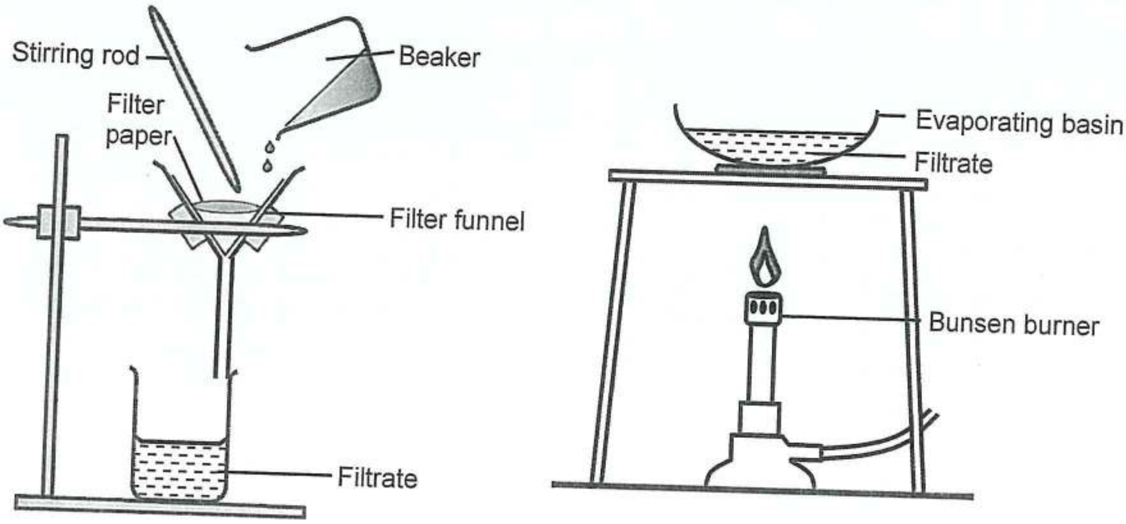
Question 29 (6 marks)

A student collected and analysed a 600 mL sample of saltwater from a tidal creek near the ocean. It was filtered and the filtrate was evaporated to dryness, as shown in the diagrams below.



The following data were collected.

Mass of filter paper	0.171 g
Mass of filter paper and solid	0.221 g
Mass of evaporating basin	44.33 g
Mass of basin and solid remaining	45.25 g

(a) Calculate the percentage by mass of total dissolved solids in the creek sample. **2**

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Question 29 continues on page 20

Question 29 (continued)

(b) It is suspected that the compound Iron (II) chloride has contaminated the creek. **2**

Describe chemical tests that could be carried out on the water sample to determine the presence of iron (II) ions and chloride ions.

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(c) The concentrations of ions in this creek were being regularly tested and results were sent to a local water authority. **2**

Justify the monitoring of the creek water.

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End of Question 29

STUDENT NUMBER/NAME: ……………………..

Question 31 (6 marks)

Silver nitrate is highly soluble in water but is poorly soluble in most organic solvents.

(a) Explain in some detail how silver nitrate dissolves in water. **2**

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(b) A student makes up 250.0 mL of a 2.0×10^{-3} mol L^{-1} aqueous solution of silver nitrate and mixes it with 250.0 mL of a 4.0×10^{-2} mol L^{-1} aqueous solution of sodium carbonate. **4**

Show correct working to determine whether a precipitate will form.

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Question 32 (4 marks)

(a) Write an equation for the reaction of ethanamine (ethylamine) with water. **1**

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(b) Ethanamine has a boiling point of 16.6°C.

Would you expect the boiling point of ethanamide (acetamide) to be higher or lower than 16.6°C? **3**

Draw the structural formula for ethanamide and explain your answer in terms of molecular structure.

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Question 33 (3 marks)

Calculate the pH of a 0.750 mol L^{-1} ammonium chloride solution given that: **3**

$$pK_a\,(NH_4^+) = 9.25.$$

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Question 34 (6 marks)

The element nickel causes algae to stop growing at concentrations above 40 ppm. A sample of river water was analysed for nickel using Atomic Absorption Spectroscopy. Four standardised samples of water containing nickel were each placed separately in a spectrometer. The absorbance results for these samples are recorded in the table below.

Sample	*Nickel concentration* *($g\ mL^{-1}$)*	*Absorbance*
1	2.0×10^{-6}	0.134
2	4.0×10^{-6}	0.272
3	6.0×10^{-6}	0.416
4	8.0×10^{-6}	0.564

(a) Draw a line of best fit calibration graph for the standard nickel solutions and suggest a reason to explain why the four plotted points on this graph may not lie on the line of best fit. **4**

Question 34 continues on page 26

Question 34 (continued)

(b) A 25.0 mL sample of this water was diluted to 250 mL with distilled water and its absorbance was measured as 0.459. **2**

Determine the concentration of nickel in the original sample of river water in parts per million (ppm) and comment on its effect on the growth of algae.

