2023

HIGHER
SCHOOL
CERTIFICATE
TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations
- Write your Student ID at the bottom of this page and at the top of page 11

Total marks:
100

Section I — 20 marks (pages 2–10)

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

Section II — 80 marks (pages 11–29)

- Attempt Questions 21–34
- Allow about 2 hours and 25 minutes for this section

Student ID: _____

Section I

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

Use the multiple-choice answer sheet for Questions 1–20

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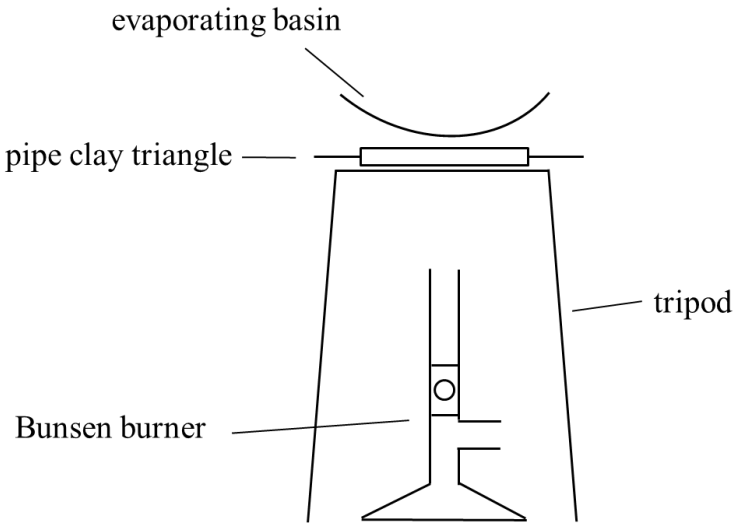
1 Students wish to carry out an investigation in which they evaporate excess water from a salt sample. They set up their apparatus as shown in the diagram.



What best describes the system they have created?

A. Open

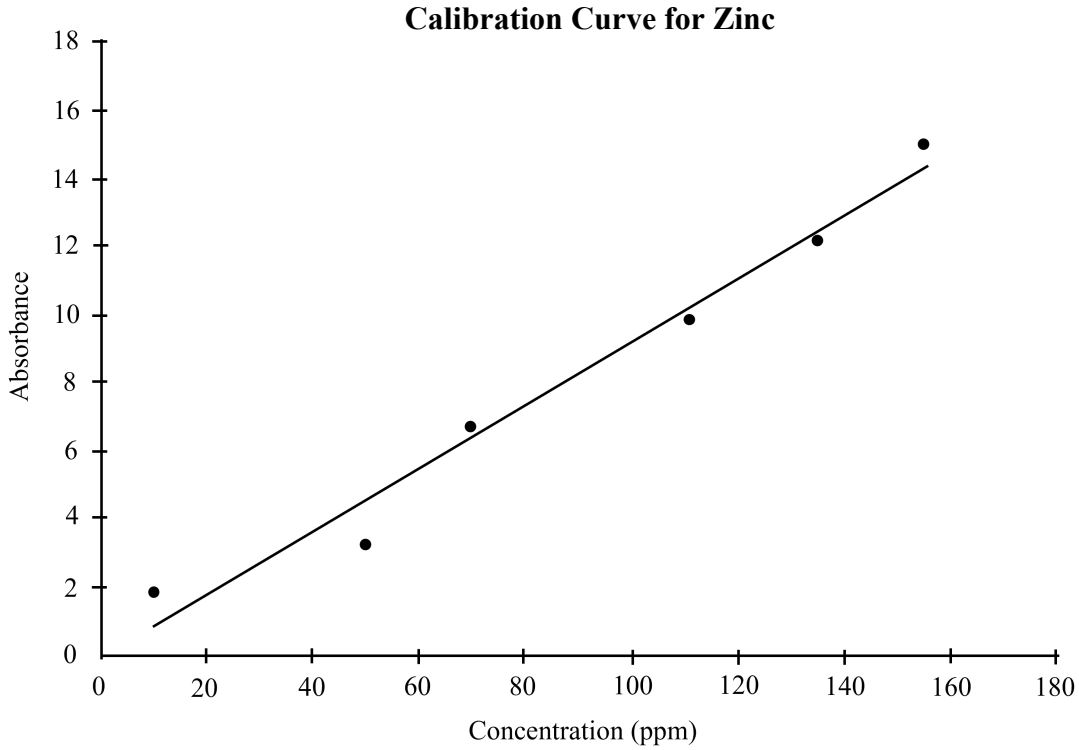
B. Closed

C. Isolated

D. Controlled

2 Atomic absorption spectroscopy (AAS) is a technique that measures the concentration of ions in a solution.

The graph shows a calibration curve used to determine the concentration of zinc in oysters and other shellfish.



An oyster sample is found to have an absorbance of 11.

The sample's approximate expected concentration of zinc is

A. 1.

B. 60.

C. 120.

D. 135.

3 Which statement best describes a system that has reached dynamic equilibrium?

A. The macroscopic properties of the substances in the system will vary.

B. There are no products, so the reverse reaction will be unable to occur.

C. The rate of the forward reaction is the same as the rate of the reverse reaction.

D. The concentration of the reactants will be higher than that of the products.

4 Aboriginal and Torres Strait Islander Peoples used their knowledge of equilibrium systems to remove toxicity from food sources such as the fruit of the cycad tree.

Eating the fruit without removing these toxins could lead to gastrointestinal and liver disorder, nerve damage, and even death.

What name is given to the process that was used by Aboriginal and Torres Strait Islander Peoples to remove these toxins?

A. Leaching

B. Dissolution

C. Precipitation

D. Neutralisation

5 What products will form during a reaction between nitric acid and copper(II) carbonate?

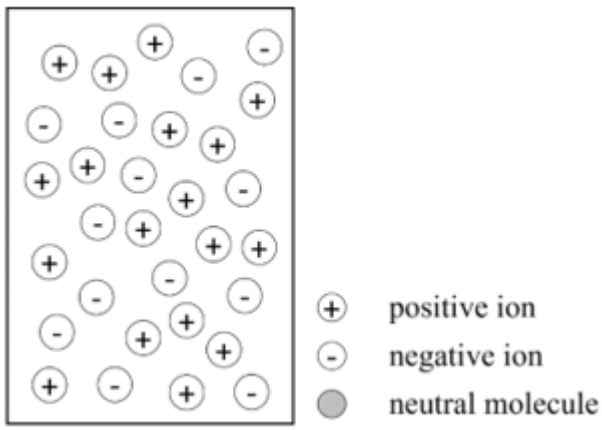
A. $Cu(NO_3)_2$

B. $Cu(NO_3)_2$ and H_2

C. $Cu(NO_3)_2$ and H_2O

D. $Cu(NO_3)_2$, CO_2 and H_2O

6 A student used the diagram to help construct a model as part of a depth study activity.



Which type of acid solution would the model best represent?

A. Dilute solution of a weak acid

B. Dilute solution of a strong acid

C. Concentrated solution of a weak acid

D. Concentrated solution of a strong acid

7 Which of these substances is an example of a polyprotic acid?

A. HCl

B. HNO_3

C. H_3CrO_4

D. CH_3COOH

8 A 3.25 g precipitate of calcium phosphate was produced when a solution of sodium phosphate was combined with a solution of calcium nitrate.

The equation for the reaction is:

$$3Ca(NO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6NaNO_3(aq).$$

What mass of sodium phosphate was needed to produce this precipitate?

