SYDNEY GRAMMAR SCHOOL

TRIAL EXAMINATION 2022

FORM VI CHEMISTRY

STRUCTURE OF PAPER

SECTION I

A: Multiple Choice 20 marks

Allow about 30 minutes for this section.

SECTION II 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE: Fri 12th August 8.40am

DURATION: 3 hours + 5 minutes reading time

MARKS: 100

CHECKLIST

Each boy should have the following:

- ☐ 1 Examination Paper (data sheet attached on back)
- ☐ 1 Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the paper in a neat bundle.
- WRITE YOUR CANDIDATE NUMBER IN THE SPACE PROVIDED AT THE TOP OF EACH PAGE WHERE INDICATED ON PAGE 11, 15, 21 and 27.

Authors: MTK, TW, AKBB, JLS

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SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

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1 Which of the following is part of Arrhenius's theory of acids and bases?

(A) Bases liberate OH^- ions in solution.

(B) Acidity is due to the presence of oxygen in non-metal compounds.

(C) Compounds which contain hydrogen are acidic in nature.

(D) All acids taste sour.

2 Which class of organic molecules undergo addition reactions?

(A) alkenes

(B) alkanes

(C) alkanols

(D) amines

3 If a solution of HCl(aq) has a pH of 2 and an equimolar concentration of acid X has a pH of 1.8, acid X is most likely to be a:

(A) Strong monoprotic acid

(B) Strong polyprotic acid

(C) Weak monoprotic acid

(D) Weak polyprotic acid

4 In which of the following reactions would decreasing the volume of the reaction vessel (at constant temperature) leave the amount of reactants and products unchanged?

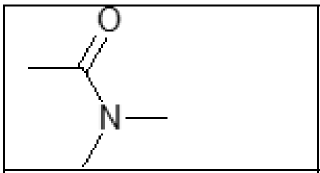
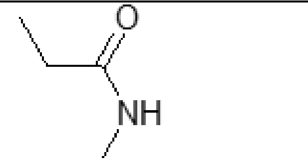
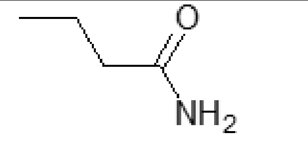
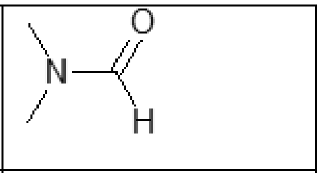
(A) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(B) $2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$

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

(D) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

5 Which of the following molecules is a secondary amide?

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

6 Consider the titration apparatus below.

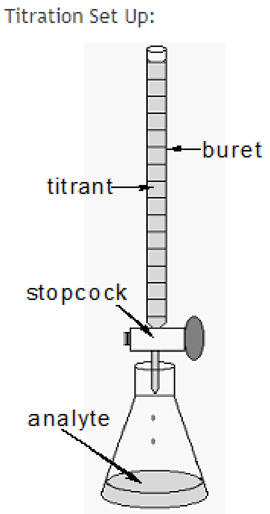


Figure 1: Titration Setup

Which of the following combinations of liquids should be used to rinse the glassware prior to commencing the titration to enhance the accuracy of the process?

	Burette	Pipette	Conical flask
(A)	deionised water	deionised water	deionised water
(B)	deionised water	analyte	deionised water
(C)	titrant	analyte	deionised water
(D)	titrant	deionised water	deionised water

7 In which of the following titration reactions would buffering of the solution occur?

(A) A strong acid added to a strong base

(B) A strong acid added to a weak base

(C) A strong base added to a strong acid

(D) A weak acid added to water

8 Which of the following molecules will **not** react with acidified potassium dichromate solution?

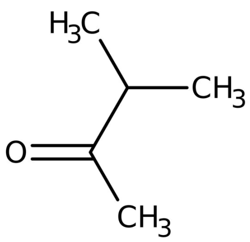
(A) 2-methylbutan-2-ol

(B) butanal

(C) butan-2-ol

(D) butan-1-ol

9 Which of the following is true for 3-methylbutan-2-one, shown below?



(A) It forms a silver mirror on treatment with Tollens' reagent $[Ag(NH_3)^2]^+$.

(B) It is a functional group isomer of pentan-1-ol.

(C) It may be prepared by the catalysed hydration of 3-methylbut-1-yne.

(D) It will show five distinct carbon atoms in spectroscopy.

10 A 35 mL sample of 0.25 M NaOH solution was placed in a 1 L volumetric flask and then filled with deionised water up to the mark. What is the pH of the final solution?

(A) 0.00875

(B) 2.06

(C) 11.94

(D) 12.15

11 Methane reacts with an **excess** of chlorine in the presence of UV light. What are the products of the reaction if it goes to completion?

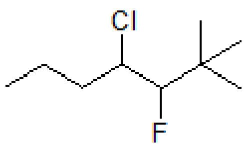
(A) CH_3Cl and H_2

(B) CH_3Cl and HCl

(C) CCl_4 and H_2

(D) CCl_4 and HCl

12 What is the IUPAC name for the compound shown below?



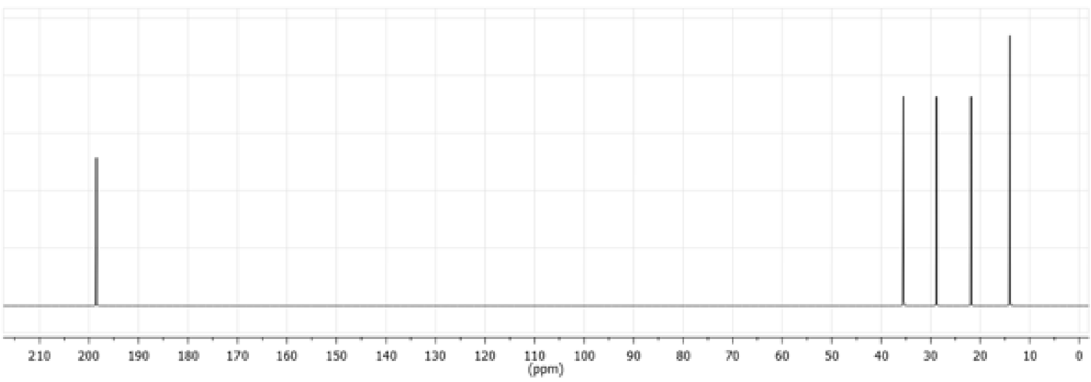
(A) 2,2-dimethyl-3-fluoro-4-chloroheptane

(B) 4-chloro-5-fluoro-6,6-dimethylheptane

(C) 4-chloro-3-fluoro-2,2-dimethylheptane

(D) 4-chloro-2,2-dimethyl-3-fluoroheptane

13 Consider the following ^{13}C NMR spectrum.



Which of the following compounds would have this spectrum?

(A) pentane

(B) pentanal

(C) pentanoic acid

(D) 2-methylbutane

14 Equal amounts of four compounds are added to the same volume of water. Which compound would produce a solution with the highest pH?

(A) $CH_3CONHCH_3$

(B) CH_3COOH

(C) CH_3COOCH_3

(D) $CH_3CH_2NH_2$

15 Sulfur trioxide can be produced from the reaction of sulfur dioxide and oxygen according to the following equation:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

One mole of sulfur dioxide and two moles of oxygen are mixed in a reaction vessel, and the system allowed to proceed towards equilibrium.

Which of the following statements about this system is true?

(A) The concentration of $O_2(g)$ will always be half of the concentration of $SO_2(g)$.

(B) The concentration of $SO_2(g)$ will increase at the same rate as the $SO_3(g)$ concentration is increasing.

(C) The concentration of $O_2(g)$ will decrease at double the rate that the $SO_2(g)$ concentration is decreasing.

(D) The concentration of $O_2(g)$ will decrease at half the rate that the $SO_3(g)$ concentration is increasing.

16 The K_{sp} of chromium(III) hydroxide is 6.3×10^{-31}. What is the concentration (in mol L^{-1}) of chromium(III) ions in a saturated solution of chromium(III) hydroxide?

(A) $\sqrt{6.3 \times 10^{-31}}$

(B) $\sqrt[3]{\frac{6.3 \times 10^{-31}}{4}}$

(C) $\sqrt[4]{\frac{6.3 \times 10^{-31}}{27}}$

(D) $\sqrt[5]{\frac{6.3 \times 10^{-31}}{108}}$

17 If 1 mL of an acid with a pH of 5 is added to 999 mL of deionised water, what is the pH of the new solution?

(A) pH 5
(B) pH 6
(C) pH 7
(D) pH 8

18 Which of the following compounds has the highest solubility (in g L^{-1})?

Compound		Molar mass (g mol^{-1})	K_{sp}
(A)	Lithium chloride	42.39	395
(B)	Sodium chloride	58.44	42
(C)	Potassium chloride	74.55	22
(D)	Rubidium chloride	120.9	56

19 Consider the following reaction:

$$H_2(g) + I_2(s) \rightleftharpoons 2HI(g) \qquad \Delta H^{\ominus} = -9.5 \text{ kJ mol}^{-1}$$

Which of the following changes, when imposed on this system at equilibrium, will result in an increased concentration of HI(g) when equilibrium is re-established?

(A) Halving the volume of the system.
(B) Adding $I_2(s)$.
(C) Removing $HI(g)$.
(D) Increasing the temperature of the system.

20 Consider the following reaction:

$$W(g) + 2X(g) \rightleftharpoons 2Y(g) + Z(g) \qquad K_c = 200$$

If 0.5 mol of W and 0.5 mol of X are placed in a sealed 0.5 L vessel and allowed to react, which of the following is true once the system reaches equilibrium?

(A) 2[W] = [X]

(B) [W] > [X]

(C) [Y] = [X]

(D) [Z] > [Y]

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SECTION II: 80 marks

Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 21 (5 marks) **Marks**

The definition of acids and bases has changed often over time.

a) State the Brønsted-Lowry definition of a base. **1**

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b) Explain how the Brønsted-Lowry definition of a base is an improvement on the Arrhenius model, using an example and a relevant equation to illustrate this. **3**

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c) Identify a limitation of the Brønsted-Lowry model. **1**

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Question 22 (3 marks) **Marks**

The K_{sp} for barium fluoride is 3.10×10^{-6}. Calculate the solubility (in g per 100 mL) of barium fluoride.