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End of Question 34

Question 35 (8 marks)

Analyse the processes of infrared spectroscopy, mass spectroscopy and nuclear magnetic resonance spectroscopy and explain how these processes contribute to the understanding of the structure of the organic compounds propanone and 1-propanol. **8**

More space to answer Question 35 is provided on page 28

Question 35 (continued)

End of paper

Section II extra writing space

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

Section II extra writing space

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

STUDENT NUMBER/NAME: ....

Chemistry

FORMULAE SHEET

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

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

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

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

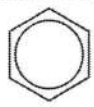
Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	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
$-\overset{\vert}{\underset{\vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$		5–40
$R-\overset{\vert}{\underset{\vert}{C}}-Cl$ or Br		10–70
$R-\underset{\underset{O}{\Vert}}{C}-\overset{\vert}{\underset{\vert}{C}}-$		20–50
$R-\overset{\vert}{\underset{\vert}{C}}-N\langle$		25–60
$-\overset{\vert}{\underset{\vert}{C}}-O-$	alcohols, ethers or esters	50–90
$\rangle C=C\langle$		90–150
$R-C\equiv N$		110–125
		110–160
$R-\underset{\underset{O}{\Vert}}{C}-$	esters or acids	160–185
$R-\underset{\underset{O}{\Vert}}{C}-$	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

STUDENT NUMBER/NAME: ……………………..

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
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	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
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	

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.

STUDENT NUMBER/NAME: ....

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.

NSW INDEPENDENT TRIAL EXAMS – 2024
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	D	A	B	D	C	D	C	C	A	A	C	A	B	D	B	B	A	C

Section II

Question 21

Criteria	Marks
• Thoroughly explains how Indigenous Peoples use the principles of solubility equilibria to remove toxins from food	3
• Explains how Indigenous Peoples use the principles of solubility equilibria to remove toxins from food	2
• Provides some correct information about how Indigenous Peoples use the principles of solubility equilibria to remove toxins from food	1

Sample answer:

Aboriginal and Torres Strait Islander Peoples remove soluble toxic substances from foods (such as cycad seeds) mainly by leaching and heating. In making bread, a paste is formed which has a relatively large surface area, and it is left in water until the solubility of the poison in water is reached (at equilibrium). The solution has then become saturated with the toxin. The equilibrium is then destroyed by removing the saturated solution containing the toxin, adding new pure water and waiting until equilibrium is restored.

Each step drives the equilibrium in the direction that reduces the amount of toxin remaining in the seed.

In many cases, equilibrium is never reached because the cycad seed paste is left in porous bags (dilly bags) for several days of leaching. The seed is then roasted to remove any residual toxin, before being used in cooking.

Question 22(a)

Criteria	Marks
• Identifies TWO valid methods to measure the pH of the final solution • Calculates the correct pH of the final mixture to two significant figures	5
• Identifies ONE valid method to measure the pH of the final solution • Calculates the correct pH of the final mixture OR • Identifies TWO valid methods to measure the pH of the final solution • Calculates a pH of the final mixture using correct processes	4
• Identifies ONE or TWO valid methods to measure the pH of the final solution • Calculates a pH of the final mixture using a correct process	2–3
• Identifies ONE valid method to measure the pH of the final solution	1

Sample answer:

Several drops of universal indicator could be added to the final mixture and the colour of the liquid could be compared against a colour chart. Alternatively, a pH probe from a pH meter could be immersed into the final solution to measure pH of the final solution.

$NaOH(aq) + HNO_3(aq) \rightarrow H_2O(l) + NaNO_3(aq)$
Volume NaOH = 50 – 21.7 = 28.3 mL
n NaOH = $0.0273 \times 0.0283 = 7.7259 \times 10^{-4}$
n HNO_3 = $0.0355 \times 0.0217 = 7.7035 \times 10^{-4}$
n excess NaOH = $7.7259 \times 10^{-4} - 7.7035 \times 10^{-4} = 2.24 \times 10^{-6}$ in 50 mL

$\therefore [NaOH] = \dfrac{2.24 \times 10^{-6}}{0.05} = 4.48 \times 10^{-5}$ mol L^{-1}
pOH = $-\log 4.48 \times 10^{-5} = 4.3487$
$\therefore$ pH = 14 – 4.3487 = 9.65 (2 sf.)