A. 1.28×10^{-4} g

B. 0.859 g

C. 3.44 g

D. 5.16 g

9 A flame test was carried out to determine the presence of calcium ions in a water sample.

A positive result for this test could be confirmed if the flame was to change to

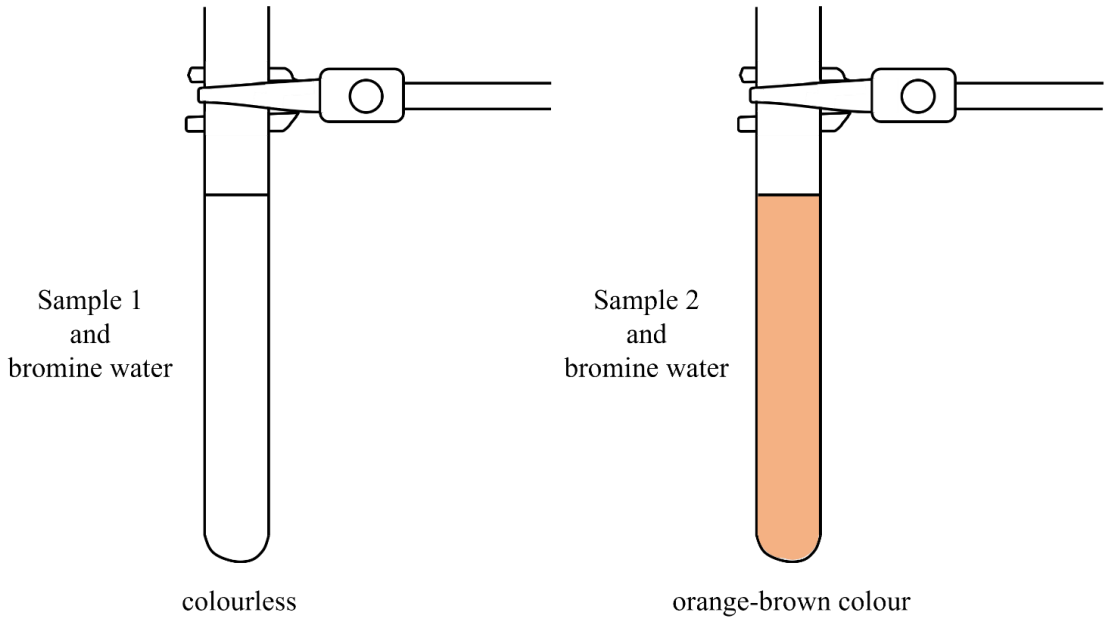
A. lilac.

B. green.

C. blue-green.

D. orange-red.

10 Two different hydrocarbon samples are placed in separate test tubes to which a small amount of bromine water is added.



Based on the results shown in the diagram, which of the following inferences can the student correctly make?

A. Sample 2 is an alkene because the solution became colourless once the sample was added.

B. Sample 1 is an alkene because the solution became colourless once the sample was added.

C. Sample 2 is an alkene because the solution remained orange-brown once the sample was added.

D. Sample 1 is an alkene because the solution remained orange-brown once the sample was added.

11 Fermentation is a process where glucose is broken down to ethanol and carbon dioxide.

Which row shows conditions which are all required for fermentation to take place?

A.	Presence of air	Presence of water	Presence of yeast
B.	Temperature of 10°C	Absence of air	Presence of water
C.	Presence of yeast	Temperature of 60°C	Presence of air
D.	Presence of water	Presence of yeast	Temperature of 37°C

12 In 1884, Svante Arrhenius published his definition of an acid, putting an end to the previous theory put forward by Humphry Davy.

Which of the following was identified as a limitation to Arrhenius's acid theory?

A. The theory could not explain why metal oxides were basic

B. The theory could not explain how some substances can act as both an acid and a base

C. The theory could not explain why there were some acids that did not contain oxygen

D. The theory could not explain why other compounds that contained hydrogen were not acidic

13 Which of the following pairs of substances would be appropriate for use in a buffer solution?

A. NH_4^+ and NH_3

B. HCl and NaOH

C. HPO_4^{2-} and CO_3^{2-}

D. CH_3COOH and HCO_3^-

14 Below is an ionic equation for a reversible reaction.

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

The reaction's correct equilibrium expression is

A.

B.

C.

D.

15 Which of the statements best summarises the effect of temperature on the value of K_{eq} for the following reaction.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = 58.0 \text{ kJ}$$

A. K_{eq} decreases as the temperature at which the reaction occurs increases.

B. K_{eq} increases as the temperature at which the reaction occurs increases.

C. K_{eq} increases as the temperature at which the reaction occurs decreases.

D. K_{eq} decreases as the temperature at which the reaction occurs decreases.

16 The halogenation of an alkane is an example of a substitution reaction.

Which of the following equations correctly shows the halogenation of an alkane?

A. $2CHCl_3 + Cl_2 \rightarrow 2CCl_4 + H_2$

B. $CHBr_3 + Br_2 \rightarrow CH_2Br_2 + HBr$

C. $C_2H_4Br_2 + Br \rightarrow C_2H_3Br_3 + H$

D. $CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$

17 While putting away his groceries, a student notices the recycling symbol on the side of a bottle of laundry liquid.

From the symbol, he correctly identifies that the bottle is made of HDPE, high density polyethylene.

Knowing this, what can be predicted about the structure of the plastic used to make the bottle?

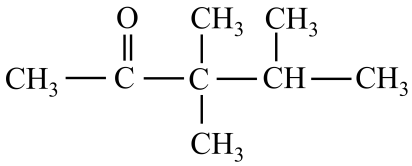
A. The carbon chains are unbranched so the molecules can pack close together.

B. The carbon chains are connected by double bonds that increase the density of the plastic.

C. The carbon chains are halogenated which allows the molecules to pack close together.

D. The carbon chains are branched which prevents the molecules from packing close together.

18 Look at the structural formula for the molecule shown.



What is the correct name for this molecule?

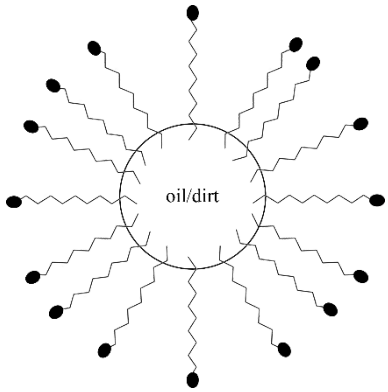
A. 2,3,3-trimethylpentan-2-one

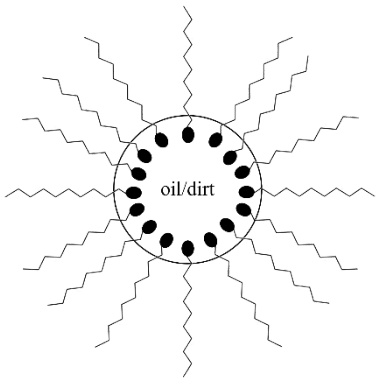
B. 3,3,4-trimethylpentan-2-one

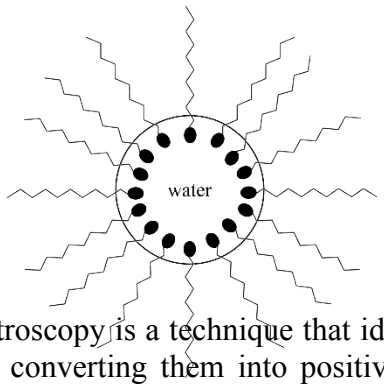
C. 2,3,3-trimethylpentan-4-one

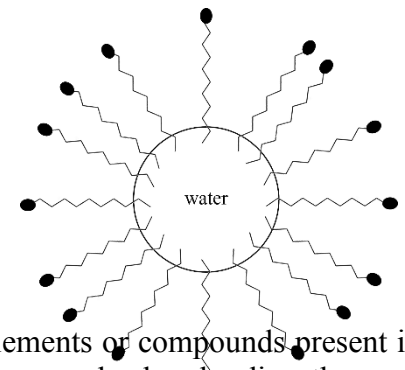
D. 3,3,4,4-tetramethylbutan-2-one

19 Which given diagram best demonstrates how a soap molecule can form a micelle?

A. 

B. 

C. 

D. 

20 Mass spectroscopy is a technique that identifies the elements or compounds present in a sample by converting them into positive ions. This occurs by bombarding them with electrons or irradiating them with ultraviolet (UV) light and then determining the mass-to-charge ratio or m/z.

Which statement about the *molecular ion* is most correct?

A. The molecular ion peak is normally given a relative intensity of 100%.

B. The molecular ion is represented by the most intense peak on a mass spectrum.

C. The molecular ion normally forms the peak with the largest mass-to-charge ratio.

D. The molecular ion will form peaks that are smaller than those formed by fragment ions.

Student ID: _____

2023

HIGHER SCHOOL CERTIFICATE
TRIAL EXAMINATION

Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours 25 minutes for this section

Instructions

- Write your Student ID above
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in question 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.

Please turn over

Question 21 (4 marks)

Potassium chloride is a salt that is often used as a medication to treat and prevent low blood potassium.

(a) A scientist creates a solution of potassium chloride that is saturated. **1**

State what is meant by this statement.

.....

.....

.....

(b) Draw a diagram in the space below that shows the hydrated potassium and chloride ions as they would appear in the scientist's potassium chloride solution. **3**

Question 22 (5 marks)

Hydrangeas are a type of plant whose flowers act as a natural indicator. They will appear pink/red in alkaline soil, and blue/purple in acidic soil.

A student creates an indicator solution using some hydrangea flowers and uses it to help determine the acidity of an unknown solution. When the indicator is added to the unknown solution, the solution turns purple.

They decide to use another laboratory indicator to confirm the findings.