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Question 23 (6 marks)

Titration is an analytical technique used to determine the unknown concentration of an acid or base.

(a) A piece of equipment often used in a titration is shown in the diagram above. Name this piece of equipment and identify its purpose in a titration. **2**

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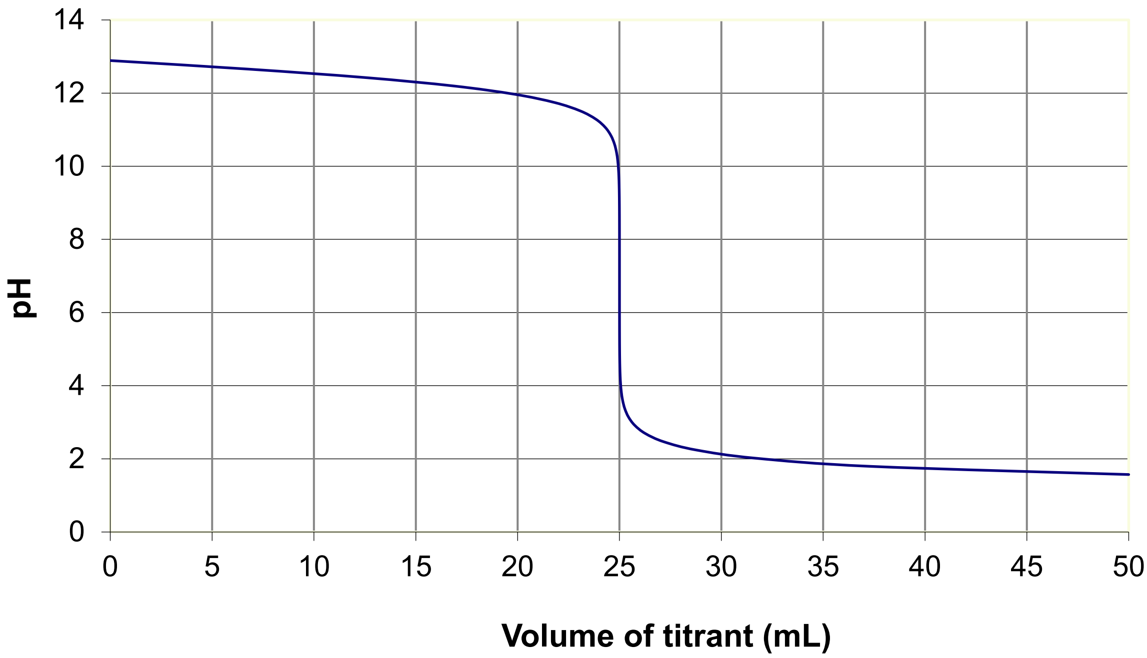
Question cont. **Marks**

(b) The titration curve below represents the change in pH when a monoprotic 0.1 M strong acid is incrementally added to a strong base during a titration.



On the same graph, sketch the curve you would get if you were to incrementally add a monoprotic 0.1 M **weak** acid to the same base solution.

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(c) Indicators used in titrations are usually weak acids. Identify and explain the effect of adding too much indicator when conducting this titration. **2**

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Question 24 (7 marks) **Marks**

Dinitrogen tetraoxide, a colourless gas, decomposes to form brown nitrogen dioxide gas, according to the following equation.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H^\ominus = +57 \text{ kJ mol}^{-1}$$

A mixture of dinitrogen tetraoxide and nitrogen dioxide is placed in a sealed syringe.

(a) Using collision theory, explain the effect of increasing the temperature of this system on the equilibrium constant, K_c. **4**

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A 1.00 L reaction vessel containing 0.100 mol of dinitrogen tetraoxide gas is allowed to come to equilibrium. 0.250 mol of nitrogen dioxide is then added and the system allowed to reach equilibrium again. The final concentration of nitrogen dioxide in the vessel is 0.400 mol L^{-1}. The temperature is constant throughout these experiments.

(b) Calculate the equilibrium constant, K_c, for this reaction. **3**

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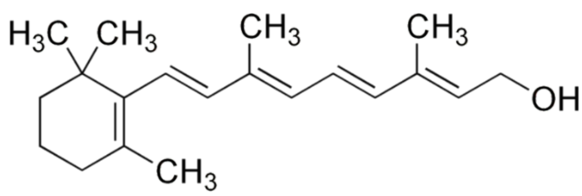
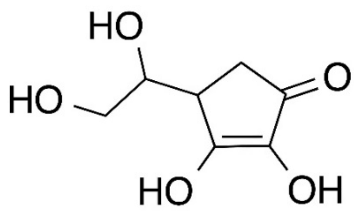
Question 25 (3 marks)

Vitamins are biologically important molecules. Two examples, Vitamins A and C, have their structures shown below.



Vitamin A



Vitamin C

Vitamin A is a fat-soluble whereas Vitamin C is water soluble. Account for the difference in solubilities of these two vitamins.

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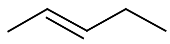
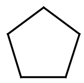
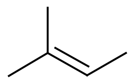
Question 26 (6 marks) **Marks**

The following table gives the names of some structural isomers with the molecular formula C_5H_{10}.

Isomer	**Structure**
A	
B	
C	

(a) Draw a position isomer of isomer A. **1**

(b) Chemical tests can be used to distinguish between samples of isomer A and isomer B. Identify a suitable test, stating expected results. **2**

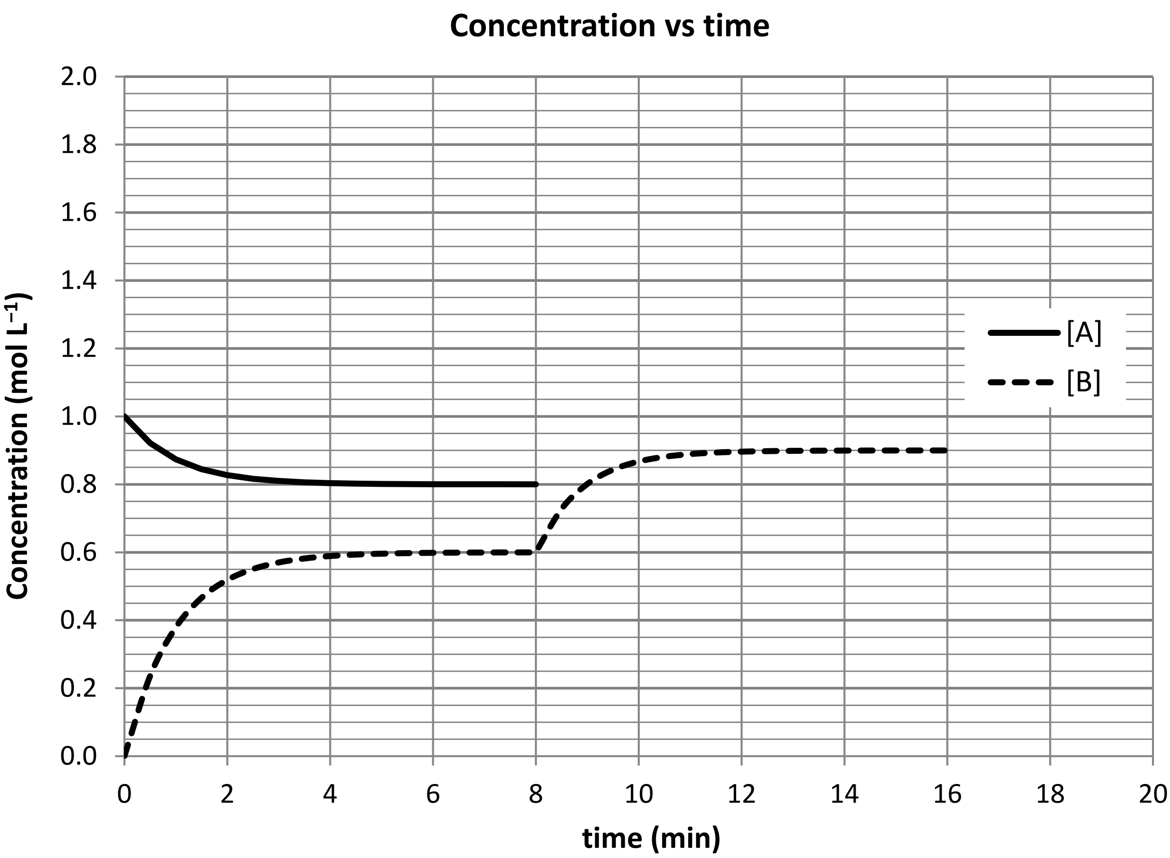
(c) Name isomer C. **1**

Question cont. **Marks**

(d) Draw the product(s) formed when isomer C is hydrated using dilute sulfuric acid. **2**

Question 27 (8 marks) **Marks**

Gaseous **A** molecules undergo a reversible chemical reaction to form gaseous **B** molecules. The graph below shows how the concentrations of **A**(g) and **B**(g) molecules change over time, when placed in a 2.0 L reaction vessel at constant temperature. The graph for **A**(g) is not completed yet.



(a) Explain the shape of the [B] curve from 0 to 8 min. **3**

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Question cont. **Marks**

(b) Calculate the equilibrium constant for this system. **2**

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At t = 8 min, some **A**(g) is added to the 2.0 L reaction vessel.

(c) Calculate the amount (in mol) of **A**(g) added to the 2.0 L reaction vessel. **3**

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Question 28 (3 marks)

pKa is a convenient way to express the relative strength of a weak acid.

If the pKa of methanoic acid is 3.75, determine the pH of a 2.0 M solution.

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CANDIDATE NUMBER

Question 29 (4 marks)

When 100 mL of 0.500 mol L^{-1} copper(II) nitrate solution is added to 150 mL of 0.800 mol L^{-1} potassium hydroxide solution, a precipitate is produced.

Calculate the concentrations of copper(II) ions and hydroxide ions remaining in the solution after precipitation occurs?

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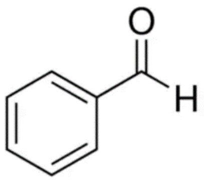
Question 30 (6 marks) **Marks**

Ethyl benzoate has a pleasant odour described as cherry and grape. It can be synthesised from benzaldehyde via intermediate A as seen in the diagram below.

