2021
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 a Periodic Table are provided
- Write your student number and/or name at the top of every page

Total marks – 100

Section I – Pages 2–11
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – Pages 12–33
80 marks
- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

This paper MUST NOT be removed from the examination room

STUDENT NUMBER/NAME: .....

STUDENT NUMBER/NAME: .....

Section I

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

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

	A	B	C	D
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	A	B	C	D
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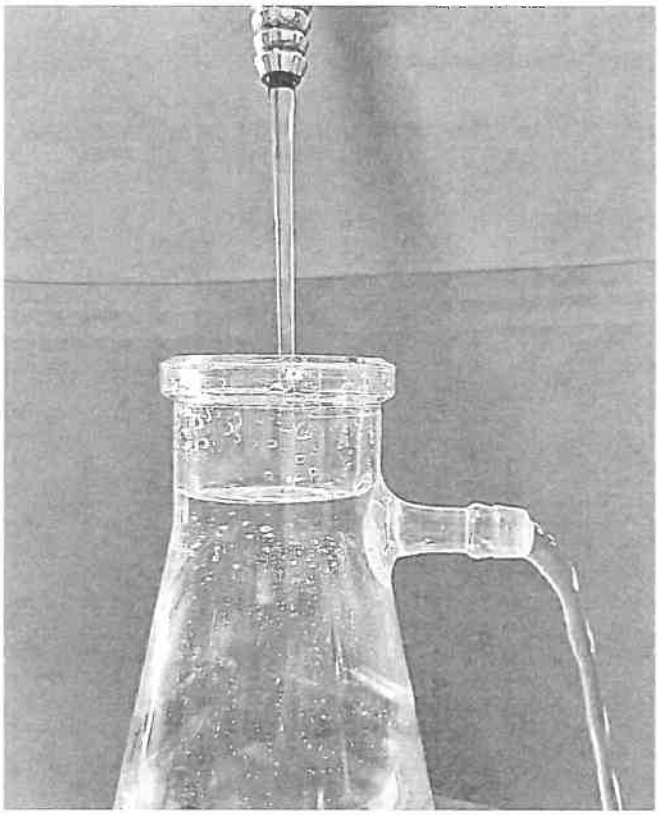
1 A side-arm conical flask is being filled with water in a sink. The water enters and leaves the flask at a constant rate.



Which type of system is represented?

A. Open, because water is lost and gained by the system

B. Open, because the system does not have a constant temperature

C. Closed, because the level of the water is constant in the flask

D. Closed, because the system is homogenous as it is composed of water

2 Consider the compound represented by the following formula:

$$CH_3CH_2CONH_2$$

What is the name of this compound?