(a) Select which indicator from the table below would be most appropriate to use and state why you have made this choice. **2**

Indicator	*pH Range*
Methyl orange	3.1 – 4.4
Bromothymol blue	6.0 – 7.6
Litmus	5.0 – 7.6
Phenolphthalein	8.0 – 10.0

(b) Digital probes are often used in favour of indicators when scientists are carrying out investigations into pH. **3**

Discuss the use of digital probes in scientific investigations.

Question 23 (4 marks)

An investigation is carried out where several solutions are combined to determine whether a precipitate will form.

(a) Complete the table below to show the expected results for this investigation. **2**
Use the following symbols:

✓ = precipitate formed
✗ = no precipitate formed

Cation	*Anion*		
	NO_3^- nitrate	SO_4^{2-} sulfate	OH^- hydroxide
Na^+			
Fe^{2+}			
Ba^{2+}			
Ca^{2+}			

(b) Precipitation reactions such as these are often used to monitor the quality of environmental water samples, in particular, to test for the presence of calcium ions. **2**

Suggest another test that could be carried out to determine if calcium ions were present in a water sample, and the expected results that a scientist could use to make this determination.

Question 24 (6 marks)

Sulfur dioxide and oxygen can be reacted to form sulfur trioxide according to the equation:

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

(a) Use Le Chatelier's Principle to predict any changes in the direction of the reaction if the overall pressure of the system is decreased. **3**

(b) Explain these changes using collision theory. **3**

Question 25 (6 marks)

For many years, it has been possible to purchase fuels that contain differing amounts of ethanol. The ethanol used to create these fuels can be produced using either fermentation or by hydrating an alkene.

(a) Write balanced chemical equations for each of these chemical reactions. **2**

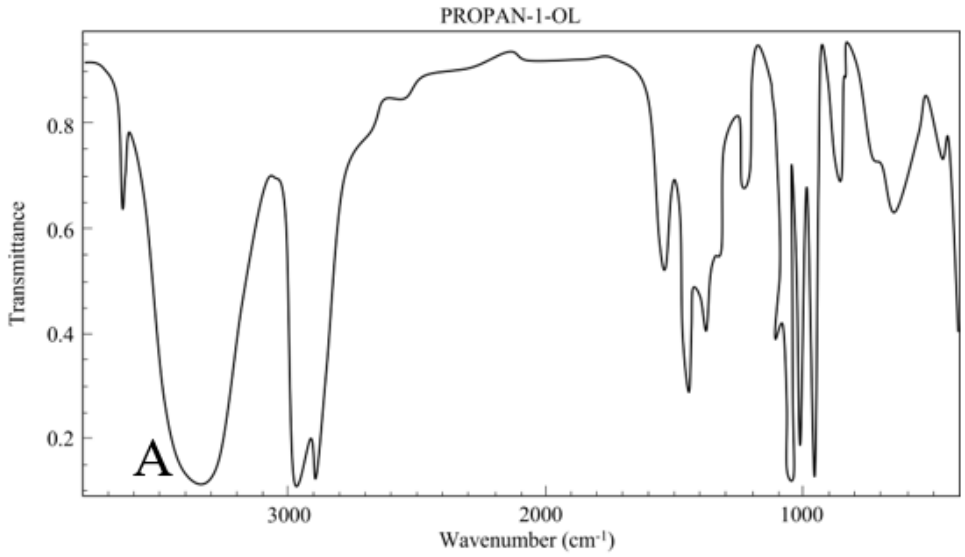
(b) The information given shows the conditions that must be maintained in order for the hydration reaction to occur. **4**

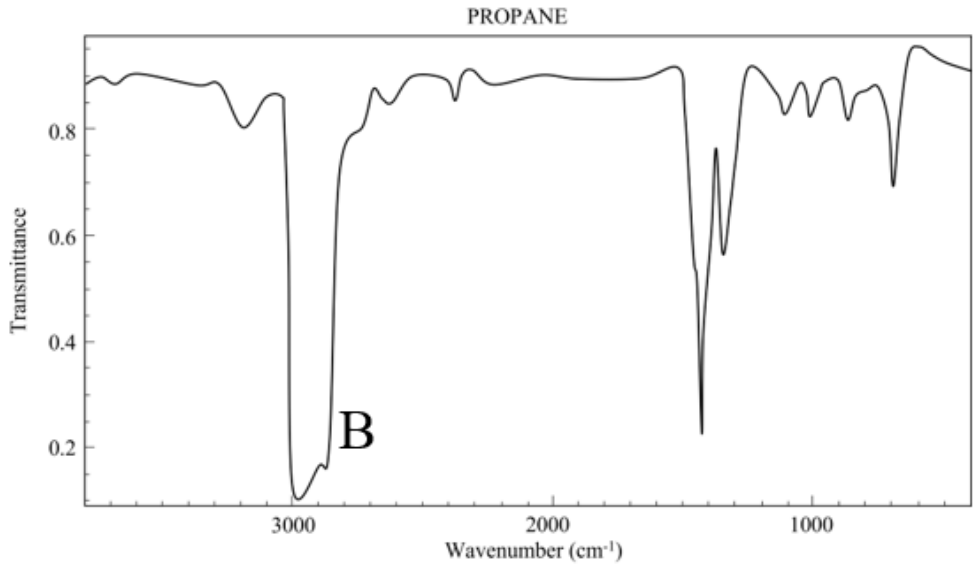
Hydration	• H_3PO_4 catalyst • temperature of 300°C

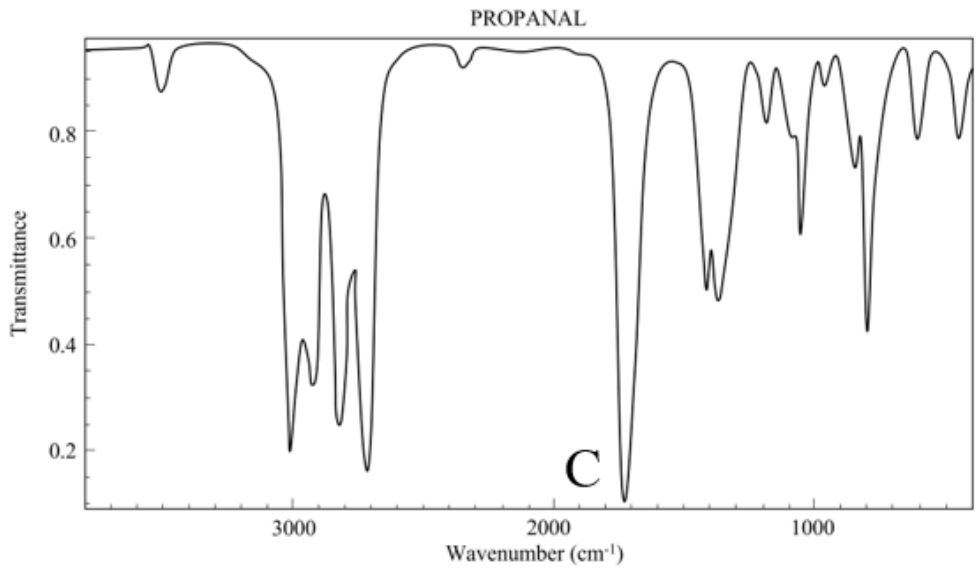
Use the information, and your knowledge of these two reactions, to justify why fermentation is still the preferred method of ethanol production in some countries.

Question 26 (7 marks)

The images below show the infrared spectra of propan-1-ol, propane and propanal.







Question 31 continues on page 18

Question 26 (continued)

(a) Identify the bonds that are represented by the peaks that have been labelled A, B and C. **3**

(b) The *y*-axis on an infrared spectrum is labelled *Transmittance*. **2**

Define this term and explain why it results in the shape found on the spectrum.

(c) The absorption bands located below wavenumber of 1400 cm^{-1} are often referred to as the fingerprint region. **2**

What is meant by this statement?

Question 27 (4 marks)

As part of your studies, you have carried out an investigation to analyse the reversibility of chemical reactions. **4**

Outline the investigation that you carried out and describe what you learnt from your observations.

Question 28 (7 marks)

Polytetrafluoroethene or PTFE is an example of an addition polymer. It is a versatile material with many unique properties that put it in high demand across various industries. This polymer currently generates around $4.4 billion in global revenue, and this is expected to reach $6.0 billion by 2028.

(a) What is an addition polymer? **2**

(b) Name and draw the structural formula of the monomer used to produce polytetrafluoroethylene. **2**

Question 28 continues on page 21

Question 28 (continued)

(c) Identify TWO properties of polytetrafluoroethylene and explain how these properties enable its specific use or application. **3**

End of Question 28

Question 29 (8 marks)

A student carries out a titration.