Question 22(b)

Criteria	Marks
• Calculates the maximum temperature reached	3
• Calculates a maximum temperature reached using a correct formula and a correct process	2
• Calculates a maximum temperature reached using a correct formula OR a correct process	1

Sample answer:

$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$
n NaOH = $c \times V = 0.6 \times 0.03 = 0.018$
n HNO_3 = $c \times V = 0.9 \times 0.02 = 0.018$
n H_2O formed = 0.018
$\therefore$ heat produced = $52.8 \times 0.018 = 0.9504$ kJ

$q = mc\Delta T$
950.4 J = $0.05 \times 4.18 \times 10^3 \times \Delta T$
$\therefore \Delta T = \dfrac{950.4}{209} = 4.55$°C
$\therefore$ maximum temperature = 21.5 + 4.55 = 26.1°C

Question 23(a)

Criteria	Marks
• Correctly names the compound with the formula C_3H_7Cl • Correctly identifies reaction type 1	2
• Correctly names the compound with the formula C_3H_7Cl OR • Correctly identifies reaction type 1	1

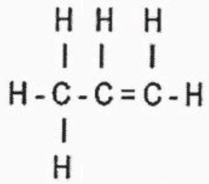
Sample answer:

1-chloropropane. Reaction 1 is a substitution reaction

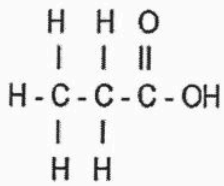
Question 23(b)

Criteria	Marks
• Correctly identifies and draws the structures of both compounds A and B	2
• Correctly identifies and draws the structure of either compound A OR B	1

Sample answer:



Compound A

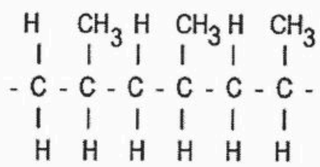


Compound B

Question 23(c)

Criteria	Marks
• Correctly draws the structure of polypropylene showing at least THREE monomer units joined together	1

Sample answer:



Question 23(d)

Criteria	Marks
• Identifies the main apparatus used in esterification reactions • Thoroughly describes the conditions to perform reaction 2 • Indicates a minimum of TWO significant safety conditions used in performing reaction 2	4
• Identifies the main apparatus used in esterification reactions • Describes some conditions necessary to perform reaction 2 • Indicates a minimum of TWO safety conditions used in performing reaction 2	3
• Identifies the main apparatus used in esterification reactions AND • Describes a condition necessary to perform reaction 2 OR • Indicates a safety condition used in performing rection 2	2
• Provides some relevant details about reaction 2	1

Sample answer:

Apparatus used in esterification reactions:

- Reflux apparatus – heating mantle or water bath, round-bottom (boiling) flask, condenser.

Reaction conditions:

- Small volumes (e.g. 10 mL) of both ethanol and propanoic acid added to the flask.
- Small amount of concentrated sulfuric acid added to the mixture in the flask.
- Vertical water-cooled condenser attached to the top of the flask.
- Flask is heated in the water bath at about 90 to 100°C (so that any vapours that form are condensed and returned to the reaction mixture) for approximately 15 minutes.

Safety concerns:

- Wear personal protective equipment (PPE) – lab coat, safety glasses and enclosed shoes and any other protective equipment determined by your risk assessment.
- Work in a well-ventilated area to avoid breathing in vapours.
- Replace lids on bottles of chemicals used and move the bottles away from any heating equipment.
- Ensure any flames are kept well clear of the equipment.

Question 24(a)

Criteria	Marks
• Writes a correctly balanced equilibrium equation • Provides thorough reasoning to justify whether the reaction is endothermic or exothermic	**3**
• Writes a correctly balanced equilibrium equation • Provides reasoning to justify whether the reaction is endothermic or exothermic	**2**
• Writes a correctly balanced equilibrium equation OR • Provides a reason to justify whether the reaction is endothermic or exothermic	**1**

Sample answer:

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2 \times [O_2]}$$

The reaction is exothermic. Since K_{eq} diminishes as the temperature increases, the concentration of $NO_2(g)$ must be decreasing relative to the concentrations of $NO(g)$ and $O_2(g)$. This would happen if heat was produced during the reaction driving the reaction back towards the reactants.

Question 24(b)

Criteria	Marks
• Calculates the correct concentration of nitric oxide	**2**
• Calculates a concentration of nitric oxide using a correct process	**1**

Sample answer:

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2 \times [O_2]}$$

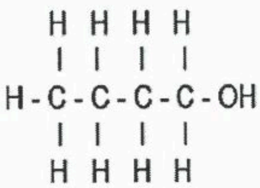
$$[NO]^2 = \frac{[NO_2]^2}{K_{eq} \times [O_2]} = \frac{(0.65)^2}{1.50 \times 0.16} = 1.76$$