(a) Complete the boxes in the flow diagram below to show how ethyl benzoate can be synthesised from benzaldehyde in two steps. You should include:

i) Structure for intermediate A.
ii) Reagent required for Step 1.
iii) Structure for the reactant of Step 2.
iv) Conditions required for Step 2. **4**



benzaldehyde

STEP 1 →

ii) Reagent:

i) Structure for intermediate A

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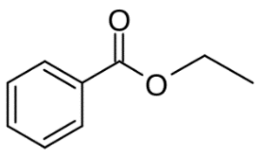
iii) Structure for reactant added in Step 2

← STEP 2

iv) Conditions



ethyl benzoate

(b) Identify a **chemical** test (including the predicted results) that can be used to distinguish between ethyl benzoate and benzaldehyde. **2**

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Question 31 (6 marks) **Marks**

Enthalpy of neutralisation is a measure of the amount of energy released per mole of water formed when an acid reacts completely with a base. The enthalpy of neutralisation when sodium hydroxide reacts with sulfuric acid is **–**57.3 kJ mol^{-1}**.**

(a) Write the net ionic equation for this neutralisation reaction. Include details of ΔH. **1**

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(b) 110.0 mL of 1.00 mol L^{-1} sodium hydroxide (density 1.04 g mL^{-1}) is mixed with 50.0 mL of 1.00 mol L^{-1} sulfuric acid (density 1.06 g mL^{-1}) in a Styrofoam cup. The initial temperature of each solution is 25.0°C.

Assuming that the resulting solution has a specific heat capacity of 3.93 J K^{-1} g^{-1}, calculate the final temperature reached. **5**

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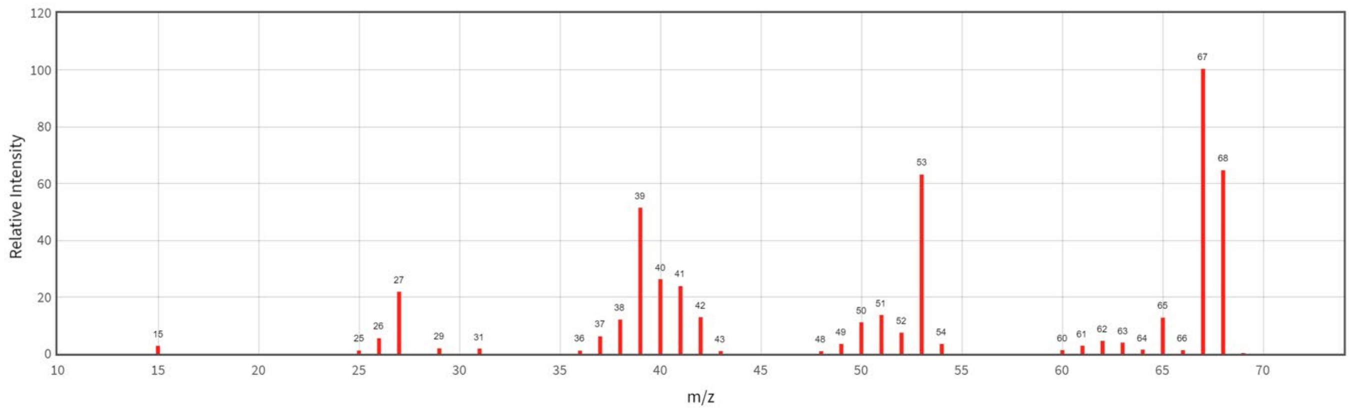
Question 32 (5 marks) **Marks**

This question is about polymers. Some golf balls are made from polymers including polyisoprene and polyurethane**.**

(a) Polyisoprene is an addition polymer. Its monomer, isoprene, is a branched, non-cyclic hydrocarbon that is 88.16% carbon by mass. Its mass spectrum is shown below.



Draw a possible structure for the monomer, isoprene. Show all working. **3**

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Question cont. **Marks**

(b) Polyurethane is a condensation polymer. **1**

i. Describe one difference between an addition polymer and a condensation polymer.

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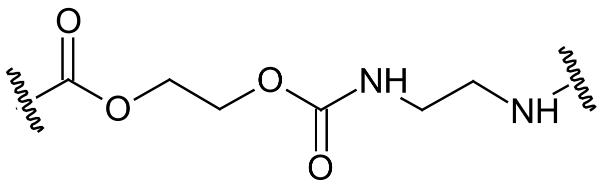
ii. The repeating unit for polyurethane is shown below. **1**



Draw the structure of possible monomers that could be combined to synthesise polyurethane.

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CANDIDATE NUMBER

Question 33 (4 marks)

If 12 mL of calcium hydroxide (pH = 11.5) is mixed with 7.0 mL of nitric acid (pH = 1.8), calculate the final pH of the solution.

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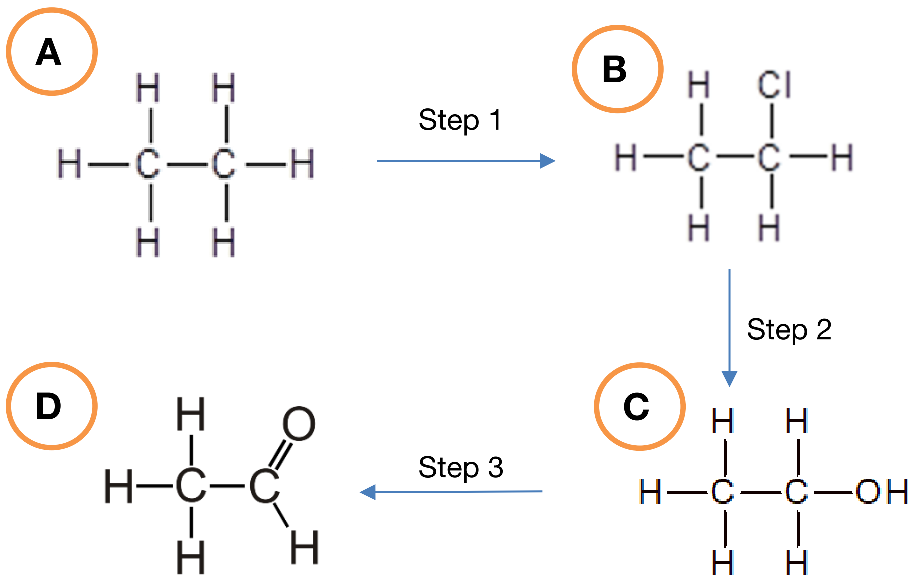
Question 34 (9 marks)

Consider the following reaction scheme.



Outline the reagents and conditions for each of the steps of this scheme and then discuss whether you could use the features shown in both IR and proton NMR spectroscopy to confirm that these products have been formed from the reactants in each step.

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Question 35 (5 marks) **Marks**

Three unknown 0.1 M solutions each contain one cation and one anion, though it is not certain if the ions are either:

cations: Mg^{2+}, Na^{+}, Ag^{+}, Pb^{2+}

anions: CO_3^{2-}, CH_3COO^{-}, SO_4^{2-}, Cl^{-}

Some experiments are performed on new samples of each solution with the results shown in the table below:

Experiment / Result	**A**	**B**	**C**
Add $HNO_3(aq)$	bubbles	vinegar smell	NVR
Add $BaCl_2(aq)$	white precipitate	white precipitate that darkened in UV	NVR
Add $NH_3(aq)$ or $OH^{-}(aq)$	NVR	brown precipitate that dissolved when excess ammonia is added	white precipitate

(a) Determine the chemical formulae for samples A-C. **3**

A: ....

B: ....

C: ....

(b) Outline why the brown precipitate dissolved in excess ammonia for solution B. **1**

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(c) Identify why you would need to monitor the environment for any one of these ions. **1**

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END OF EXAMINATION

2019 | HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$n = \dfrac{m}{MM}$	$c = \dfrac{n}{V}$	$PV = nRT$
$q = mC\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$pH = -\log_{10}[H^+]$
$pK_a = -\log_{10}[K_a]$	$A = \varepsilon lc = \log_{10}\dfrac{I_o}{I}$	

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

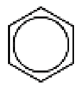
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	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}

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

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
$R-\underset{\Vert \atop O}{C}-\overset{\vert}{\underset{\vert}{C}}-$		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
$R-\underset{\Vert \atop O}{C}-$	esters or acids	160–185
$R-\underset{\Vert \atop O}{C}-$	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

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

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.

SYDNEY GRAMMAR SCHOOL

				C	R	I	B

CANDIDATE NUMBER

2022
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section I - Multiple Choice

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

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

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

correct

A ⊗ B ⊗ C ○ D ○

Start Here →

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

SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following is part of Arrhenius's theory of acids and bases?

(A) Bases liberate OH^- ions in solution.

(B) Acidity is due to the presence of oxygen in non-metal compounds.

(C) Compounds which contain hydrogen are acidic in nature.

(D) All acids taste sour.

2 Which class of organic molecules undergo addition reactions?

(A) alkenes

(B) alkanes

(C) alkanols

(D) amines

3 If a solution of HCl(aq) has a pH of 2 and an equimolar concentration of acid X has a pH of 1.8, acid X is most likely to be a:

(A) Strong monoprotic acid

(B) Strong polyprotic acid

(C) Weak monoprotic acid

(D) Weak polyprotic acid

4 In which of the following reactions would decreasing the volume of the reaction vessel (at constant temperature) leave the amount of reactants and products unchanged?

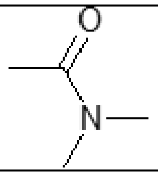
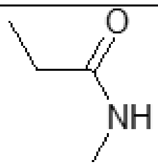
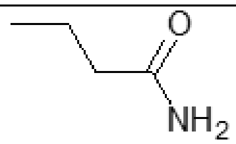
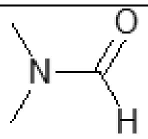
(A) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(B) $2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$

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

(D) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

5 Which of the following molecules is a secondary amide?

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

6 Consider the titration apparatus below.

Titration Set Up:

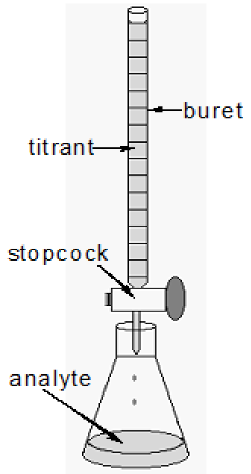


Figure 1: Titration Setup

Which of the following combinations of liquids should be used to rinse the glassware prior to commencing the titration to enhance the accuracy of the process?