The equipment list is shown below:

- 20 mL orange juice
- 200 mL 0.1 mol L^{-1} sodium hydroxide solution
- pH meter
- burette
- 10 mL measuring cylinder
- 100 mL measuring cylinder
- retort stand, bosshead and clamp
- 150 mL beaker
- 250 mL beaker
- distilled water bottle
- digital balance
- funnel

(a) Outline a procedure that the student could follow to carry out the investigation. **3**

Question 25 continues on page 23

Question 29 (continued)

(b) The student's results revealed that the average volume of sodium hydroxide used in the titration was 18.0 mL. **5**

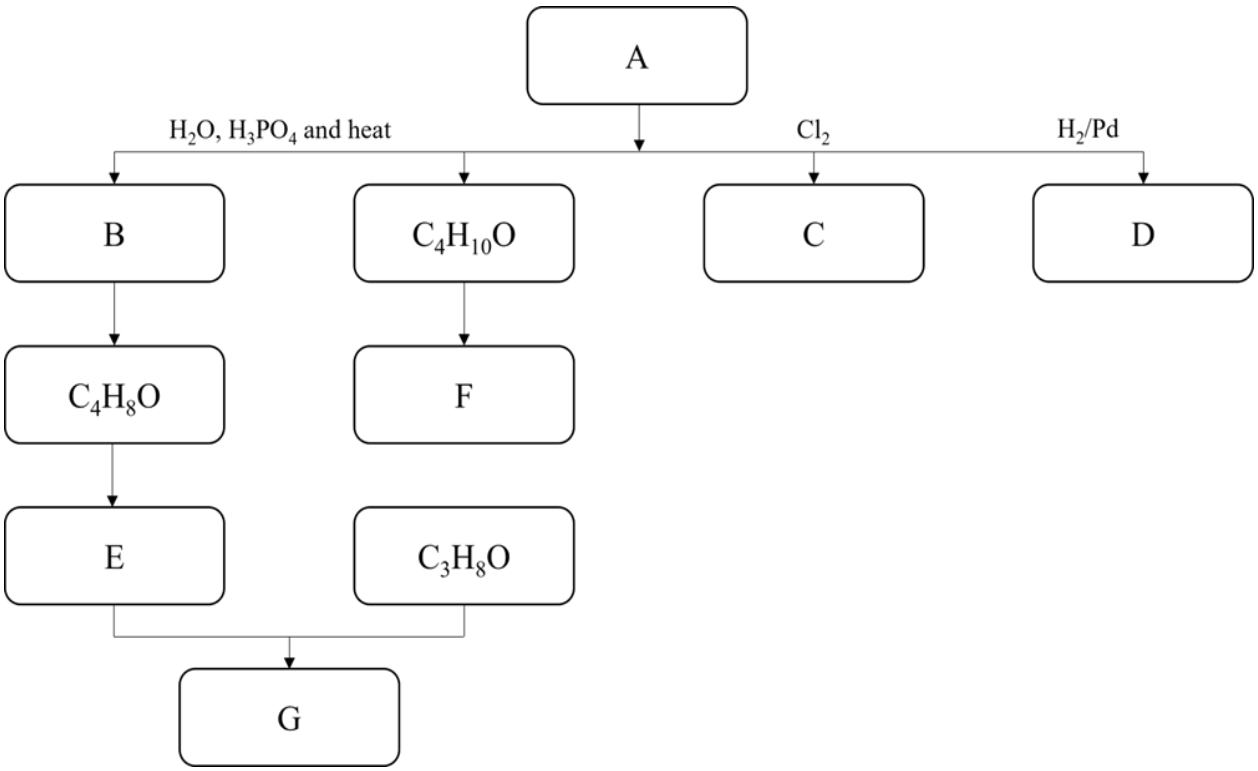
Use the equation given to calculate the percentage of citric acid found in the orange juice sample. Show all working out.

$$3NaOH(aq) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$$

End of Question 25

Question 30 (7 marks)

The flowchart shows several reaction pathways used in organic chemistry. **7**



Complete the table to show the name and structural formula of each of the unknown substances.

Substance	*Name*	*Structural formula*
A		
B		

Question 30 continues on page 25

Question 30 (continued)

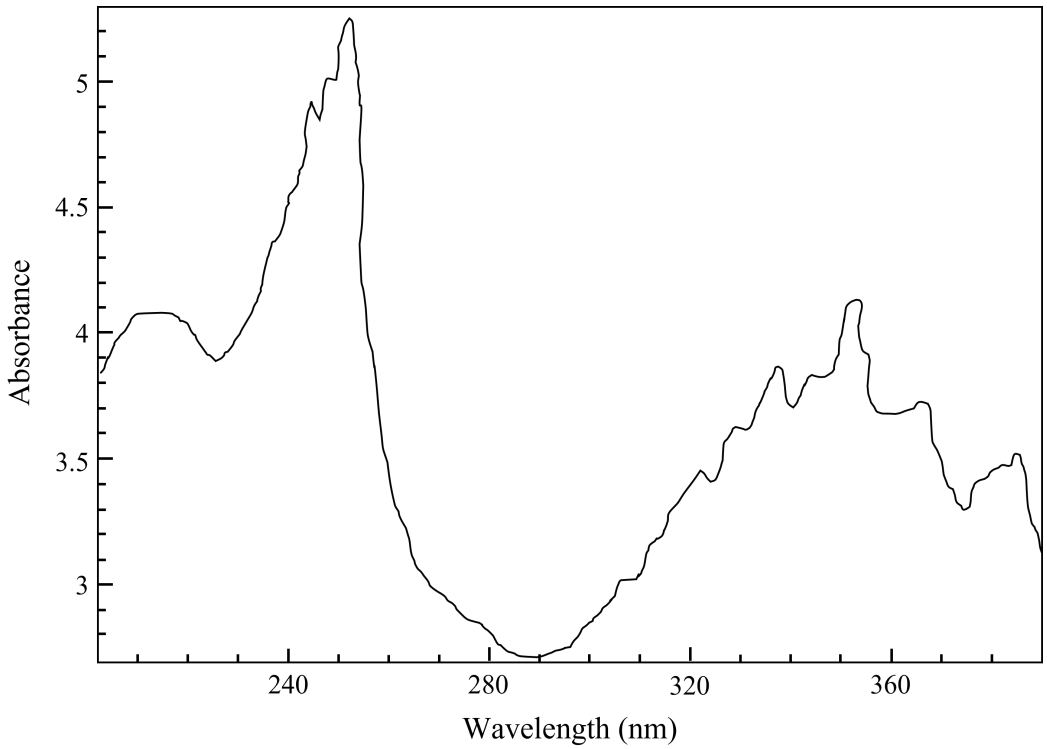
C		
D		
E		
F		
G		

End of Question 30

Question 31 (4 marks)

Pyridine (C H N) is a highly flammable, weakly alkaline, water-miscible liquid with a distinctive, unpleasant fish-like smell.

The image below shows the UV/VIS spectrum for pyridine (C H N).



(a) Circle the location of λ_{max} on the spectrum. **1**

(b) Outline how a Uv-Vis spectrophotometer works. **3**

Question 32 (5 marks)

A major petrochemical manufacturer has been producing several different polymers for many years. After researching the market, it is planning to expand its industry and add polystyrene to the list of polymers that it is producing. **5**

Analyse the factors that should be considered before the manufacturer starts developing a new chemical synthesis process.

Question 33 (6 marks)

A 0.0015 g sample of silver carbonate was placed into 125 mL of water at 25°C and stirred. **6**

The K_{sp} for silver carbonate at 25°C is 8.46×10^{-12}.

Determine whether a precipitate forms. Show all working out.

Question 34 (7 marks)

Propanoic acid, CH_3CH_2COOH is a naturally occurring carboxylic acid. It is a liquid with a pungent and unpleasant smell that resembles body odour. The K_a for propanoic acid is 1.34×10^{-5}. **7**

For a 0.65 mol L^{-1} propanoic acid solution, calculate the value of pKa, pH and K_b. Show all working out.

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.