$[NO] = 1.3 \text{ mol L}^{-1}$

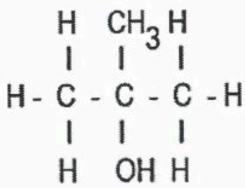
Question 25

Criteria	Marks
• States the correct name of each isomer • Draws the correct structural formulae of each isomer • Correctly outlines a chemical test that can distinguish between a primary and a tertiary alkanol	**4**
• States the correct name of each isomer • Draws the correct structural formulae of each isomer • Identifies a chemical test that can distinguish between a primary and a tertiary alkanol OR • Provides the correct name and structural formulae of a primary OR a tertiary alkanol • Correctly outlines a chemical test that can distinguish between a primary and a tertiary alkanol	**3**
• States the correct name of each isomer • Draws the correct structural formulae of each isomer OR • Provides the correct name and structural formulae of a primary OR a tertiary alkanol • Identifies a chemical test that can distinguish between a primary and a tertiary alkanol OR • Correctly outlines a chemical test that can distinguish between a primary and a tertiary alkanol	**2**
• Provides the correct name and structural formula of a primary OR a tertiary alkanol OR • Identifies a chemical test that can distinguish between a primary and a tertiary alkanol	**1**

Sample answer:



1-butanol



methylpropan-2-ol

Primary alkanols can be oxidised by an acidified solution of $KMnO_4$, tertiary alkanols cannot. Add a small amount of acidified $KMnO_4$ solution to samples of 1-butanol and methylpropan-2-ol in separate test tubes. Carefully shake the test tubes to mix the contents. The sample containing 1-butanol will change from a purple colour to colourless solution, possibly with a brown precipitate. The sample containing methylpropan-2-ol will remain purple.

Question 26(a)

Criteria	Marks
• Writes a suitable equilibrium equation • Using Le Chatelier's principle, gives appropriate reasons why dissolved carbon dioxide is released into the atmosphere	3
• Writes a suitable equilibrium equation AND • Using Le Chatelier's principle, gives an appropriate reason why dissolved carbon dioxide is released into the atmosphere OR • Using Le Chatelier's principle, gives appropriate reasons why dissolved carbon dioxide is released into the atmosphere	2
• Writes a suitable equilibrium equation or provides some relevant information	1

Sample answer:

Equation: $CO_2(g) \rightleftharpoons CO_2(aq)$ OR $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

When the soda water bottle is opened the high-pressure environment within the bottle drops to atmospheric pressure. As a result, the carbon dioxide equilibrium of the soda water is altered, and by Le Chatelier's Principle, shifts the equilibrium to the left to increase pressure, favouring the production of carbon dioxide gas which is now released to the environment thereby decarbonating the soda water.

Question 26(b)

Criteria	Marks
• Correctly calculates the volume of carbon dioxide	2
• Calculates a volume of carbon dioxide using a correct process	1

Sample answer:

Total mass before = 1508 g

Total mass after = 1496 g

mass CO_2 released = 1508 – 1496 = 12 g

$$n\,CO_2 = \frac{12}{44.01} = 0.2727$$

$V\,CO_2 = 0.2727 \times 24.79 = 6.76$ L

Question 27

Criteria	Marks
• Defines the term *amphiprotic* • Explains why $NaHCO_3$ is amphiprotic • Writes a minimum of TWO correct and relevant chemical equations	3
• Defines the term *amphiprotic* • Explains why $NaHCO_3$ is amphiprotic OR • Explains why $NaHCO_3$ is amphiprotic • Writes a minimum of TWO correct and relevant chemical equations	2
• Provides some relevant information	1

Sample answer:

Amphiprotic means the compound has the ability to act as an acid with a base and a base with an acid. Sodium hydrogen carbonate can react with water in two ways: one by accepting a proton from water and second by donating a proton to water. In an aqueous solution, $NaHCO_3$ dissociates to form Na^+ and HCO_3^- ions. The HCO_3^- ion is then capable of acting as an acid (proton donor) or as a base (proton receiver) as shown in the following equations.

As an acid: $HCO_3^- + H_2O \rightarrow CO_3^{2-} + H_3O^+$
As a base: $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$

Question 28

Criteria	Marks
• Provides a correct definition of *homologous series* • Clearly identifies and thoroughly explains the trends shown in both graphs in terms of intermolecular forces	4
• Provides a correct definition of *homologous series* • Identifies and explains the trends shown in both graphs in terms of intermolecular forces	3
• Provides a correct definition of *homologous series* • Identifies and explains the trends shown in ONE graph in terms of intermolecular forces OR • Identifies and explains the trends shown in BOTH graphs in terms of intermolecular forces	2
• Provides a correct definition of *homologous series* OR • Attempts to explain the trend in ONE of the graphs with some relevant information related to intermolecular forces	1

Sample answer:

A homologous series is a series of compounds with similar chemical properties that have the same functional group but differ in carbon chain length, each member of the series differing from the successive member by a CH_2 unit.

Graph 1 shows a decrease in solubility as the molar mass increases. Solubility depends on the strength of the interactions between solvent and solute molecules. Short chained alkanols with lower molar masses are polar and can establish strong hydrogen bonds with water molecules resulting in a high solubility in water. Alkanols with a higher molar mass have longer carbon chains. Being considerably less polar, these longer chains cannot establish strong interactions with water molecules, hence the ability to dissolve in water is decreased. The longer the chain, the lower the solubility.