	Burette	Pipette	Conical flask
(A)	deionised water	deionised water	deionised water
(B)	deionised water	analyte	deionised water
(C)	titrant	analyte	deionised water
(D)	titrant	deionised water	deionised water

7 In which of the following titration reactions would buffering of the solution occur?

(A) A strong acid added to a strong base

(B) A strong acid added to a weak base

(C) A strong base added to a strong acid

(D) A weak acid added to water

8 Which of the following molecules will **not** react with acidified potassium dichromate solution?

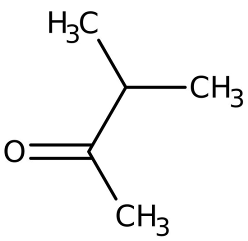
(A) 2-methylbutan-2-ol

(B) butanal

(C) butan-2-ol

(D) butan-1-ol

9 Which of the following is true for 3-methylbutan-2-one, shown below?



(A) It forms a silver mirror on treatment with Tollens' reagent $[Ag(NH_3)^2]^+$.

(B) It is a functional group isomer of pentan-1-ol.

(C) It may be prepared by the catalysed hydration of 3-methylbut-1-yne.

(D) It will show five distinct carbon atoms in spectroscopy.

10 A 35 mL sample of 0.25 M NaOH solution was placed in a 1 L volumetric flask and then filled with deionised water up to the mark. What is the pH of the final solution?

(A) 0.00875

(B) 2.06

(C) 11.94

(D) 12.15

$35 \times 0{\cdot}25 = 1000 \times x$

$x = 8{\cdot}75 \times 10^{-3}$

$pOH = 2.1$

$pH = 11{\cdot}9$

11 Methane reacts with an **excess** of chlorine in the presence of UV light. What are the products of the reaction if it goes to completion?

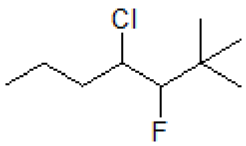
(A) CH_3Cl and H_2

(B) CH_3Cl and HCl

(C) CCl_4 and H_2

(D) CCl_4 and HCl

12 What is the IUPAC name for the compound shown below?



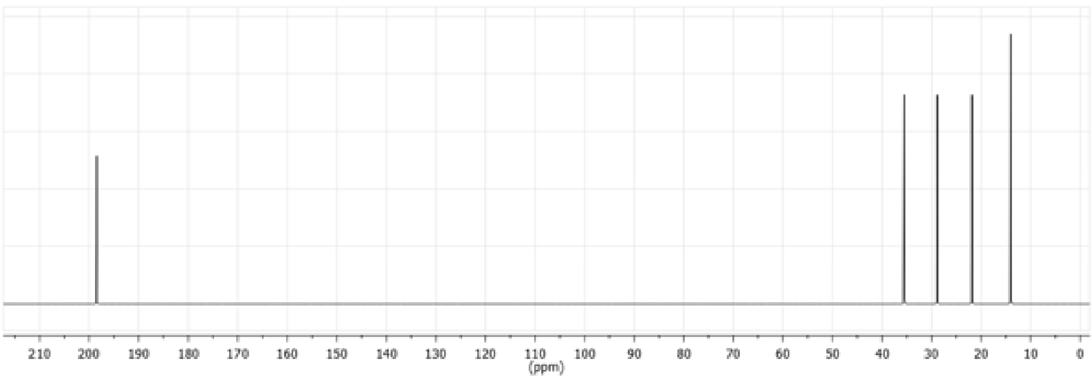
(A) 2,2-dimethyl-3-fluoro-4-chloroheptane

(B) 4-chloro-5-fluoro-6,6-dimethylheptane

(C) 4-chloro-3-fluoro-2,2-dimethylheptane

(D) 4-chloro-2,2-dimethyl-3-fluoroheptane

13 Consider the following ^{13}C NMR spectrum.



Which of the following compounds would have this spectrum?

(A) pentane

(B) pentanal

(C) pentanoic acid

(D) 2-methylbutane

14 Equal amounts of four compounds are added to the same volume of water. Which compound would produce a solution with the highest pH?

(A) $CH_3CONHCH_3$

(B) CH_3COOH

(C) CH_3COOCH_3

(D) $CH_3CH_2NH_2$

15 Sulfur trioxide can be produced from the reaction of sulfur dioxide and oxygen according to the following equation:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

One mole of sulfur dioxide and two moles of oxygen are mixed in a reaction vessel, and the system allowed to proceed towards equilibrium.

Which of the following statements about this system is true?

(A) The concentration of $O_2(g)$ will always be half of the concentration of $SO_2(g)$.

(B) The concentration of $SO_2(g)$ will increase at the same rate as the $SO_3(g)$ concentration is increasing.

(C) The concentration of $O_2(g)$ will decrease at double the rate that the $SO_2(g)$ concentration is decreasing.

(D) The concentration of $O_2(g)$ will decrease at half the rate that the $SO_3(g)$ concentration is increasing.

16 The K_{sp} of chromium(III) hydroxide is 6.3×10^{-31}. What is the concentration (in mol L^{-1}) of chromium(III) ions in a saturated solution of chromium(III) hydroxide?

(A) $\sqrt{6.3 \times 10^{-31}}$

(B) $\sqrt[3]{\frac{6.3 \times 10^{-31}}{4}}$

(C) $\sqrt[4]{\frac{6.3 \times 10^{-31}}{27}}$

(D) $\sqrt[5]{\frac{6.3 \times 10^{-31}}{108}}$

17 If 1 mL of an acid with a pH of 5 is added to 999 mL of deionised water, what is the pH of the new solution?

(A) pH 5
(B) pH 6
(C) pH 7
(D) pH 8

18 Which of the following compounds has the highest solubility (in g L^{-1})?

Compound		Molar mass (g mol^{-1})	K_{sp}
(A)	Lithium chloride	42.39	395
(B)	Sodium chloride	58.44	42
(C)	Potassium chloride	74.55	22
(D)	Rubidium chloride	120.9	56

$\sqrt{K_{sp}} \times M$ as $\frac{mol}{L} \times \frac{g}{mol} = \frac{g}{L}$

19 Consider the following reaction:

$$H_2(g) + I_2(s) \rightleftharpoons 2HI(g) \qquad \Delta H^\ominus = -9.5 \text{ kJ mol}^{-1}$$

Which of the following changes, when imposed on this system at equilibrium, will result in an increased concentration of HI(g) when equilibrium is re-established?

(A) Halving the volume of the system.
(B) Adding $I_2(s)$.
(C) Removing $HI(g)$.
(D) Increasing the temperature of the system.

20 Consider the following reaction:

$$W(g) + 2X(g) \rightleftharpoons 2Y(g) + Z(g) \qquad K_c = 200$$

If 0.5 mol of W and 0.5 mol of X are placed in a sealed 0.5 L vessel and allowed to react, which of the following is true once the system reaches equilibrium?

(A) 2[W] = [X]

(B) [W] > [X]

(C) [Y] = [X]

(D) [Z] > [Y]

SECTION II: 80 marks

Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 21 (5 marks) **Marks**

The definition of acids and bases has changed often over time.

a) State the Brønsted-Lowry definition of a base. **1**

A base is a proton acceptor

b) Explain how the Brønsted-Lowry definition of a base is an improvement on the Arrhenius model, using an example and a relevant equation to illustrate this. **3**

SAMPLE ANSWER-

3 MARKS	COMPREHENSIVE ANSWER	* Arrhenius - defined a base as a substance which has $OH^-(aq)$
2 MARKS	MISSING SOME DETAILS	* $NH_{3(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)}$ (Must have example)
1 MARK	ANY RELEVANT INFORMATION	* NH_3 is a BL base but not an Arrhenius base

c) Identify a limitation of the Brønsted-Lowry model. **1**

ANY eg. (It) does not explain acid-base reactions that do not involve H^+

Question 22 (3 marks) **Marks**

The K_{sp} for barium fluoride is 3.10×10^{-6}. Calculate the solubility (in g per 100 mL) of barium fluoride.

$BaF_2 \rightarrow Ba^{2+} + 2F^-$

BaF_2 molar mass 175.32 g/mol.

3 MARKS	CORRECT ANSWER
2 MARKS	SINGLE ERROR
1 MARK	ANY RELEVANT INFO

$K_{sp} = [Ba^{2+}][F^-]^2 = 3.1\times10^{-6}$

$= [x][2x]^2 = 3.1\times10^{-6}$

$= 4x^3 = 3.1\times10^{-6}$

$x = \sqrt[3]{\frac{3.10\times10^{-6}}{4}}$

$= 9.185\times10^{-3}$ mol/L

$\therefore 175.32 \times 9.185\times10^{-3}$

$= 1.61$ g/L

Thus 0.161 g/100mL

Question 23 (6 marks)

Titration is an analytical technique used to determine the unknown concentration of an acid or base.