2023 HSC TRIAL EXAMINATION

Chemistry

FORMULAE SHEET

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

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

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

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

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

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

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

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

DATA SHEET

Solubility constants at 25°C

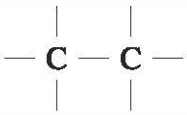
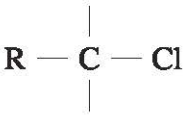
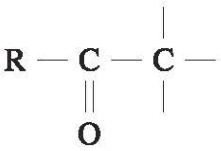
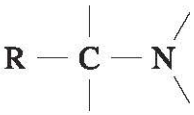
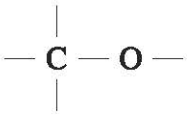
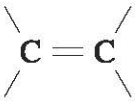
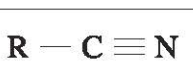
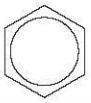
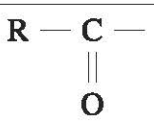
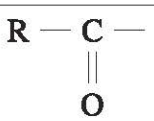
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	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
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	aldehydes or ketones	190–220

UV absorption

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

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

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

Some standard potentials

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

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.

Student ID: _____

2023

HIGHER SCHOOL CERTIFICATE
TRIAL EXAMINATION

Chemistry HSC Trial Examination

Section I –Multiple Choice Answer Sheet

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. Fill in the response circle completely.

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

2023 HSC Chemistry Marking Guidelines

Section I

Multiple-choice Answer Key (Explanations over page)

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

Explanation of Multiple Choice Answers

Question	Answer	Explanation
1	A	Correct answer is A. Open system allows exchange of energy as well as matter with the surroundings. The evaporation basin in open to the atmosphere, hence energy and matter (water vapor) is exchanged with the surroundings. B is incorrect as the evaporating basin does not have a lid to contain the vapour. C is incorrect as the system is not fully enclosed and insulated. D is a distractor.
2	C	Correct answer is C. A line drawn from the *y*-axis (absorbance) at 11 until intercepting the standard curve and then from there to the *x*-axis will represent concentration of 120 ppm. A, B and D are incorrect as those values do not correspond to absorbance of 11.
3	C	Correct answer is C. Dynamic equilibrium is reached when the rate of the forward reaction is equal to the rate of reverse reaction. In other words, the amount of reactants producing products is equal to the amount of products producing the reactants. B and D are incorrect as these statements are not correct for a system in dynamic equilibria. A is a distractor.
4	A	Correct answer is A. Leaching is a process where toxins are removed from the seeds due to their solubility in water. B is incorrect as the toxins do not dissociate. C is incorrect as the toxins do not precipitate out. D is incorrect as this is not a neutralisation reaction.
5	D	Correct answer is D. A reaction between a carbonate salt and acid will produce salt, carbon dioxide gas and water. A, B and C are incorrect as some of the products of a reaction between an acid and a carbonate are missing in the equations.
6	D	Correct answer is D. The model shows equal number of positive and negative ions and no neutral molecules. The lack of neutral molecules indicates an acid that is fully dissociated. As there are many ions, the acid is concentrated. A is incorrect as there are no neutral molecules in the diagram. B is incorrect as there are many positive and negative ions in the diagram indicating strong acid. C is incorrect as there are no neural molecules.
7	C	Correct answer is C. Polyprotic acid is an acid that has more than one (poly=many) hydrogen atoms in its molecule. A, B and D are incorrect as those acids have only one hydrogen atom.

8	C	Correct answer is C. $m(Ca_3(PO_4)_2)$ =3.25 g $m(Na_3PO_4)$ = ? $MM(Ca_3(PO_4)_2$ = (40.08 x3) + (30.97 x 2) + (16 x 8) = 310.18 $gmol^{-1}$ $MM(Na_3PO_4)$ = (22.99 x 3) +(30.97) + (16 x 4) = 163.94 $gmol^{-1}$ $n(Ca_3(PO_4)_2)$= = 0.010477 mol $n(Na_3PO_4) = n(Ca_3(PO_4)_2)$ x = 0.010477 x = 0.02095 mol $m(Na_3PO_4)$ = n x MM = 0.02095 x 163.94 = 3.3445 = 3.44 g (3 significant figures) B is incorrect as wrong ratio between calcium phosphate and sodium phosphate is used. A and D are incorrect as wrong values are used.
9	D	Correct answer is D. Calcium ions produce orange-red colour in the flame test. A is incorrect as lilac is positive test for potassium ions. B is incorrect as green is positive test for barium ions. C is incorrect as blue-green is positive test for copper ions.
10	B	Correct answer is B. A reaction between an alkene and bromine water will change the colour of the solution from orange to colourless. A, C and D are incorrect as alkene will react and the colour would change.
11	D	Correct answer is D. Ideal conditions for fermentation of glucose are fruit or grain (glucose source) mixed in water, absence of air, suitable yeast and temperature of 37 C. A is incorrect as presence of air is not a favoured condition. B and C are incorrect as temperatures are too cold or too hot to activate the enzymes in the yeast.
12	B	Correct answer is B. Arrhenius theory could not provide explanation as to why some substances are amphoteric. A and C are incorrect as these statements are limitations of Lavoisier theory. D is a distractor.
13	A	Correct answer is A. A buffer is made of a weak acid and its salt or weak base and its salt. NH_4^+ and NH_3 are suitable components for a basic buffer. B is incorrect as strong acid and strong base cannot be used to make a buffer. C is incorrect as HPO_4^{2-} and CO_3^{2-} are not from the same acid. D is incorrect as HCO^- is not from CH_3COOH.

14	B	Correct answer is B. The equilibrium constant for a reaction is the concentration of the products divided by the concentration of the concentration of reactants. The index of each component concentration is same as the coefficient in the balanced equation. The concentration of pure solid and pure liquid is constant and is removed from the equation. A is incorrect as it has wrong combination of products and reactants. C is incorrect as it has water in liquid state in the equation. D is incorrect as it represents reactants over products.
15	B	Correct answer is B. As ΔH = +58kJ, the reaction is endothermic. Increasing the temperature of the reaction will favour the forward reaction. As a result, the K_{eq} will increase. A is incorrect as, if the forward reaction is favoured, more products are produced, hence K_{eq} increases. C is incorrect as decreasing temperature will favour the reverse reaction, which will result in decrease of K_{eq}. D is incorrect as it is a distractor.
16	D	Correct answer is D. This equation correctly shows the substitution reaction of dichloromethane. A is incorrect as it is a distractor. B is incorrect as this is not a substitution reaction. C is incorrect as this Br and H are incorrectly written (they exist as diatomic molecules).
17	A	Correct answer is A. HPDE is made using low pressure and low temperature using Ziegler-Natta catalysts. Those mild conditions allow the ethene to polymerise slowly, without side branches which results in molecules being closer together. This produces a polymer that has high density, hardness, and a high melting point. B is incorrect as HDPE does not contain a double bond in its structure. C is incorrect as HDPE does not contain halogen. D is incorrect as HDPE has a linear structure with very little side branching.
18	B	Correct answer is B. The compound is a ketone, has 5 carbons in the longest chain and contains two methyl groups on the 2nd carbon and one in the 3rd carbon. A is incorrect as the numbering of methyl groups is taking preference over numbering the carbonyl group. C is incorrect as the numbering of the carbonyl group is wrong. D is incorrect as there are only three methyl groups in this structure.
19	A	Correct answer is A. The long hydrocarbon tail is hydrophobic as it is non-polar. Therefore, it would move away from the water and towards the oil/dirt which is also non-polar. The head is hydrophilic as it is polar and will move towards the water which is also polar. B is incorrect as the polar part of the molecule cannot move towards the non-polar oil. C and D are incorrect as they wrong solvent (oil instead of water).
20	C	Correct answer is C. The peak that has the highest mass to charge ratio is the base peak which is the same as the molecular mass of the ion. A is incorrect as base peak gives 100% intensity. B is incorrect as molecular ion does not produce the most intense peak. D is a distractor.

Section II

Question 21 (4 marks)

(a) 1 mark

Criteria	Marks
• Provides correct statement about saturated solutions	1

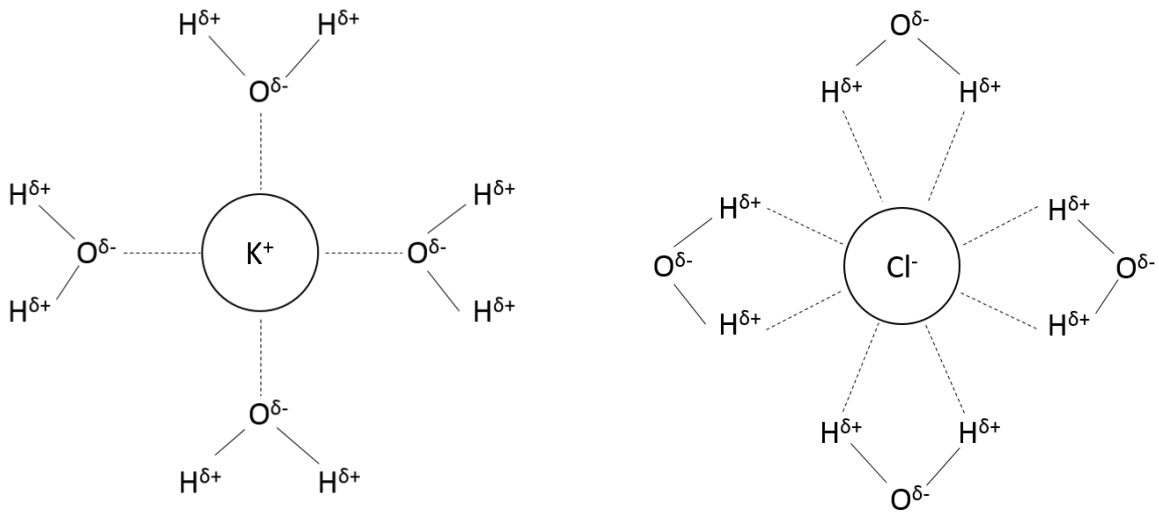
Sample answer:

A saturated solution is one in which no more solute (in this case potassium chloride) can dissolve at a given temperature.