Graph 2 shows an increase in boiling point as molar mass increases. The boiling point of a compound depends on the strength of the intermolecular forces within the compound. The stronger the forces the higher the boiling point. As the molar mass of a compound increases, the overall strength of the dispersion forces between the molecules increases, resulting in a higher boiling point.

Question 29(a)

Criteria	Marks
• Calculates the correct percentage by mass of TDS	2
• Calculates a percentage by mass of TDS using a correct process	1

Sample answer:

mass total dissolved solid = 45.25 – 44.33 = 0.920 g

mass water = 600 g

$$\% \, TDS = \frac{0.92}{600 + 0.92} \times 100 = 0.153\%$$

Question 29(b)

Criteria	Marks
• Describes a correct chemical test for Fe^{2+} ions and Cl^- ions	2
• Describes a correct chemical test for Fe^{2+} ions OR Cl^- ions	1

Sample answer:

A few drops of 1.0 mol L^{-1} NaOH solution could be added to 100 mL of the water sample. A green or white-green precipitate will positively identify the presence of Fe^{2+} ions in the sample.

(Other tests may be applicable, e.g. drops of purple $KMnO_4$ solution are decolourised by Fe^{2+} ions; add drops of potassium ferricyanide solution and a deep blue colour will indicate the presence of Fe^{2+} ions).

Adding drops of silver nitrate solution, $AgNO_3$, to an acidified sample of the creek water produces a white precipitate. This identifies the presence of chloride ions.

Question 29(c)

Criteria	Marks
• Gives a detailed reason to explain why the creek water is monitored	2
• Gives a reason to explain why the creek water is monitored	1

Sample answer:

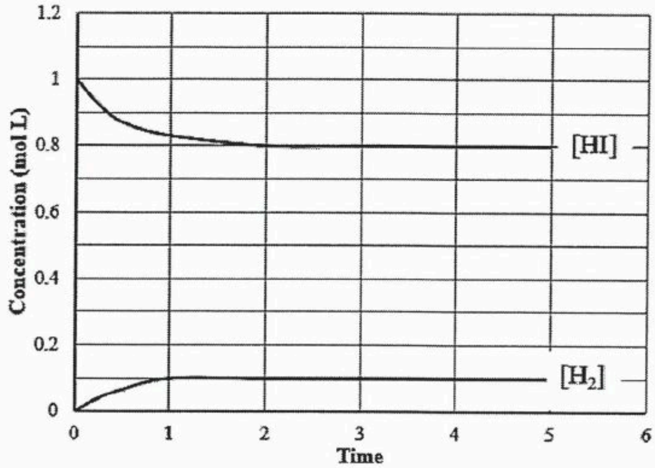
The concentration of ions in water supplies are often monitored because they can affect the health and well-being of humans and ecosystems. The ions may be toxic over a certain concentration or they may accumulate over time, eventually damaging body organs or body systems. Some ions such as lead are easily absorbed directly through drinking water but can also be ingested by eating large fish such as tuna. Certain amounts of lead can disrupt the nervous system. Excess iron can directly damage cells. Excess chloride ions adversely affects blood pressure.

Question 30(a)

Criteria	Marks
• Draws an accurate line that shows how the concentration of hydrogen changes over time • Calculates the correct equilibrium constant for the reaction	2
• Draws an accurate line that shows how the concentration of hydrogen changes over time OR • Calculates the correct equilibrium constant for the reaction	1

Sample answer:

$$K_{eq} = \frac{[H_2][I_2]}{[HI]^2} = \frac{0.1^2}{0.8^2} = 0.16$$



Question 30(b)

Criteria	Marks
• Defines *collision theory* • Explains how the reaction approaches and reaches equilibrium by referring to collision theory and reaction rate in some detail • Includes a relevant diagram	4
• Defines *collision theory* • Explains how the reaction approaches and reaches equilibrium by referring to collision theory and reaction rate in some detail OR • Explains how the reaction approaches and reaches equilibrium by referring to collision theory and reaction rate in some detail • Includes a relevant diagram	3
• Explains how the reaction approaches and reaches equilibrium by referring to collision theory OR reaction rate • Includes a relevant diagram	2
• Provides some relevant information related to collision theory	1

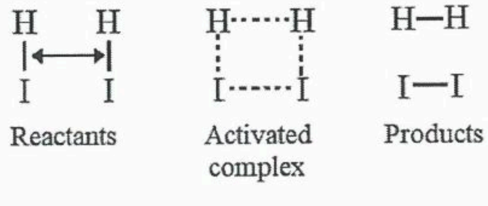
Sample answer:

Collision theory states that for a chemical reaction to occur, reacting particles must collide with one another and that the rate of the reaction depends on the frequency of collisions. For collisions to be successful, reacting particles must collide with sufficient energy to disrupt the bonds of the reactant molecules and with a suitable orientation so bonds can be broken and formed.