A. 1-propylamine

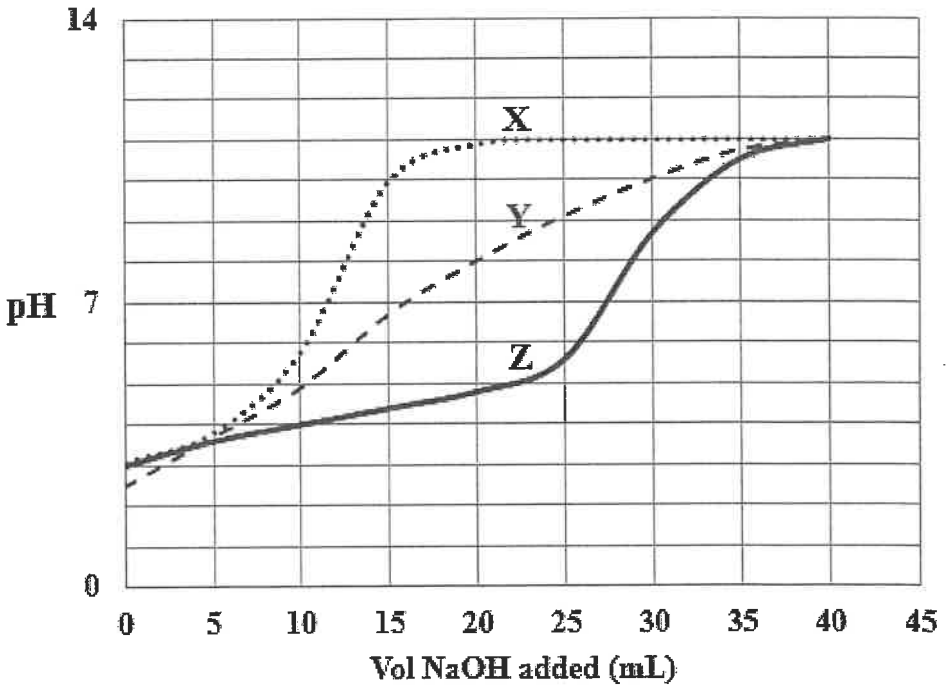
B. Propanoic amine

C. Propanoic acid

D. Propanamide

3 During a first-hand investigation, three brands of carbonated drinks were titrated with a standardised sodium hydroxide solution.

The results of these titrations are shown on the following grid.



Which of these drinks is buffered?

A. X only

B. Y only

C. Z only

D. X and Z

4 Which of the following is measured by an atomic absorption spectrometer?

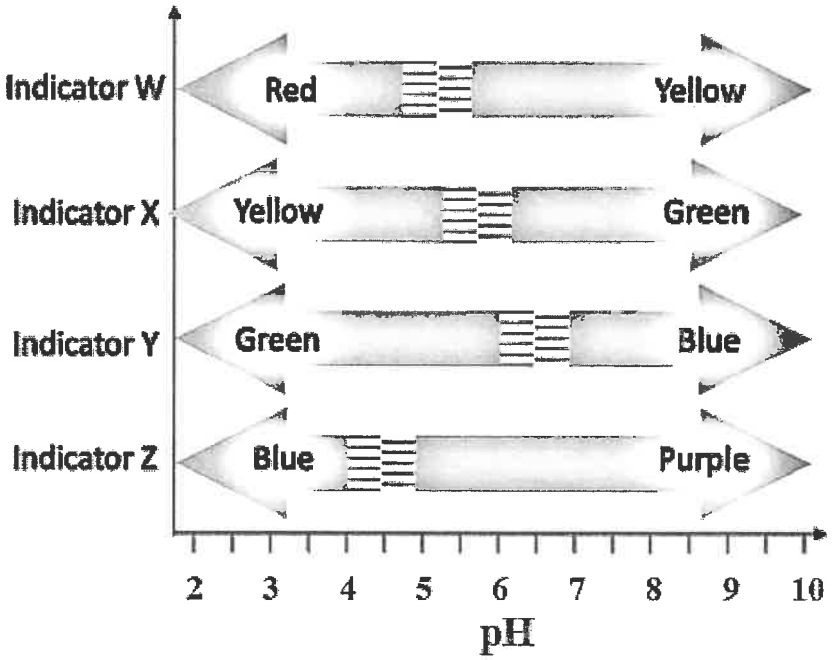
A. Mass

B. Absorbance

C. Charge

D. Concentration

5 Four indicators, W, X, Y and Z, are used to test a solution of industrial wastewater. The pH range of the colour change for each indicator is shown.



The wastewater tests yellow for indicators W and X.

Which gives the most likely colours for indicators Y and Z?

	Indicator Y	*Indicator Z*
A.	Green	Blue
B.	Green	Purple
C.	Blue	Blue
D.	Blue	Purple

6 Which describes the relationship between compounds methyl ethanoate and propanoic acid?

A. Members of the same homologous series

B. Position isomers

C. Chain isomers

D. Functional group isomers

7 The gases dinitrogen tetraoxide (N_2O_4) and nitrogen dioxide (NO_2) are found in the atmosphere around all major industrial cities. N_2O_4 is a colourless gas while NO_2 is a red-brown gas. These gases form an equilibrium:

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

The following data for temperature and equilibrium was collected.