(b) 3 marks

Criteria	Marks
• Correctly draws a labelled diagram depicting hydrated potassium AND chloride ions	3
• Correctly draws a labelled diagram depicting hydrated potassium OR chloride ions OR • Correctly draws a diagram depicting hydrated potassium OR chloride ions that is not appropriately labelled	2
• Provides some relevant information	1

Sample answer:



Question 22 (5 marks)

(a) 2 marks

Criteria	Marks
• Selects and appropriate indicator • States which the indicator has been chosen	2
• Selects and appropriate indicator	1

Sample answer:

Methyl orange is the most appropriate indicator to use as it is functional within a pH range of 3.1-4.4, which would allow it to show the presence of an acid.

(b) 3 marks

Criteria	Marks
• Provides a detailed discussion about the use of digital probes in scientific investigations	3
• Provides a discussion about the use of digital probes in scientific investigations	2
• Provides some relevant information	1

Sample answer:

The use of an indicator is a destructive test and observing colour changes can be subjective. Using a probe helps to remove these issues and provides a more accurate reading that cannot be misinterpreted. They are more expensive than indicators and have greater learning curves, and this may limit their use or effectiveness.

Question 23 (4 marks)

(a) 2 marks

Criteria	Marks
• Correctly provides all expected results for the investigation	2
• Correctly provides some of the expected results for the investigation	1

Sample answer:

Cation	Anion		
	NO_3^- nitrate	SO_4^{2-} sulfate	OH^- hydroxide
Na^+	✘	✘	✘
Fe^{2+}	✘	✘	✓
Ba^{2+}	✘	✓	✘
Ca^{2+}	✘	✓	✓

(b) 2 marks

Criteria	Marks
• Suggests another test that could be carried out to determine the presence of calcium ions • Identifies expected results	2
• Suggests another test that could be carried out to determine the presence of calcium ions	1

Sample answer:

Answers may vary.

A flame test could be used to determine if there were calcium ions present in a sample of water. If there were calcium ions present, the flame would become an orange-red (brick red) colour.

Question 24 (6 marks)

(a) 3 marks

Criteria	Marks
• Correctly predicts the change in the direction of the reaction • States why this change will occur • Supports response with clear reference to Le Chatelier's Principle	3
• Correctly predicts the change in the direction of the reaction • States why this change will occur	2
• Provides some relevant information OR • States Le Chatelier's Principle	1

Sample answer:

Le Chatelier's Principle states that if a system at equilibrium is disturbed, then the system will adjust itself to minimise the disturbance and return to equilibrium. Decreasing the overall pressure of the system will lead to a decrease in the concentration of all gases. The reaction will shift to the left, favouring the reverse reaction, as this is the direction which forms the most gas and that will lead to an increase in the overall system pressure.

(b) 3 marks

Criteria	Marks
• Explains changes that occur in the reaction • Links change to increased volume as a result of pressure change • Supports response with clear reference to collision theory	3
• Explains changes that occur in the reaction • Links change to increased volume as a result of pressure change	2
• Provides some relevant information OR • States collision theory	1

Sample answer:

Collision theory states that for a reaction to occur, the particles must collide with sufficient energy to break the bonds and have the appropriate orientation to allow the new bonds to form. Decreasing the system pressure leads to an increase in its volume. The gas molecules have more space in which they can move around. This decreases the chance that successful collisions will occur, and this prevents the forward reaction from proceeding.

Question 25 (6 marks)

(a) 2 marks

Criteria	Marks
• Provides a balanced chemical equation for fermentation AND • Provides a balanced chemical equation for the hydration of an alkene	2
• Provides a balanced chemical equation for fermentation OR • Provides a balanced chemical equation for the hydration of an alkene	1

Sample answer:

$C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$

(b) 4 marks

Criteria	Marks
• Provides a thorough justification as to why fermentation is still the preferred method of ethanol production in some countries • References data table	4
• Provides a basic justification as to why fermentation is still the preferred method of ethanol production in some countries	3
• Identifies a series of points that support the idea that fermentation is still the preferred method of ethanol production in some countries	2
• Provides some relevant information	1

Sample answer:

Fermentation is still the preferred method of ethanol production in some countries as this reaction only requires a temperature of 37°C, whereas a hydration reaction would require a temperature of 300°C. Maintaining very high temperatures would require much more energy than maintain lower ones and using more energy costs makes production more expensive. Sourcing a phosphoric acid catalyst may be expensive and its use and disposal may pose risks to employees and the environment. Fermentation requires water and yeast, both of which are readily available, and its waste products have additional uses that can generate additional income.

Question 26 (7 marks)

(a) 3 marks

Criteria	Marks
• Correctly identifies ALL three peaks	3
• Correctly identifies TWO of the three peaks	2
• Correctly identifies ONE of the three peaks	1

Sample answer:

The broad peak at A represents a O–H bond as it is located at a wavenumber between 3230 and 2550 cm^{-1}. The peak at B represents a C–H bond as it is located at a wavenumber between 2850 and 3300 cm^{-1}. The peak at C represents a C=O bond as it is located at a wavenumber between 1689 and 1750 cm^{-1}.

(b) 2 marks

Criteria	Marks
• Provides a definition of transmittance • Provides a link between transmittance and the shape of the spectra	2
• Provides a definition of transmittance	1

Sample answer:

Transmittance refers to how much infrared energy has passed through a sample without being absorbed. Lower values on this axis show that something was present at that wavenumber to absorb some of the infrared energy, leading to the formation of an 'upside-down' peak.

(c) 2 marks

Criteria	Marks
• Explains clearly what is meant by the statement	2
• Provides some relevant information	1

Sample answer:

The absorption bands found within the fingerprint region are often unique to the compound that has been analysed and can, therefore, be used to identify an unknown sample. For example, the bands above 1400 cm^{-1} may identify a substance as being an alcohol, but the fingerprint region may allow for the distinction between it being propan-1-ol or propan-2-ol.

Question 27 (4 marks)

Criteria	Marks
• Outlines a suitable investigation that demonstrates the reversibility of a chemical reaction • Describes what they have learnt from their observations • References equilibrium or a change in the direction of a reaction	4
• Outlines a suitable investigation that demonstrates the reversibility of a chemical reaction • Describes what they have learnt from their observations	3
• Outlines a suitable investigation that demonstrates the reversibility of a chemical reaction OR • Describes what they have learnt from their observations	2
• Provides some relevant information	1

Sample answer:

1. Label two test tubes A and B.
2. Add about 1 mL of potassium chromate to both test tubes.
3. Test tube A is a reference solution.
4. Add hydrochloric acid dropwise to test tube B until a colour change occurs.
5. Record observations.
6. Add sodium hydroxide dropwise to test tube B until another colour change occurs.
7. Record observations.

When acid was added to the test tube, there was a colour change from yellow to orange as the dichromate ion was formed. When a base was added, the solution changed back to yellow as the equilibrium shifted in favour of the reverse reaction according to the following equation:

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

Question 28 (7 marks)

(a) 2 marks

Criteria	Marks
• Correctly defines an addition polymer	2
• Provides any relevant information	1

Sample answer:

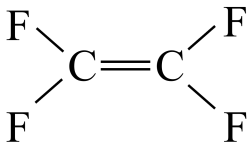
An addition polymer is a polymer that is formed by an addition reaction in which many unsaturated monomers bond together by a rearrangement of C=C double bonds without the loss of any atom or molecule.