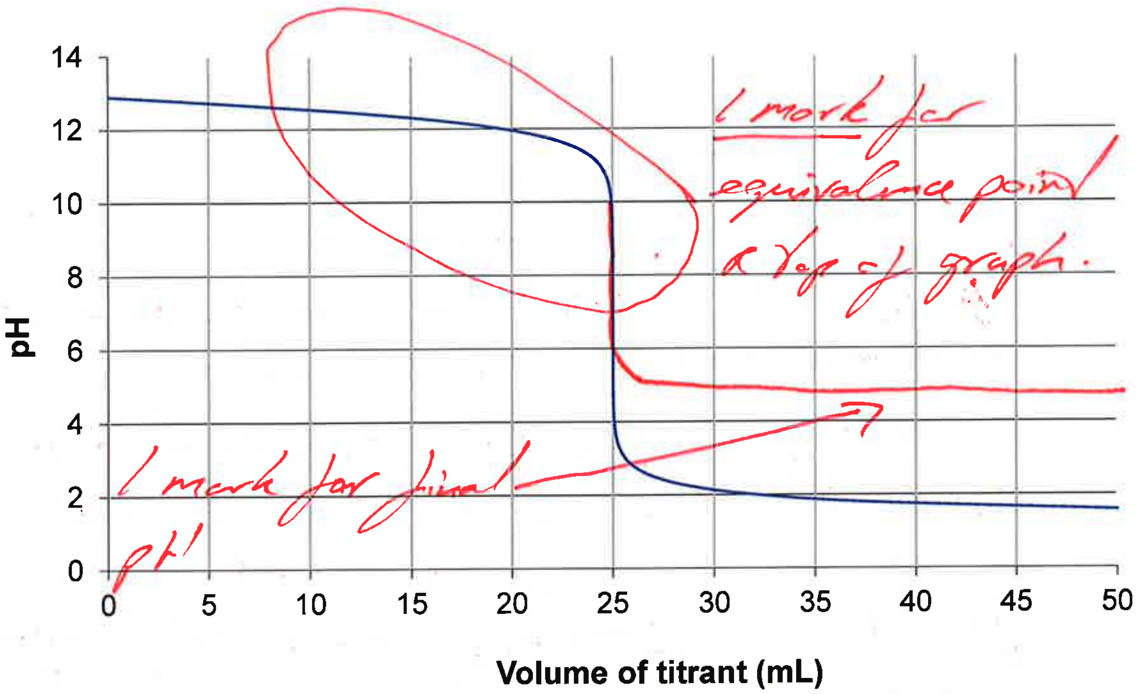
(a) A piece of equipment often used in a titration is shown in the diagram above. Name this piece of equipment and identify its purpose in a titration. **2**

Pipette – 1 mark

Transferring a precise/known/accurate volume/amount of liquid – 1 mark

Question cont. **Marks**

(b) The titration curve below represents the change in pH when a monoprotic 0.1 M strong acid is incrementally added to a strong base during a titration.



On the same graph, sketch the curve you would get if you were to incrementally add a monoprotic 0.1 M **weak** acid to the same base solution. **2**

(c) Indicators used in titrations are usually weak acids. Identify and explain the effect of adding too much indicator when conducting this titration. **2**

IDENTIFY - eg ~~leading to~~ inaccurate volumes required / change pH of sol^n / affect volume / buffer sol^n etc

EXPLAIN - eg Less acid needs to be added therefore the calculated conc. of base will be lower than in reality.

Question 24 (7 marks) **Marks**

Dinitrogen tetraoxide, a colourless gas, decomposes to form brown nitrogen dioxide gas, according to the following equation.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H^{\ominus} = +57 \text{ kJ mol}^{-1}$$

A mixture of dinitrogen tetraoxide and nitrogen dioxide is placed in a sealed syringe.

(a) Using collision theory, explain the effect of increasing the temperature of this system on the equilibrium constant, K_c. **4**

	SAMPLE ANSWER -
4 MARKS FULLY COMPREHENSIVE	ENDO - The forward reaction is endothermic
3 MARKS MISSING SINGLE DETAIL	RATES $\rightleftharpoons$ ↑ - Increasing the temperature will increase the rate of reaction in both directions
2 MARKS BASIC DI	FORWARD ↑ - The effect will be greater in the forward direction
1 MARK ANY RELEVANT INFO	$K_c = \frac{[\ ]}{[\ ]}$ - This leads to an increase in [PRODUCTS] relative to [REACTANTS] ∴ increasing K_c.

A 1.00 L reaction vessel containing 0.100 mol of dinitrogen tetraoxide gas is allowed to come to equilibrium. 0.250 mol of nitrogen dioxide is then added and the system allowed to reach equilibrium again. The final concentration of nitrogen dioxide in the vessel is 0.400 mol L^{-1}. The temperature is constant throughout these experiments.

(b) Calculate the equilibrium constant, K_c, for this reaction. **3**

Since K is constant, the system will reach the same equilibrium irrespective of timing of addition of extra nitrogen dioxide. Thus you will get the same result if you assume it all reacts initially, none reacts initially or it partly reacts to first equilibrium. Easiest to draw an ICE table as if all added at the start recognising it shifted right because the final value of 0.**4** is greater than 0.**25**.

	N_2O_4	NO_2
I	0.100	0+0.**25**
C	$^-$x	+**2**x
E	0.1 - x	0.4

2x = 0.15 therefore x = 0.075 so end values are $[N_2O_4]$ = 0.025 and from the question $[NO_2]$ = 0.4.

$K = [NO_2]^2 / [N_2O_4] = .4^2 / 0.025 = 6.4$

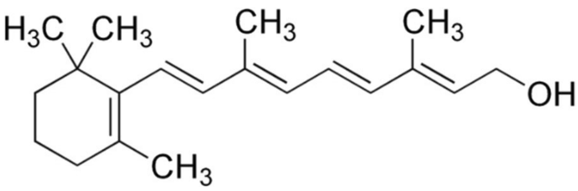
3 marks - calculates 6.4
2 marks - 1 error
1 mark - any relevant information

CRIB - JLS

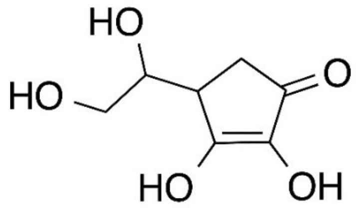
CANDIDATE NUMBER

Question 25 (3 marks)

Vitamins are biologically important molecules. Two examples, Vitamins A and C, have their structures shown below.



Vitamin A



Vitamin C

Vitamin A is a fat-soluble whereas Vitamin C is water soluble. Account for the difference in solubilities of these two vitamins.

NOTE: MARKED HOLISTICALLY

For 3 marks:

Clear and comprehensive account including:

- Identify Vitamin A as being mostly non-polar and vitamin C as being mostly polar
  OR
  State that Vitamin C contains more hydroxyl groups than Vitamin A.
- Identify intermolecular forces involved in dissolving Vitamin A in fat (dispersion forces) and vitamin C in water (Hydrogen bonds).
- Explain dissolving in terms of thermodynamic effects / intermolecular forces strong enough to overcome intermolecular forces between solvent molecules

For 2 marks:

Clear account including 2/3 points above

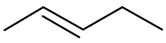
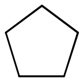
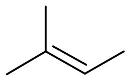
For 1 marks:

Clear account including 1/3 points above

NOTES:
1. Many boys used incorrect terminology when referring to hydroxyl groups
2. Many boys ignored thermodynamic effects involved in dissolving

Question 26 (6 marks) **Marks**

The following table gives the names of some structural isomers with the molecular formula C_5H_{10}.

Isomer	Structure
A	
B	
C	

(a) Draw a position isomer of isomer A. NOTE: Any type of structure accepted. **1**

(b) Chemical tests can be used to distinguish between samples of isomer A and isomer B. Identify a suitable test, stating expected results. **2**

M1 Chemical test e.g. Add Br_2 (aq)

M2 Expected result for both isomers. eg. Isomer A will decolourise bromine water and isomer B will not.

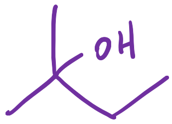
NOTE: A few boys wrote the solution will go clear rather than colourless (not awarded)

(c) Name isomer C. **1**

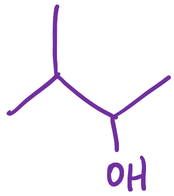
2-methylbut-2-ene

Question cont. **Marks**

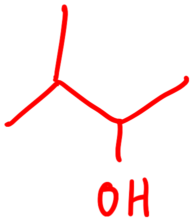
(d) Draw the product(s) formed when isomer C is hydrated using dilute sulfuric acid. **2**



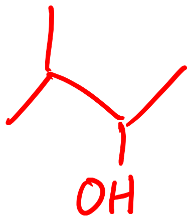
and



NOTE:



ACCEPTED

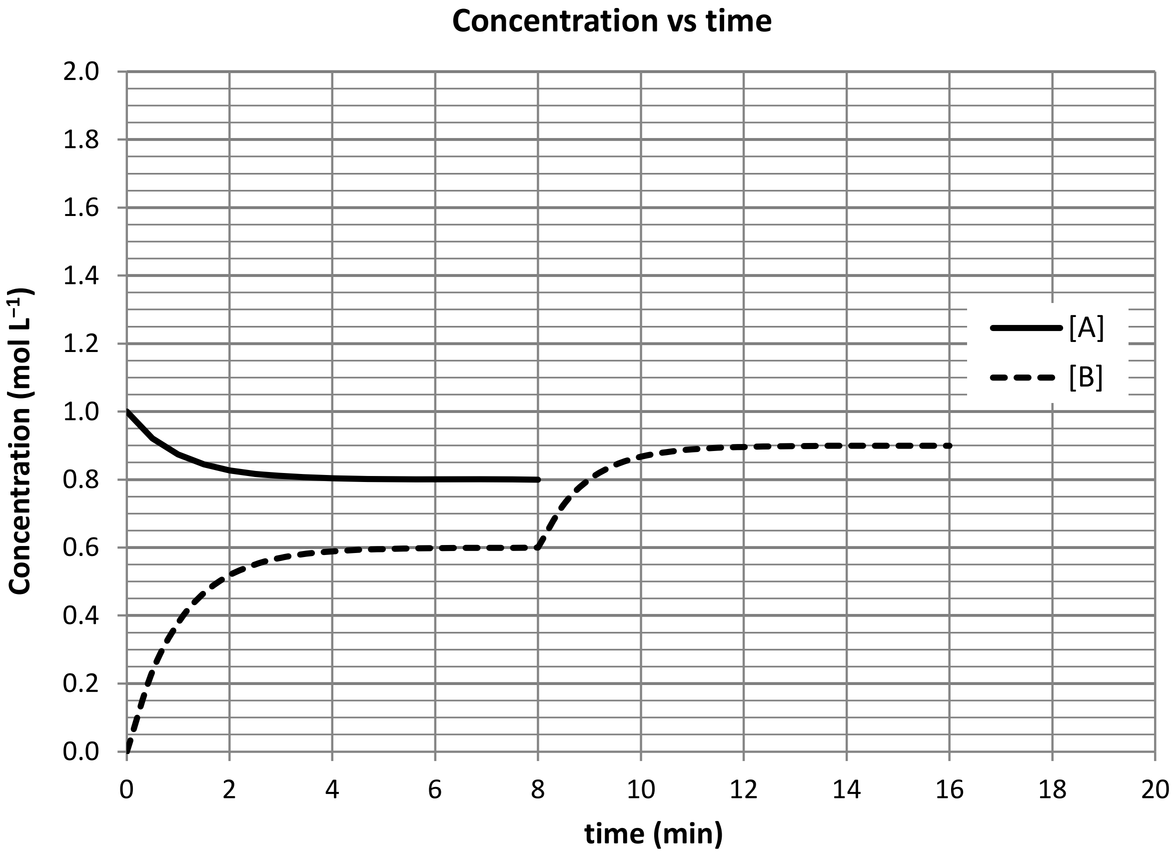


NOT ACCEPTED

The bond must be drawn to the O atom of the OH group.