Temperature (°C)	*Equilibrium constant (K)*
25	4.5×10^{-3}
100	0.5
220	40.0

Based on this data, which statement is correct?

A. Equilibrium has not been achieved for the reaction.

B. Equilibrium can only be measured when the values for $[N_2O_4]$ and $[NO_2]$ are identical.

C. The process is exothermic and the atmosphere would be clear on a hot day.

D. The process is endothermic and the atmosphere would be coloured red-brown on a hot day.

8 Which classification of soap molecules is produced by the saponification of fats?

A. Cationic surfactants

B. Anionic surfactants

C. Non-ionic surfactants

D. Acidic surfactants

9 Which results identify each of the ions in the compound, copper acetate, $Cu(CH_3COO)_2$?

	Cu^{2+}	CH_3COO^-
A.	Forms a precipitate with chloride ions	Produces bubbles on reaction with a carbonate
B.	Does not produce a noticeable colour in a flame test	Does not produce a precipitate with any dilute cation solutions
C.	Flame test produces a green colour	pH meter gives a reading of 8.9
D.	Forms a blue precipitate with hydroxide ions	pH meter gives a reading of 6.9

10 The complete combustion of one mole of ethanol releases 1367 kJ of energy and 88.02 grams of carbon dioxide.

How much energy and carbon dioxide are released by the complete combustion of one mole of methanol?

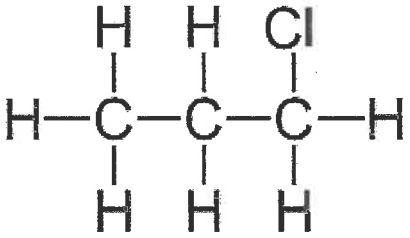
A. Less than 1367 kJ and less than 88.02 g of carbon dioxide

B. More than 1367 kJ and less than 88.02 g of carbon dioxide

C. Less than 1367 kJ and more than 88.02 g of carbon dioxide

D. More than 1367 kJ and more than 88.02 g of carbon dioxide

11 Consider the compound represented by the following formula.



This compound can be produced in both addition and substitution reactions using different inorganic reagents acting on different hydrocarbons.

Which identifies the inorganic reagents required to react with a suitable hydrocarbon to produce the above compound in both an addition reaction and a substitution reaction?

	Addition	*Substitution*
A.	Cl_2	HCl
B.	H_2	NaCl
C.	HCl	Cl_2
D.	NaCl	HCl

12 A sample of 0.010 mole of phosphorus pentachloride was placed in a 1.00 litre flask at 250°C. It dissociates according to the following equation:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

At equilibrium, the concentration of chlorine was found to be 0.008 mol L^{-1}.

What is the equilibrium constant for this reaction?