The forward reaction in (a) is endothermic. Initially, HI molecules absorb energy, collide and form an activated complex. This complex then separates and forms separate molecules H_2 and I_2.

When a chemical reaction first occurs the forward reaction is relatively fast as the reactants are concentrated and the chances of more successful collisions is therefore greater. 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 increases. This continues until the forward reaction rate equals the reverse reaction rate and the system is now said to be in equilibrium.



Question 31(a)

Criteria	Marks
• Describes a minimum of TWO main processes involved in the dissolution of silver nitrate in water	2
• Describes a main process involved in the dissolution of silver nitrate in water	1

Sample answer:

Solid silver nitrate ($AgNO_3$) has an ionic lattice structure. When $AgNO_3$ dissolves, three main processes occur. Firstly, the outer ions form ion-dipole interactions with polar water molecules. This generates forces that overcome the hydrogen bonds between water molecules causing their separation. At the same time, electrostatic forces present between ions in the lattice structure of the ionic compound are weakened, leading to ion separation. Finally, the ions become hydrated and surrounded as ion-dipole forces are fully established.

Question 31(b)

Criteria	Marks
• Shows correct processes to calculate THE ionic product of silver carbonate • Compares the ionic product of silver carbonate to its K_{sp} • Determines if a precipitate will form	4
• Shows some correct processes to calculate AN ionic product of silver carbonate • Compares the ionic product of silver carbonate to its K_{sp} • Determines if a precipitate will form	2–3
• Shows a correct process to calculate AN ionic product of silver carbonate • States if a precipitate will form	1

Sample answer:

$Ag_2CO_3(s) \rightleftharpoons 2Ag^+(aq) + CO_3^{2-}(aq)$

$K_{sp}\ Ag_2CO_3 = [Ag^+]^2[CO_3^{2-}] = 8.46 \times 10^{-12}$

$n\ AgNO_3 = c \times V = 2.0 \times 10^{-3} \times 0.25 = 5.0 \times 10^{-4}$

$\therefore n\ Ag^+ = 5.0 \times 10^{-4}$

$$\therefore [Ag^+] = \frac{5.0 \times 10^{-4}}{0.5} = 1.0 \times 10^{-3} \text{ mol L}^{-1}$$

$n\ Na_2CO_3 = c \times V = 4.0 \times 10^{-2} \times 0.25 = 0.01$

$\therefore n\ CO_3^{2-} = 0.01$

$$\therefore [CO_3^{2-}] = \frac{0.01}{0.5} = 0.02 \text{ mol L}^{-1}$$

$Q_{sp} = (1.0 \times 10^{-3})^2 \times 0.02 = 2.0 \times 10^{-8}$

$Q_{sp} > K_{sp}$ A precipitate will form when the solutions are mixed.

Question 32(a)

Criteria	Marks
• Provides a correct equation	1

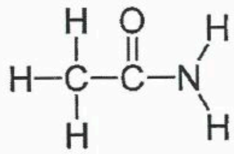
Sample answer:

$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ + OH^-$

Question 32(b)

Criteria	Marks
• Draws a correct structural formula for ethanamide • Explains why ethanamide has a higher boiling point in terms of molecular structure	3
• Draws a correct structural formula for ethanamide • Provides some relevant information about ethanamide that would result in it having a higher boiling point	2
• Draws a correct structural formula for ethanamide OR • Provides some relevant information about ethanamide that would result in it having a higher boiling point	1

Sample answer:



Ethanamide molecules contain a highly electronegative O atom attached by a double bond to the carbon atom attached to the nitrogen atom. The presence of this O atom increases the polarity of the molecules, strengthening the dipole-dipole interactions between molecules, as well as allowing for more extensive hydrogen bonding between molecules. These stronger intermolecular forces result in a higher boiling point for ethanamide.

Question 33

Criteria	Marks
• Calculates the correct pH of the ammonium chloride solution	**3**
• Calculates a pH of the ammonium chloride solution using a correct process AND formula	**2**
• Calculates a pH of the ammonium chloride solution using a correct process OR formula	**1**

Sample answer:

$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

$pK_a = 9.25$

$\therefore K_a = 5.62 \times 10^{-10}$

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]} = \frac{X^2}{0.750} = 5.62 \times 10^{-10}$$