Question 27 (8 marks) **Marks**

Gaseous **A** molecules undergo a reversible chemical reaction to form gaseous **B** molecules. The graph below shows how the concentrations of **A**(g) and **B**(g) molecules change over time, when placed in a 2.0 L reaction vessel at constant temperature. The graph for **A**(g) is not completed yet.



(a) Explain the shape of the [B] curve from 0 to 8 min. **3**

M1 [B] increases rapidly as reaction proceeds in the forward direction as:
Rate (forward) >> Rate (reverse) / [A] is high / Q < K

M2 [B] increases at an increasingly slower rate / Rate (forward) decreases because:
[A] is decreasing / fewer collisions

M3 Equilibrium is reached at 6 min so [A] and [B] remain constant from 6–8 min / Rate (forward) = Rate (reverse) / Q = K

Question cont. **Marks**

(b) Calculate the equilibrium constant for this system. **2**

M1 $[A]_{eq} = 0.8$ M $[B]_{eq} = 0.6$ M from graph

M2 $K_{eq} = \frac{[B]^3}{[A]} = \frac{0.6^3}{0.8} = 0.27$

At t = 8 min, some **A**(g) is added to the 2.0 L reaction vessel.

(c) Calculate the amount (in mol) of **A**(g) added to the 2.0 L reaction vessel. **3**

	[A]	[B]
I (M)	0.8	0.6
C (M)	+y	—
	−x	+3x
E (M)	0.7 + y	0.9

M1

M2 $K_{eq} = \frac{[B]^3}{[A]} = \frac{0.9^3}{0.7 + y} = 0.27$

$y = 2.0$ M

M3 4.0 mol of A added

NOTE: Error carried forward (ecf) marks awarded if incorrect value for K_{eq} was used

3 marks awarded if $K_{eq} = 0.75$ n(A) = 1.4 mol

Question 28 (3 marks)

pKa is a convenient way to express the relative strength of a weak acid.

If the pKa of methanoic acid is 3.75, determine the pH of a 2.0 M solution.

M1 Calculation of Ka

$$K_a = \frac{[H^+][A^-]}{[HA]} = 10^{-3.75} = 1.778 \times 10^{-4}$$

M2 Calculation of $[H_3O^+]$

	$[HA]$	$[H_3O^+]$	$[A^-]$
I	2.0	0	0
C	$-x$	$+x$	$+x$
E	$2.0-x$	x	x

$$K_a = \frac{x^2}{2.0-x}$$

Assume $x << 2.0$

NOTE: Many boys did not state that they made x is small assumption. – you need to do this!

$$x = \sqrt{K_a \times 2.0} = 0.0189 \text{ mol L}^{-1}$$

M3 Calculation of pH

$$pH = -\log 0.0189$$
$$= 1.72$$

1 mark max also awarded for any relevant information including:

$pK_a = -\log K_a$

CANDIDATE NUMBER

Question 29 (4 marks)

When 100 mL of 0.500 mol L^{-1} copper(II) nitrate solution is added to 150 mL of 0.800 mol L^{-1} potassium hydroxide solution, a precipitate is produced.

Calculate the concentrations of copper(II) ions and hydroxide ions remaining in the solution after precipitation occurs?

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

$n(Cu^{2+}) = 100\,mL \times 0.500\,mol\,L^{-1} = 50.0\,mmol$

$n(OH^-) = 150\,mL \times 0.800\,mol\,L^{-1} = 120\,mmol.$

$\therefore$ the Cu^{2+} is the limiting reagent, and 50.0 mmol of $Cu(OH)_2(s)$ is produced, leaving 20 mmol $OH^-(aq)$.

$[OH^-] = \dfrac{20\,mmol}{250\,mL} = 0.080\,mol\,L^{-1}$

$K_{sp}(Cu(OH)_2) = [Cu^{2+}][OH^-]^2 = 2.2 \times 10^{-20}$

$\therefore [Cu^{2+}] = \dfrac{2.2 \times 10^{-20}}{(0.080)^2} = 3.4 \times 10^{-18}\,mol\,L^{-1}.$

(4) Correct calculation

(3) One error

(2) Two steps

(1) Any relevant information.

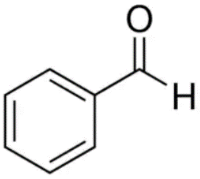
Question 30 (6 marks) **Marks**

Ethyl benzoate has a pleasant odour described as cherry and grape. It can be synthesised from benzaldehyde via intermediate A as seen in the diagram below.

(a) Complete the boxes in the flow diagram below to show how ethyl benzoate can be synthesised from benzaldehyde in two steps. You should include:

i) Structure for intermediate A.
ii) Reagent required for Step 1.
iii) Structure for the reactant of Step 2.
iv) Conditions required for Step 2.

1 each **4**



benzaldehyde

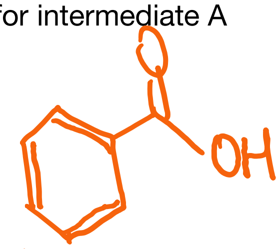
STEP 1 →

ii) Reagent:

Any [O]

e.g. MnO_4^-/H^+, $Cr_2O_7^{2-}/H^+$, $[Ag(NH_3)_2]^+$ etc.

i) Structure for intermediate A



STEP 2 ←

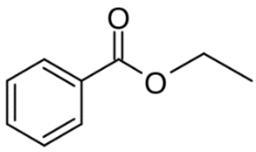
iii) Structure for reactant added in Step 2

(not  !)

iv) Conditions

conc. H_2SO_4

heat under reflux



ethyl benzoate

(b) Identify a **chemical** test (including the predicted results) that can be used to distinguish between ethyl benzoate and benzaldehyde. **2**

e.g. 2,4-DNP test or silver mirror test. 1

+ results 1

Question 31 (6 marks) **Marks**

Enthalpy of neutralisation is a measure of the amount of energy released per mole of water formed when an acid reacts completely with a base. The enthalpy of neutralisation when sodium hydroxide reacts with sulfuric acid is –57.3 kJ mol^{-1}.

(a) Write the net ionic equation for this neutralisation reaction. Include details of ΔH. **1**

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \quad \Delta H = -57.3\ kJ\ mol^{-1}$

(b) 110.0 mL of 1.00 mol L^{-1} sodium hydroxide (density 1.04 g mL^{-1}) is mixed with 50.0 mL of 1.00 mol L^{-1} sulfuric acid (density 1.06 g mL^{-1}) in a Styrofoam cup. The initial temperature of each solution is 25.0°C.

Assuming that the resulting solution has a specific heat capacity of 3.93 J K^{-1} g^{-1}, calculate the final temperature reached. **5**

$n(NaOH) = 110.0\ mL \times 1.00\ mol\ L^{-1} = 110\ mmol$

$n(H_2SO_4) = 50.0\ mL \times 1.00\ mol\ L^{-1} = 50.0\ mmol$

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

$\therefore H_2SO_4$ is the limiting reagent,

$\therefore n(H_2O\ produced) = 50.0\ mmol \times 2 = 100\ mmol.$

$q_{solution} = 0.100\ mol \times 57.3\ kJ\ mol^{-1} = 5.73\ kJ = 5730\ J.$

$m(solution) = 110.0\ mL \times 1.04\ g\ mL^{-1} + 50.0\ mL \times 1.06\ g\ mL^{-1}$

$= 167\ g$

$\therefore \Delta T = \frac{q}{mc} = \frac{5730}{167 \times 3.93} = 8.71°C \quad \therefore T_f = 33.7°C.$

5 correct

4 one error (e.g. $n(H_2O)$, m(solution))

3 two errors

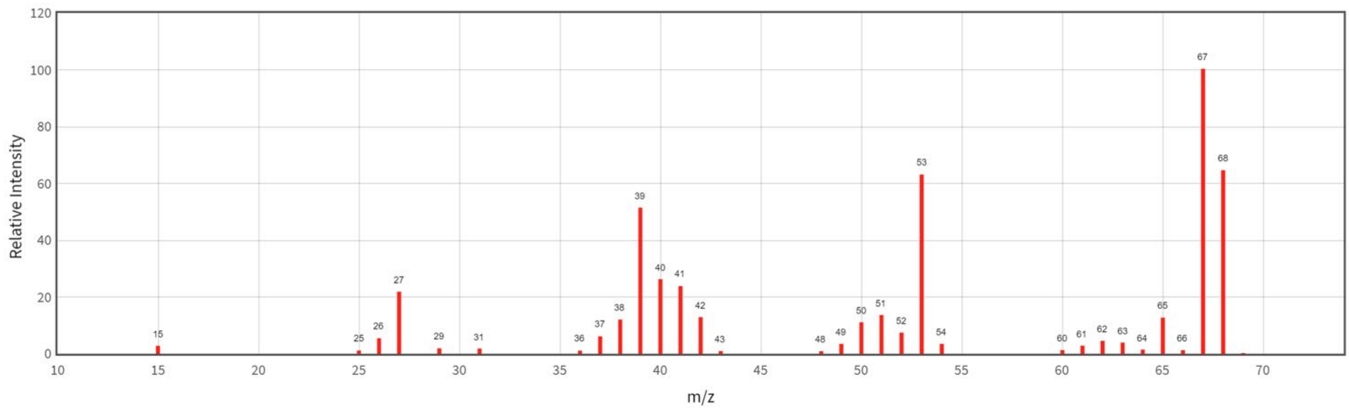
2 Two steps correct

1 Any relevant step

Question 32 (5 marks) **Marks**

This question is about polymers. Some golf balls are made from polymers including polyisoprene and polyurethane.