(b) 2 marks

Criteria	Marks
• Names AND draws the structural formula of the monomer used to produce polytetrafluoroethene	2
• Names OR draws the structural formula of the monomer used to produce polytetrafluoroethene	1

Sample answer:

Tetrafluoroethene



(c) 3 marks

Criteria	Marks
• Identifies TWO properties of polytetrafluoroethene • Identities use or application of polytetrafluoroethene • Makes clear links between properties and use	3
• Identifies TWO properties of polytetrafluoroethene • Identities use or application of polytetrafluoroethene	2
• Identifies a property of polytetrafluoroethene OR • Identities use or application of polytetrafluoroethene	1

Sample answer:

PTFE is commonly used to make seals and gaskets that are used in the automotive industry. It is a suitable material to use as it has high temperature resistance and high chemical resistance which means that it won't be damaged or degraded when exposed to any chemicals that might be in the tank or by the heat generated by the running of the vehicle.

Answers will vary and may include reference to the following:

Properties	*Uses*
high chemical resistance high temperature resistance high melting point low friction (non-stick)	electronics (wire coatings) automotive (seals and gaskets, bearings, insulation) aerospace (seals and gaskets, bearings, insulation) consumer items (cooking equipment, plumber's tape) textiles (waterproof fabrics)

Question 29 (8 marks)

(a) 3 marks

Criteria	Marks
• Outlines a procedure that could be carried out to determine the citric acid content in a sample of orange juice • Includes appropriate measurements	3
• Outlines a procedure that could be carried out to determine the citric acid content in a sample of orange juice	2
• Provides some relevant information	1

Sample answer:

1. Rinse the 150 mL beaker with a small amount of sodium hydroxide solution, empty, and then fill with about 100 mL of sodium hydroxide solution.
2. Set up burette and fill with the sodium hydroxide solution from the beaker.
3. Rinse the 250 mL with water.
4. Weigh the 250 mL beaker.
5. Pour about 20 mL of orange juice into the 250 mL beaker and reweigh it.
6. Add about 50 mL of water to the 250 mL beaker.
7. Place the pH meter in the 250 mL beaker and record the pH.
8. Place the 250 mL beaker under the burette and start the titration.
9. Stop after each millilitre of sodium hydroxide has been added and record the pH.
10. Continue adding sodium hydroxide until the pH is consistently basic.
11. Repeat titration, taking more frequent samples as the end point becomes close.

(b) 5 marks

Criteria	Marks
• Calculates moles of NaOH used • Calculates moles of $H_3C_6H_5O_7$ reacted • Calculates molar mass of $H_3C_6H_5O_7$ • Calculates mass of $H_3C_6H_5O_7$ reacted • Calculates the percentage of citric acid found in the orange juice sample	5
• Calculates moles of NaOH used • Calculates moles of $H_3C_6H_5O_7$ reacted • Calculates molar mass of $H_3C_6H_5O_7$ • Calculates mass of $H_3C_6H_5O_7$ reacted	4
• Calculates moles of NaOH used • Calculates moles of $H_3C_6H_5O_7$ reacted	3
• Calculates moles of NaOH used	2
• Provides any relevant calculation	1

See over for sample answer

Sample answer:

$3NaOH(aq) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

volume of NaOH used = 18.0 mL

moles of NaOH used = c x V
= 0.1 x 0.018
= 0.0018 mol

molar ratio = 3: 1

moles of $H_3C_6H_5O_7$ reacted =
= 0.0006 mol

molar mass of $H_3C_6H_5O_7$ = 192.124 g mol^{-1}

mass of $H_3C_6H_5O_7$ reacted = n x MM
= 0.0006 x 192.124
= 0.115 g

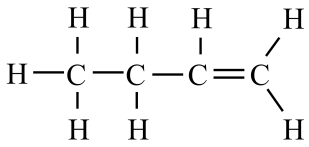
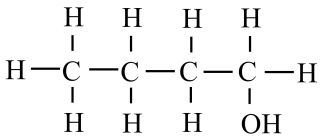
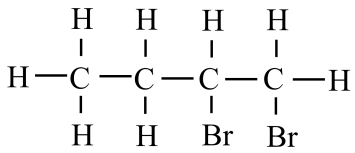
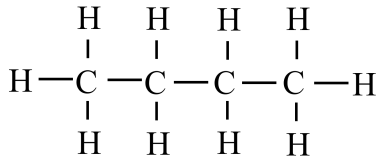
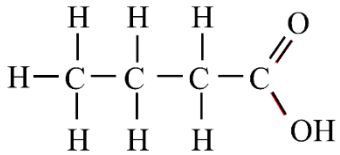
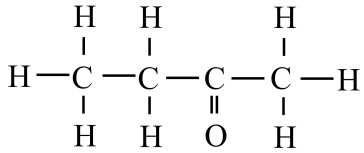
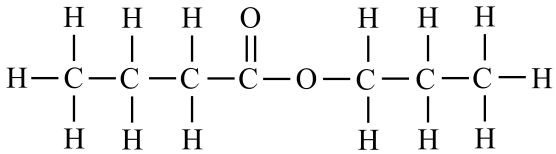
percentage of original sample =
= 0.58%

Question 30 (7 marks)

Criteria	Marks
• Correctly names all unknown substances • Provides structural formula for all unknown substances	7
• Correctly names six unknown substances • Provides structural formula for six unknown substances	6
• Correctly names five unknown substances • Provides structural formula for five unknown substances	5
• Correctly names four unknown substances • Provides structural formula for four unknown substances	4
• Correctly names three unknown substances • Provides structural formula for three unknown substances OR • Correctly names all unknown substances	3
• Correctly names two unknown substances • Provides structural formula for two unknown substances	2
• Correctly names an unknown substance • Provides structural formula for an unknown substance	1

See over for sample answer

Sample answer:

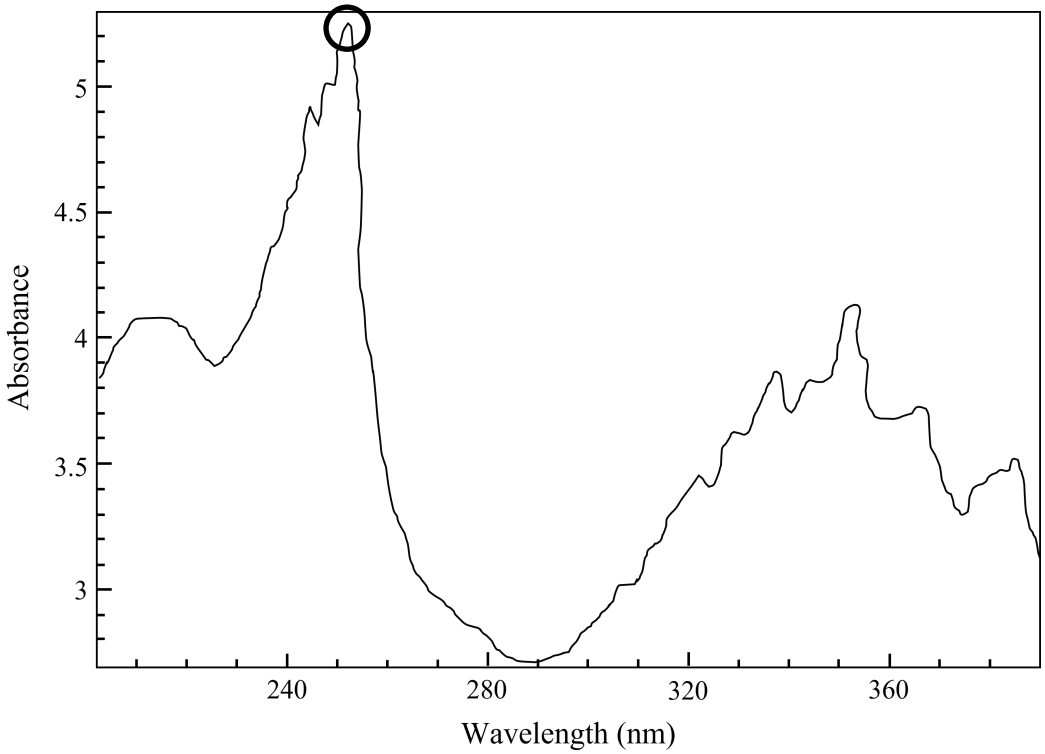
Substance	*Name*	*Structural formula*
A	but-1-ene	
B	butan-1-ol	
C	1,2-dichlorobutane	
D	butane	
E	butanoic acid	
F	butanone	
G	propyl butanoate	

Question 31 (4 marks)

(a) 1 mark

Criteria	Marks
• Identifies correct ester	1

Sample answer:



(b) 3 marks

Criteria	Marks
• Provides a thorough outline of a spectrophotometer works	3
• Provides a basic outline of a spectrophotometer works	2
• Provides some relevant information	1

Sample answer:

1. The light source provides light of wavelengths 200-800 nm.
2. A monochromator is used to separate this light into particular wavelengths.
3. The wavelength (colour) of light used should be complementary to the colour of the solution.
4. An unknown and a reference sample are both put into the device.
5. The light beam is split so that it can pass through both the sample and the reference at the same time.
6. The detector records the wavelengths at which the absorption occurs and also the amount of absorption at each wavelength.