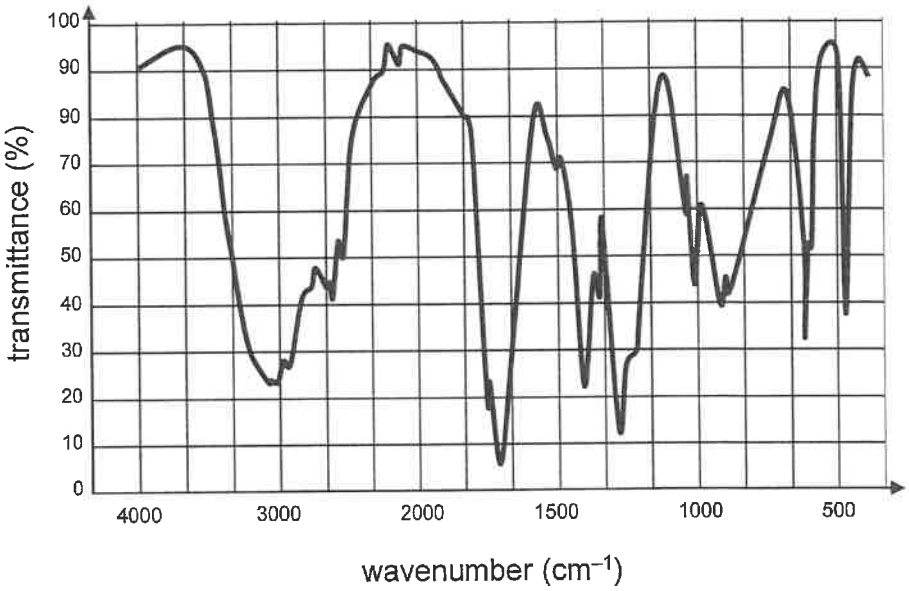
A. 0.002

B. 0.032

C. 0.061

D. 31.20

13 Examine the following infrared spectrum of an organic compound.



What can we reasonably determine by analysing this graph?

A. The compound is a carboxylic acid.

B. The compound is propanoic acid.

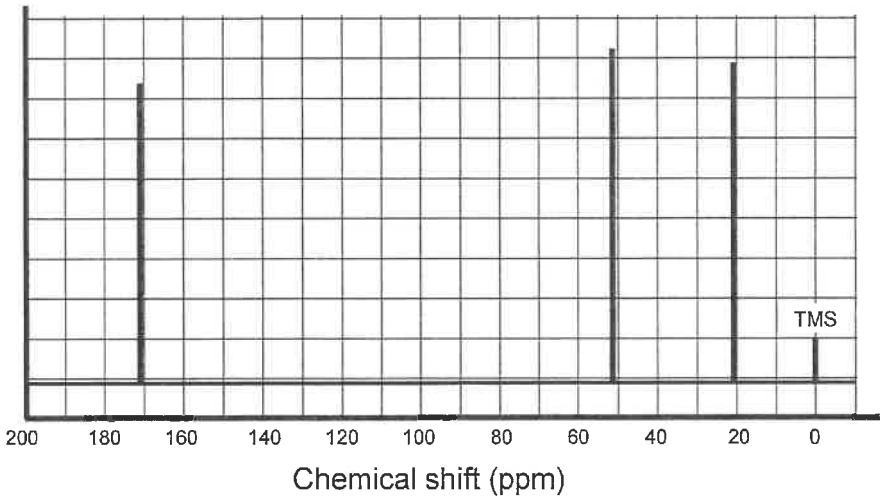
C. The compound is an alcohol.

D. The compound has a molecular mass greater than 3000.

14 Which of the following is correct about the laboratory production of alcohol by the process of fermentation?

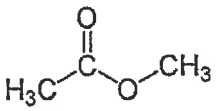
	Requires oxygen	*Produces oxygen*	*Endothermic or exothermic*	*Suitable temperature*
A.	Yes	No	Exothermic	60°C
B.	No	Yes	Exothermic	60°C
C.	No	No	Exothermic	30°C
D.	No	No	Endothermic	30°C

15 A carbon-13 NMR spectrum is shown below.

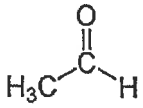


Which structural formulae best represents this spectrum?

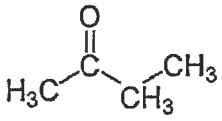
A.



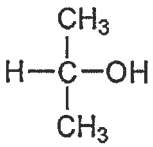
B.



C.



D.



16 At 25°C, solutions of silver ions (Ag^+) and sulfate ions (SO_4^{2-}) are mixed so that the following concentrations are initially present.

$[Ag^+]$	$[SO_4^{2-}]$
0.045 mol L^{-1}	0.020 mol L^{-1}

Which of the following identifies the correct ionic product and whether precipitation occurs for this reaction?

	Ionic Product (Q_{sp})	*Precipitation*
A.	1.09×10^{-5}	No
B.	4.05×10^{-5}	Yes
C.	4.05×10^{-5}	No
D.	9.00×10^{-4}	Yes

17 The enthalpy of neutralisation for an acid-base reaction is, $\Delta H = -57.6$ kJ mol^{-1}. 25.0 mL of a 0.200 mol L^{-1} solution of H_2SO_4 is mixed with 25.0 mL of a 0.200 mol L^{-1} solution of KOH. Both solutions are at a temperature of 20.0°C prior to mixing.