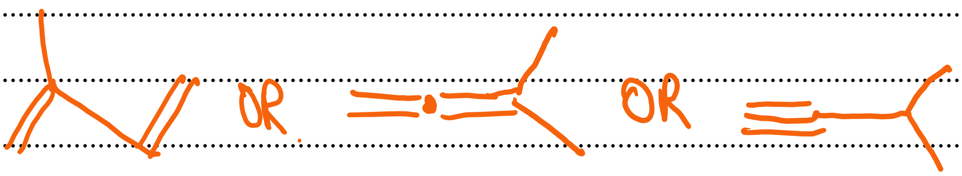
(a) Polyisoprene is an addition polymer. Its monomer, isoprene, is a branched, non-cyclic hydrocarbon that is 88.16% carbon by mass. Its mass spectrum is shown below.



Draw a possible structure for the monomer, isoprene. Show all working. **3**

M^+ at m/z = 68. 1

88.16% × 68 = 60 ⇒ 5 × C
This leaves 68 − 60 = 8 g mol of H. ⇒ 8 H 1
∴ C_5H_8



1

Correct Also ok.

Many boys missed the "branched".

Question cont. **Marks**

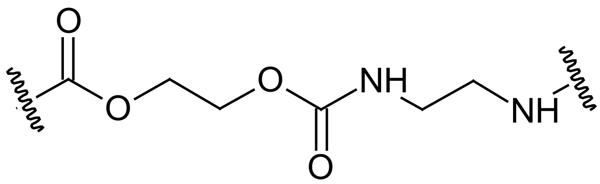
(b) Polyurethane is a condensation polymer. **1**

i. Describe one difference between an addition polymer and a condensation polymer.

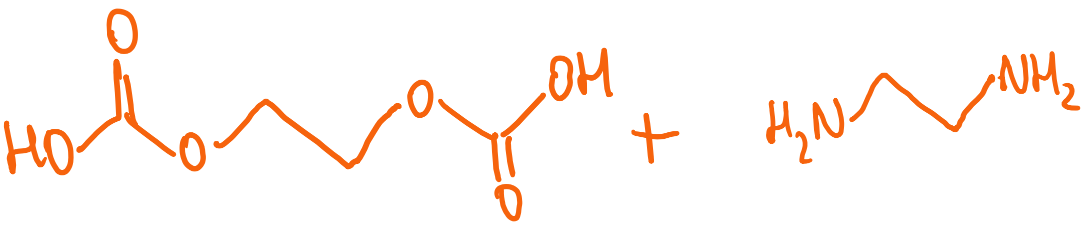
e.g. small molecule given off from condensation but not from addition

NOT addition = 1 monomer, condensation > 1 monomer.

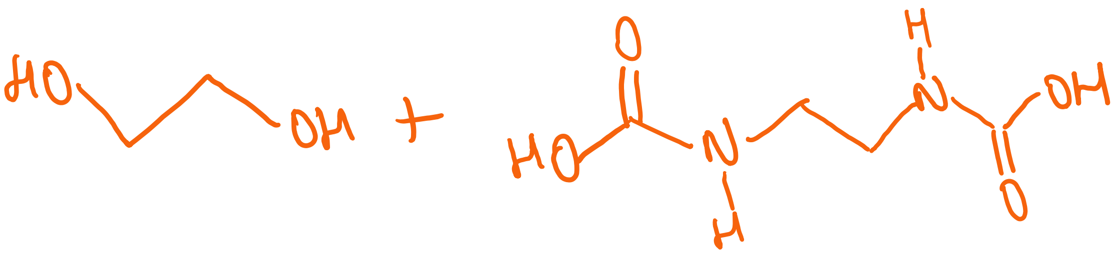
ii. The repeating unit for polyurethane is shown below. **1**



Draw the structure of possible monomers that could be combined to synthesise polyurethane.



OR



OR

etc.

CANDIDATE NUMBER

Question 33 (4 marks)

If 12 mL of calcium hydroxide (pH = 11.5) is mixed with 7.0 mL of nitric acid (pH = 1.8), calculate the final pH of the solution.

4 marks : Calculates pH = 2.4
3 marks : Missing/inaccurate step (usually not converting to [ ] from moles before pH calc ($n \div 0.019$))
2 marks : any 2 correct steps (for both H^+ + OH^-)
1 mark : any ~~thing~~ relevant information

Sample answer

$[OH^-] = 10^{-(14-11.5)} = 3.16 \times 10^{-3}$

$n(OH^-) = 3.16 \times 10^{-3} \times 0.012 = 3.795 \times 10^{-5}$ mol

$[H^+] = 10^{-1.8} = 0.01584$

$n(H^+) = 0.01584 \times 0.007 = 1.109 \times 10^{-4}$ mol

$H^+ + OH^- \rightarrow H_2O$

H^+ in excess

$n(H^+ \text{ excess}) = 1.109 \times 10^{-4} - 3.795 \times 10^{-5}$
$= 7.295 \times 10^{-5}$ mol

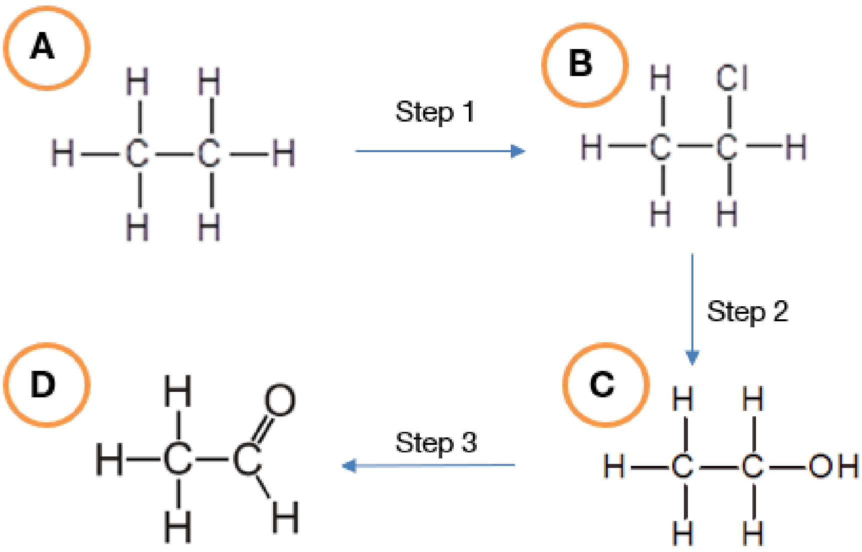
$[H^+] = \frac{n}{V} = \frac{7.295 \times 10^{-5}}{(12+7) \times 10^{-3}} = 3.84 \times 10^{-3}$

$pH = -\log_{10}[H^+] = \underline{2.4}$

Note ① Many boys applied $2 \times Ca(OH)_2$ but this is already considered in pH measurement.
② If worked out $[H^+]$ for both + added 1 mark ONLY.

Question 34 (9 marks)

Consider the following reaction scheme.



Outline the reagents and conditions for each of the steps of this scheme and then discuss whether you could use the features shown in both IR and proton NMR spectroscopy to confirm that these products have been formed from the reactants in each step.

Marked holistically, but effectively:

3 marks – reagents / conditions for each step (if missing S1, S2, S3 may be written)

6 marks – IR **and** NMR usefulness for each comparison

NC = no comparison – just a list of features (usually only awarded 4 marks)
ND = no discussion if spectroscopy is useful or not

Table of possible answers on next page. All listed items were not required – just enough of them to discuss whether useful or not, but it was necessary to consider IR AND NMR for each step.

Possible Answers could include:

	A	B	C	D
Name	Ethane	Chloroethane	Ethanol	Ethanal
Reagents / conditions	UV light + $Cl_2(g)$ (HCl not paid as radical needed)	Dil KOH(aq)	PCC Accepted strong oxidising agent if mention of stopping reaction e.g. distilling off	
IR	Usual peaks for organic compounds	Not helpful from A – or comparison to database in fingerprint area	Broad O-H peak 3230-3350 cm^{-1} useful	C=O peak at 1680-1750 cm^{-1} useful
Proton NMR				
# peaks	1	2	3	2
Integration	None (note a)	3:2	3:2:1	3:1
Splitting	None – singlet (note b)	Triplet:quartet	Triplet:quartet: singlet	Singlet:singlet (note c)
Shift	Shielded; low ppm; upfield	Deshielded; higher ppm; downfield	Deshielded; higher ppm; downfield	Deshielded; higher ppm; downfield

None of the following incorrect statements caused marks to be lost BUT be aware:

Note a – since there is only one peak, then integration is not possible. Too many boys said it would integrate to 6. Integration is a comparison of relative peaks ONLY.