Question 32 (5 marks)

Criteria	Marks
• Demonstrates a comprehensive understanding of the factors that need to be considered when designing a chemical synthesis process • Analyses at least two factors • Draws out and shows clear relationship between each factor	5
• Demonstrates a thorough understanding of the factors that need to be considered when designing a chemical synthesis process • Describes at least two factors • Shows some relationship between factors	4
• Demonstrates a sound understanding of the factors that need to be considered when designing a chemical synthesis process • Describes at least two factors	3
• Provides some relevant information	1–2

Sample answer:

There are several factors that should be considered when designing a chemical synthesis process. Some chemical reagents are inexpensive and easy to source, whereas others can be expensive, rare or are controlled substances. This may mean that acquiring them may be difficult or costly, particularly if they are needed in large amounts, at short notice or for long periods of time. Knowing what reagents are required and how easily they can be obtained is something that a chemical industry should investigate before developing a new chemical synthesis process.

The effect of the process on the environment should be considered, particularly when it comes to the disposal of waste products. Green Chemistry principles should be used by industries to determine how their processes can be carried out in an environmentally-friendly way. Economic viability needs to be considered and the process modified (if necessary) to ensure that the business can be sustained. Manufacturers could attempt to produce more than one useful product as a way to maximise their profit.

Question 33 (6 marks)

Criteria	Marks
• Provides balanced net ionic equation • Converts measurement to grams per litre • Calculates molar mass of Ag_2CO_3 • Calculates moles of Ag_2CO_3 • Calculates concentration of Ag^+ and CO_3^{2-} ions • Calculates Q_{sp} • Compares Q_{sp} to K_{sp} and states whether a precipitate will form	6
• Provides balanced net ionic equation • Converts measurement to grams per litre • Calculates molar mass of Ag_2CO_3 • Calculates moles of Ag_2CO_3 • Calculates concentration of Ag^+ and CO_3^{2-} ions • Calculates Q_{sp}	5
• Provides balanced net ionic equation • Converts measurement to grams per litre • Calculates molar mass of Ag_2CO_3 • Calculates moles of Ag_2CO_3 • Calculates concentration of Ag^+ and CO_3^{2-} ions	4
• Provides balanced net ionic equation • Converts measurement to grams per litre • Calculates molar mass of Ag_2CO_3 • Calculates moles of Ag_2CO_3	3
• Provides balanced net ionic equation • Converts measurement to grams per litre OR • Calculates molar mass of Ag_2CO_3	2
• Provides any relevant calculation OR • Provides balanced net ionic equation	1

Sample answer:

$Ag_2CO_3(s) \rightleftharpoons 2Ag^+(aq) + CO_3^{2-}(aq)$
molar ratio = 1:2:1

0.0015 g in 125 mL
$\therefore$ 0.012 g L^{-1}

Alternate working for this step:
$n(Ag_2CO_3) =$ 0.000005499 mol

$C(Ag_2CO_3) =$ 0.0000435 mol L^{-1}

Answer continued over page
$MM(Ag_2CO_3) = (2 \times 107.9) + 12.01 + (3 \times 16.00)$

= 275.81

$n = 4.35 \times 10^{-5}$ mol

$[Ag^+] = 2s$
$[CO_3^{2-}] = s$

$[Ag^+] = 8.70 \times 10^{-5}$ mol L^{-1}
$[CO_3^{2-}] = 4.35 \times 10^{-5}$ mol L^{-1}

$Q_{sp} = [Ag^+]^2 \times [CO_3^{2-}]$
$Q_{sp} = [8.70 \times 10^{-5}]^2 \times [4.35 \times 10^{-5}]$
$Q_{sp} = 3.29 \times 10^{-13}$

$K_{sp} = 8.46 \times 10^{-12}$

K_{sp} does not equal Q_{sp}
$Q_{sp} < K_{sp}$

$\therefore$ no precipitate will form

Question 34 (7 marks)

Criteria	Marks
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa, pH and K_b • Provides appropriate working out to support answer	7
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa, pH and K_b with one error or limited working out to support answer	6
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa and pH • Provides appropriate working out to support answer	5
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa and pH • Provides limited working out to support answer	4
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa and $[H_3O^+]$ • Provides appropriate working out to support answer	3
• Provides the correct equilibrium expression for K_a • Correctly calculates pKa • Provides appropriate working out to support answer	2
• Provides any relevant calculation OR • Provides the correct equilibrium expression for K_a	1

Sample answer:

$pK_a = -\log K_a$
$pK_a = -\log 1.34 \times 10^{-5}$
$pK_a = 4.9$ (two significant figures)

	$CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$		
I	0.65	0	0
C	-x	+ x	+ x
E	0.65 - x	x	x

(continues over page)

Propanoic acid is a weak acid and therefore will dissociate very little; this means that 0.65 – x is basically the same as 0.65.

$x^2 = 1.34 \times 10^{-5} \times 0.65$
$x^2 = 0.00000871$

$x = 0.00295$

$\therefore [H_3O^+] = 0.00295 \text{ mol } L^{-1}$

$pH = -\log[H_3O^+]$
$pH = -\log 0.00295$
$pH = 2.53$

$K_w = 1.0 \times 10^{-14}$
$K_w = K_a \times K_b$

$K_b = 7.46 \times 10^{-10}$

2023 HSC Chemistry Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Static and Dynamic Equilibrium	CH12-12
2	1	Analysis of Inorganic Substances	CH12-15
3	1	Static and Dynamic Equilibrium	CH12-12
4	1	Solution Equilibria	CH12-5, CH12-12
5	1	Properties of Acids and Bases	CH12-5, CH12-13
6	1	Quantitative Analysis	CH12-5, CH12-13
7	1	Properties of Acids and Bases	CH12-13
8	1	Analysis of Inorganic Substances	CH12-3, CH12-15
9	1	Analysis of Inorganic Substances	CH12-15
10	1	Analysis of Organic Substances	CH12-3, CH12-15
11	1	Alcohols	CH12-14
12	1	Properties of Acids and Bases	CH12-13
13	1	Quantitative Analysis	CH12-5, CH12-13
14	1	Calculating the Equilibrium Constant (K_{eq})	CH12-6
15	1	Calculating the Equilibrium Constant (K_{eq})	CH12-6
16	1	Products of Reactions Involving Hydrocarbons	CH12-14
17	1	Polymers	CH12-5, CH12-14
18	1	Nomenclature	CH12-7, CH12-14
19	1	Reactions of Organic Acids and Bases	CH12-7, CH12-14
20	1	Analysis of Organic Substances	CH12-15

Section II

Question	Marks	Content	Syllabus outcomes
21(a)	1	Solution Equilibria	CH12-12
21(b)	3	Solution Equilibria	CH12-7, CH12-12
22(a)	2	Properties of Acids and Bases	CH11-2, CH12-13
22(b)	3	Properties of Acids and Bases	CH12-13
23(a)	2	Analysis of Inorganic Substances	CH12-15
23(b)	2	Analysis of Inorganic Substances	CH12-15
24(a)	3	Factors that Affect Equilibrium	CH12-12
24(b)	3	Factors that Affect Equilibrium	CH12-12
25(a)	2	Alcohols	CH12-14
25(b)	4	Alcohols	CH12-6, CH12-14
26(a)	3	Analysis of Organic Substances	CH12-4, CH12-15
26(b)	2	Analysis of Organic Substances	CH12-15
26(c)	2	Analysis of Organic Substances	CH12-15
27	4	Static and Dynamic Equilibrium	CH12-7, CH12-12
28(a)	2	Polymers	CH12-14
28(b)	2	Polymers	CH12-14
28(c)	3	Polymers	CH12-7, CH12-14
29(a)	3	Quantitative Analysis	CH12-2, CH12-5
29(b)	5	Quantitative Analysis	CH12-5, CH12-13
30	7	Reactions of Organic Acids and Bases	CH12-14
31(a)	1	Analysis of Inorganic Substances	CH12-15
31(b)	3	Analysis of Inorganic Substances	CH12-7, CH12-15
32	5	Chemical Synthesis and Design	CH12-7, CH12-15
33	6	Solution Equilibria	CH12-6
34	7	Quantitative Analysis	CH12-13