$\therefore X^2 = 5.62 \times 10^{-10} \times 0.750 = 4.215 \times 10^{-10}$

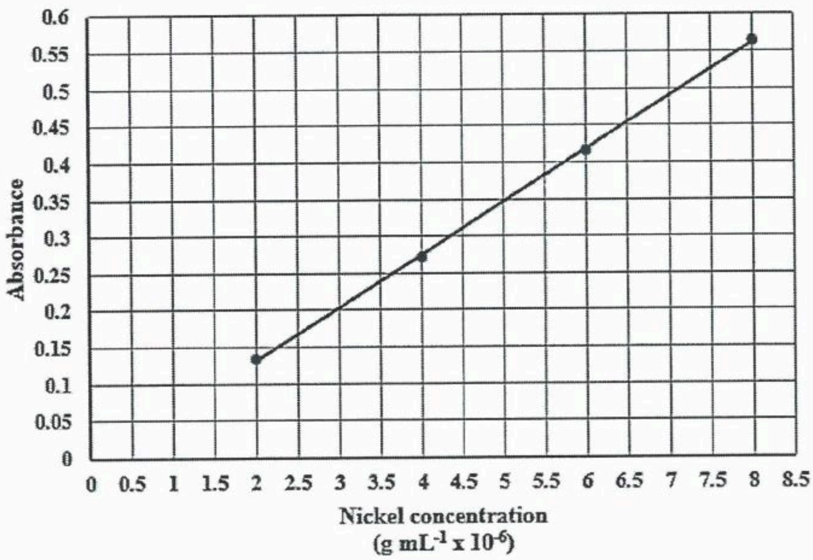
$X = [H_3O^+] = 2.053 \times 10^{-5}$

$\text{pH} = -\log 2.053 \times 10^{-5} = 4.69$

Question 34(a)

Criteria	Marks
• Draws an accurately plotted line of best fit • Scales are suitably spaced • Scales are labelled with correct names and units • Suggests a relevant reason to explain why the four plotted points are not all on the line of best fit	4
• Draws a clearly plotted line of best fit • Scales are suitably spaced • Suggests a relevant reason to explain why the four plotted points are not all on the line of best fit OR • Draws a clearly plotted line of best fit • Scales are labelled with correct names and units • Suggests a relevant reason to explain why the four plotted points are not all on the line of best fit	3
• Draws a plotted line of best fit • Suggests a relevant reason to explain why a plotted point may not be on the line of best fit	2
• Draws a plotted line of best fit OR • Suggests a relevant reason to explain why a plotted point may not be on the line of best fit	1

Sample answer:



The spectrometer may not be calibrated correctly. Small errors may have occurred in the preparation of the standard solutions. The standard solutions may have been affected by light or decomposition. *(One answer only is required.)*

Question 34(b)

Criteria	Marks
• Determines the correct concentration of nickel in parts per million • Provides a relevant comment on nickel's effects on algal growth	2
• Determines the correct concentration of nickel in parts per million	1

Sample answer:

Absorbance = 0.459

$\therefore$ [Ni] = 6.6×10^{-6} g mL^{-1} in diluted sample

$\therefore$ [Ni] = 6.6×10^{-5} g mL^{-1} = 6.6×10^{-2} mg mL^{-1} in river water

$\therefore$ [Ni] = 66 mg L^{-1} = 66 ppm

This concentration of nickel is well above 40 ppm and would stop the growth of algae in this particular river.

Question 35

Criteria	Marks
• Identifies the major parts of EACH of the THREE spectroscopes • Describes the overall function of EACH spectroscopic process • Identifies how EACH process contributes to an understanding of the structures of propanone and 1-propanol	8
• Identifies the major parts of TWO of the spectroscopes • Describes the overall function of EACH spectroscopic process • Identifies how EACH process contributes to an understanding of the structures of propanone and 1-propanol	6–7
• Identifies some major parts of the spectroscopes • Describes an overall function of a spectroscopic process • Identifies how a process contributes to an understanding of the structures of propanone and 1-propanol	4–5
• Identifies some major parts of a spectroscope • Describes an overall function of a spectroscopic process OR • Identifies how a process contributes to an understanding of the structures of propanone and 1-propanol	2–3
• Provides some relevant information	1

Sample answer:

An infrared spectrometer consists of three basic components: an infrared lamp (or other IR source), a monochromator and a detector. The IR lamp passes IR wavelengths through a sample of an organic compound and compares the transmitted radiation through a sample with the transmitted radiation through a reference cell.

Some wave frequencies make some of the bonds in molecules in the sample vibrate. When these bonds vibrate, they absorb energy from the IR light source. This means less IR light gets through the sample to the detector. The data produced is shown as a trace or spectrum with absorbance peaks. Each peak is characteristic of a particular bond or atoms vibrating. A strong peak will appear in a spectrum of propanone at 1680–1750 cm^{-1} which is characteristic of a carbonyl functional group. A strong and broad peak will appear in a spectrum of 1-propanol at 3230–2550 cm^{-1} which is characteristic of an alcohol functional group. In this way, infrared spectroscopy can distinguish between these two compounds.

A mass spectrometer consists of a vaporisation chamber, an ionisation chamber, a deflection tube and a detector. The sample to be tested is first turned into a vapour which is then exposed to high voltages and forms ions. The ions then pass into the deflection tube where they are separated in a magnetic field on the basis of their mass-to-charge ratio (m/z). The number of ions with different m/z values are measured by a detector and the data is displayed as a plot of the abundance of ions, with different mass-to-charge ratios. This is called a mass spectrum.