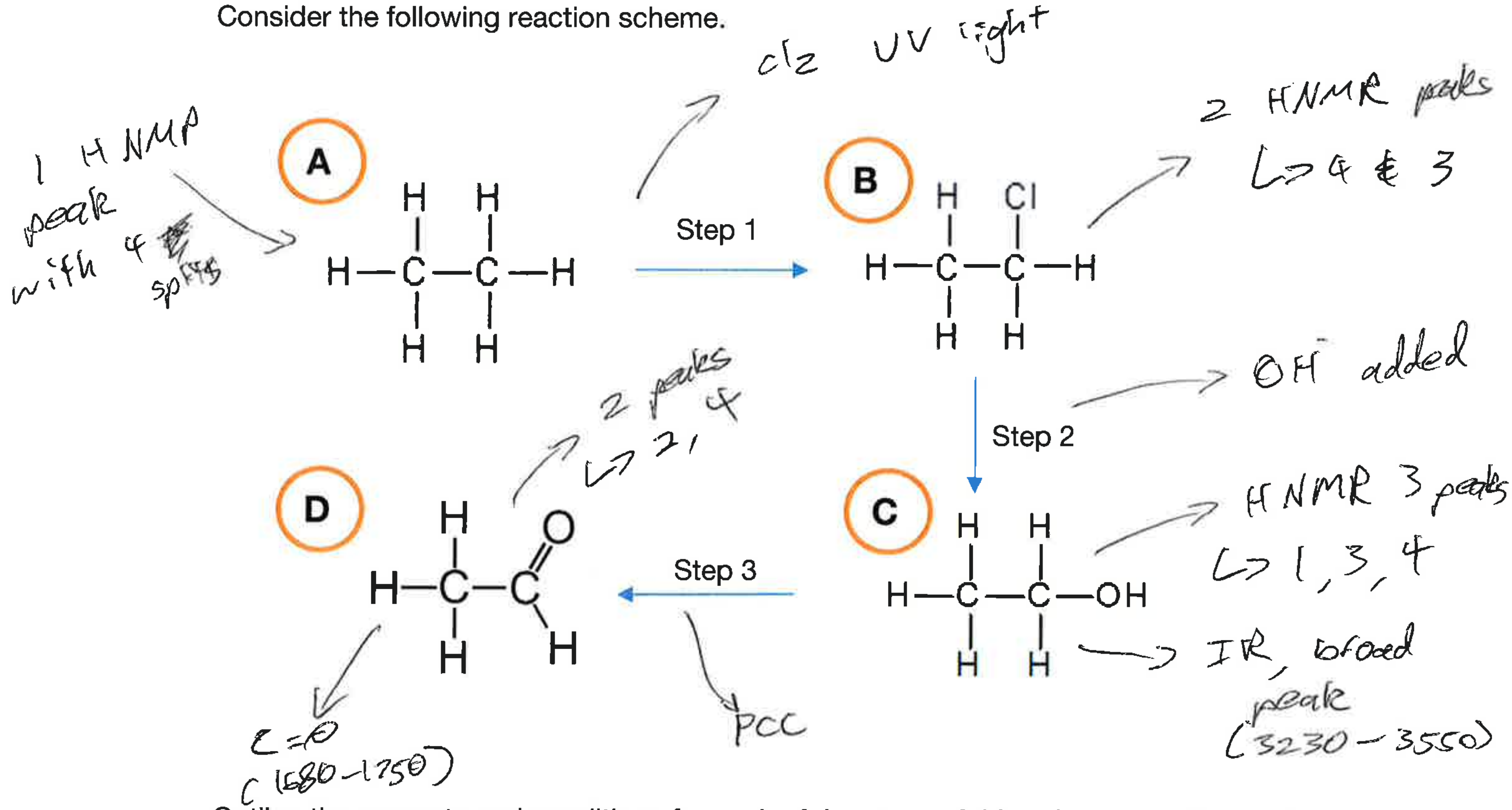
Note b – there is no splitting for hydrogens in the same H environment, therefore ethane will be a singlet.

Note c – unless very high-resolution NMR equipment is used, then aldehydes (along with -OH and NH) do not cause observable splitting, hence two singlets rather than quartet:doublet are more likely to be seen for ethanal.

Many boys discussed carbon NMR / Mass Spec – generally ignored, unless used for entry marks only (i.e. could get 1-2 marks if this was all that was written).

Question 34 (9 marks)

Consider the following reaction scheme.



Outline the reagents and conditions for each of the steps of this scheme and then discuss whether you could use the features shown in both IR and proton NMR spectroscopy to confirm that these products have been formed from the reactants in each step.

Step 1 :

step 1 requires the ~~reagents~~ reagent Cl_2 and the conditions of UV light. Proton NMR will show this product. An increase in the number of peaks from 1 to 2 shows there are no longer 2 CH_3 bonded together. The splitting with 4 & 3 will show that there is a CH_3 and CH_2. IR ~~indicates~~ does not show any data to confirm products. Which halogen that has been used cannot be determined through proton NMR and IR.

Step 2:

step 2 requires ~~requires~~ a hydroxide OH^- group to form an alcohol with conditions of heat. H NMR would show an increase in the number of peaks to 3. The splitting would indicate an alcohol group as there would be a singlet due to the single hydrogen bonded to oxygen. The other 2 peaks would be the same as B and thus not confirm products. IR would show a broad peak from 3230-3550. This would demonstrate and alcohol group and confirm that ethanol is the product combined with proton NMR data.

step 3

step 3 requires PCC as a reagent to form an aldehyde. Pd/c catalyst conditions. Proton NMR would show 1 less peak with now 2 peaks with 2 & 4 splitting. This suggests ~~ethanol~~ a double bond as there is fewer peaks. IR confirms product to be ethanal as there will be a peak at 1660-1750 showing a c=o and no peak at 1620-1680 disproving an ethene. Furthermore no very broad peak from 2500-3000 would disprove ethanoic acid confirming the product as ethanal

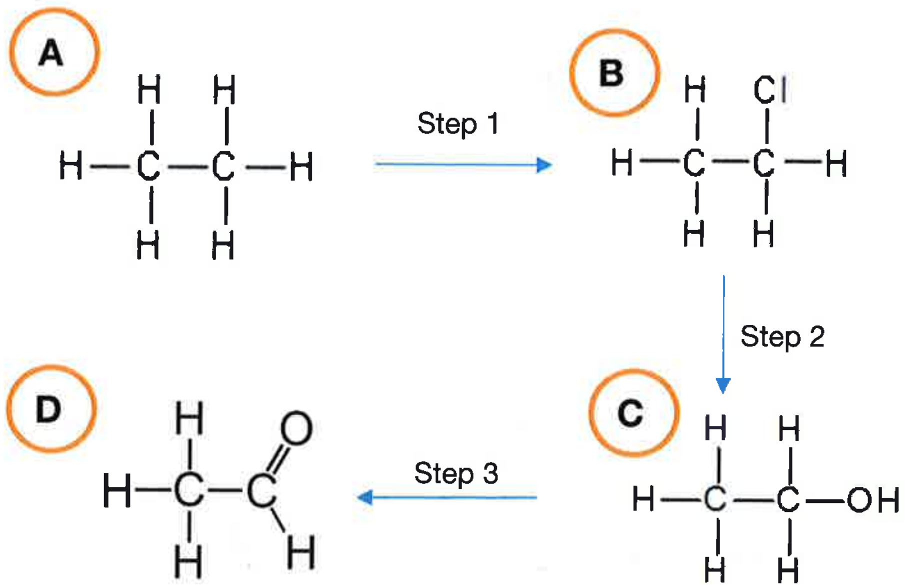
not likely to be seen!

9

good answer.

Question 34 (9 marks)

Consider the following reaction scheme.



Outline the reagents and conditions for each of the steps of this scheme and then discuss whether you could use the features shown in both IR and proton NMR spectroscopy to confirm that these products have been formed from the reactants in each step.

Step 1: reagent = $Cl_{2(g)}$ conditions = UV light

To identify B, IR will be of little use, as the C-Cl bond is not (at the very least, as far as we've been taught in this course) observable on the IR spectrum results. NMR may be more helpful. Rather than the one environment for ^1H observed on an NMR spectrum for A, now that symmetry has been eliminated, two ^1H peaks will be observable. One will have a multiplicity of 4, due to the 3 protons on the host's neighbouring C, the other will have 3 for the reversed reason. The former will have an integrated area $\frac{2}{3}$ of the latter's (a 1.0 : 1.5 ratio).

∴ Yes, NMR spectroscopy could confirm that B has been formed.

Step 2: reagent: = dilute metal hydroxide e.g. KOH $_{(aq)}$

To identify C, IR is very effective. The broad absorption "peak" around 3230-3550 wavenumbers - so characteristic of alcohols in shape and position - will be an easy identifier. In addition, there will now be three ~~other~~ H' environments on the NMR spectrum, a very identifiable change. One will have a multiplicity of 3, another of 4 and the final (the OH proton) of 1 - the lattermost will also be significantly more deshielded than its compatriots (by the O). Their areas by integration will respectively be in a 3:2:1 ratio. ∴ Yes, absolutely, C can be easily confirmed to have been produced via either spectrum.

Step 3: "reagent" = oxidant, ideally weak e.g. pyridinium chlorochromate. To identify D, IR will again function. The enormous OH peak will be absent, and in its stead a tall, thin peak around 1700 wavenumbers will appear to attest to its C=O bond. Yet again, NMR's comprehensive results will confirm D's presence. Only two H' environments will now be visible and neither will undergo any splitting (the CHO proton is attached to a host C bordering a C with attached H and would be expected to cause and participate in splitting if not for the =O bond which prevents the H' in the CHO group from being involved in splitting). Nevertheless, ~~the~~ one will have an area three times that of the other, and the latter will be greatly deshielded (by the O). ∴ Yes, absolutely, either spectrum will confirm that D has been formed.

9

good answer!

Question 35 (5 marks) **Marks**

Three unknown 0.1 M solutions each contain one cation and one anion, though it is not certain if the ions are either:

cations: Mg^{2+}, Na^+, Ag^+, Pb^{2+}

anions: CO_3^{2-}, CH_3COO^-, SO_4^{2-}, Cl^-

Some experiments are performed on new samples of each solution with the results shown in the table below:

Experiment / Result	A	B	C
Add HNO_3(aq)	bubbles CO_3^{2-}	vinegar smell CH_3COO^-	NVR not CO_3 or acetate
Add $BaCl_2$(aq)	white precipitate $BaCO_3$	white precipitate that darkened in UV Ag^+	NVR not Ag^+ or Pb^{-} not SO_4^{2-} → must be Cl^-
Add NH_3(aq) or OH^-(aq)	NVR not Pb^{2+} Mg^{2+} or Ag^+ → must be Na^+	brown precipitate that dissolved when excess ammonia is added	white precipitate not Na^+ → must be Mg^{2+}

(a) Determine the chemical formulae for samples A-C. **3**

A: Na_2CO_3

B: $AgCH_3COO$

C: $MgCl_2$

(b) Outline why the brown precipitate dissolved in excess ammonia for solution B. **1**

Soluble silver complex forms

(c) Identify why you would need to monitor the environment for any one of these ions. **1**

ANY valid eg. Pb^{2+} is toxic to humans + aquatic life even in small quantities.

END OF EXAMINATION

* Note: Straight dot point – many boys had not learnt this dot pt.