In most cases, the peaks in a mass spectrum are generated by singly charged ions. One ion called the molecular ion is formed when the entire molecule loses an electron and becomes positively charged. The m/z ratio of this ion is the same as the relative molecular mass of the ion. The other peaks in the spectrum, which have smaller m/z values than the molecular ion, represent fragment ions.

Question 35 continues on the next page

Question 35 continued

If the general formula of a compound is known then obtaining its molecular mass from a mass spectrum can help deduce its identity. Comparing mass spectra to standard mass spectra can also help identify the structure of some compounds. Propanone and 1-propanol have different molecular masses and different fragment ions, so can each be separately identified by mass spectroscopy.

A nuclear magnetic resonance (NMR) spectrometer has three main parts:
1. A large magnet to generate a magnetic field around a sample
2. A radio transmitter which generates a radio-frequency in a coil surrounding the sample
3. A detector (or receiver) which amplifies and detects the magnetic resonance signal and passes it to a computer to produce a spectrum.

NMR spectroscopy uses radio waves to cause the nuclei of certain atoms (those with an odd number of particles) to spin. Examples are ^{1}H atoms and ^{13}C atoms. These spinning nuclei act like tiny bar magnets and when they are inside the NMR spectrometer, they are normally in a low energy state. A radio transmitter is used to provide the energy to 'flip' the nuclei into a high-energy state.

Over time, the nuclei tend to flip back into a lower-energy spin. As they do, they release a pulse of energy, which is measured and displayed in graphical form as an NMR spectrum.

The difference in energy between the higher and lower energy spin states depends on the type of nucleus and the chemical environment surrounding the nucleus. Propanone has 2 carbon environments (2 spectrum signals) and 1 hydrogen environment (1 spectrum signal). On the other hand, 1-propanol has 3 carbon environments (3 spectrum signals) and 4 hydrogen environments (4 spectrum signals). In this way, NMR spectroscopy gives information about and distinguishes between the structure of these molecules.

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

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MAPPING GRID – continued

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section II				
21	3	Mod 5 Solution equilibria	12-7, 12-12	2-4
22(a)	5	Mod 6 Using Brønsted-Lowry Theory	12-3, 12-4, 12-6, 12-13	2-4
22(b)	3	Mod 6 Properties of acids and bases	12-4, 12.6, 12-13	3-4
23(a)	2	Mod 7 Nomenclature Mod 7 Products of reactions involving hydrocarbons Mod 7 Alcohols	12-6, 12-7, 12-14	3-4
23(b)	2	Mod 7 Alcohols	12-5, 12-7, 12-14	3-4
23(c)	1	Mod 7 Polymers	12-7, 12-14	3-4
23(d)	4	Mod 7 Reactions of organic acids and bases	12-2, 12-7, 12-14	3-6
24(a)	3	Mod 5 Calculating equilibria constant	12-5, 12-12	3-4
24(b)	2	Mod 5 Calculating equilibria constant	12-4, 12-6, 12-12	3-4
25	4	Mod 7 Hydrocarbons Mod 7 Alcohols	12-2. 12-7, 12-14	3-5
26(a)	3	Mod 5 Static and dynamic equilibrium Mod 5 Factors that affect equilibrium	12-6, 12-7, 12-12	3-5
26(b)	2	Mod 6 Quantitative analysis	12-4, 12-13	3-4
27	3	Mod 6 Using Brønsted-Lowry Theory	12-7, 12-13	4-5
28	4	Mod 7 Hydrocarbons Mod 7 Alcohols	12-5, 12-7, 12-14	2-4
29(a)	2	Mod 8 Analysis of inorganic substances	12-4, 12-15	3-4
29(b)	2	Mod 8 Analysis of inorganic substances	12-15	4-5
29(c)	2	Mod 8 Analysis of inorganic substances	12-5, 12-7, 12-15	4-5
30(a)	2	Mod 5 Static and dynamic equilibrium Mod 5 Calculating equilibria constant	12-4, 12-12	4-5
30(b)	4	Mod 5 Static and dynamic equilibrium Mod 5 Factors that affect equilibria	12-6, 12-7 12-12	5-6
31(a)	2	Mod 5 Solution equilibria	12-7, 12-12	4-5
31(b)	4	Mod 5 Solution equilibria	12-4, 12-12	5-6
32(a)	1	Mod 7 Reactions of organic acids and bases	12-7, 12-14	3-4
32(b)	3	Mod 7 Reactions of organic acids and bases	12-6, 12-7, 12-14	4-6
33	3	Mod 6 Quantitative analysis	12-4, 12-7, 12-13	5-6
34(a)	4	Mod 8 Analysis of inorganic substances	12-4, 12-15	3-5
34(b)	2	Mod 8 Analysis of inorganic substances	12-4, 12-5, 12-15	4-6
35	8	Mod 8 Analysis of organic substances	12-5, 12-7, 12-15	5-6