Which of the options below is closest to the increase in temperature of the mixture?

A. 1.38°C

B. 2.76°C

C. 21.4°C

D. 22.8°C

18 In a chemical reaction, a student uses 10 mL of 0.1 mol L^{-1} HCl to neutralise 10 mL of 0.1 mol L^{-1} NaOH.

What volume of 0.1 mol L^{-1} acetic acid, a weak acid, would it take to neutralise the same 10 mL of 0.1 mol L^{-1} NaOH?

A. Less than 10 mL

B. More than 10 mL

C. 10 mL

D. We need to know the K_a for acetic acid to determine this answer

19 At a certain temperature the K_a for the hydrogen sulfite ion, HSO_3^- is 6.2×10^{-8}.

Which of the values below is closest to the pH of a 0.100 mol L^{-1} solution of $NaHSO_3$?

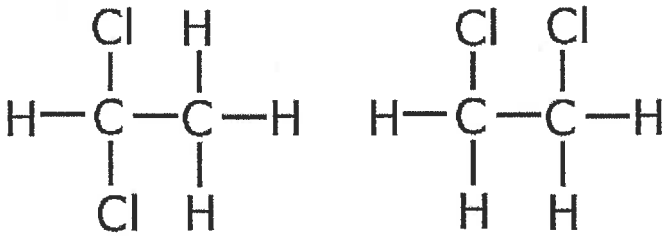
A. 7.2

B. 4.1

C. 3.6

D. 1.0

20 The structural formulae of two isomers are shown.



1,1-dichloroethane **1,2-dichloroethane**

Which of the following would show the clearest difference between these isomers?

A. Mass to charge ratio of their molecular ion

B. Functional group analysis using an infrared spectrum

C. Ultraviolet absorption at 173 nm

D. Chemical shift in a H-1 NMR spectrum

Section II

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

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

Show all relevant working in questions involving calculations.

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

Question 21 (4 marks) **Marks**

(a) Draw the structural formula of 3-methylpentan-2-ol. **1**

(b) Samples of a primary, a secondary and a tertiary alcohol were placed in separate test tubes. A small amount of acidified potassium permanganate was added to each test tube. Two of the test tubes showed a colour change, while the purple colour of the potassium permanganate remained unchanged in the third test tube. **3**

Explain these observations, identifying the organic products of any chemical reactions.

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Question 22 (4 marks) **Marks**

Vanadium is a metallic element, relatively rare in nature. It has become useful in emerging energy storage technologies, as the vanadium redox battery. This battery can offer almost unlimited energy capacity and may become a high demand product.

In 2019 it was proposed for vanadium to be mined, along with titanium and iron in the Murchison area, 740 km north of Perth. A processing plant would be located nearby.

(a) Indicate an advantage and a disadvantage of locating the vanadium processing plant near the mining site even though the mining site is in a remote area. **2**

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(b) Outline TWO environmental considerations relevant to the location of the vanadium processing plant at Murchison. **2**

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Question 23 (3 marks) **Marks**

A 1.0 litre flask at 420°C is filled with 1.5 mole of hydrogen gas and 1.0 mole of iodine gas. The flask is sealed and the following reaction takes place: **3**

$$H_2(g) + I_2(g) \rightarrow 2HI(g) \quad Keq = 54.0$$

Sometime later, the hydrogen gas concentration was measured to be 0.6 mol L^{-1} and the iodine gas concentration was measured to be 0.1 mol L^{-1}.

Calculate the hydrogen iodide gas concentration at this time and justify whether equilibrium has been achieved.

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Question 24 (4 marks) **Marks**

A student studies precipitation reactions involving different concentrations of potassium iodide, KI and lead nitrate, $Pb(NO_3)_2$ solutions. **4**

The student wonders if precipitation will occur when 100.0 mL of 0.001 mol L^{-1} KI is mixed with 100.0 mL of 0.001 mol L^{-1} $Pb(NO_3)_2$ at 25°C.

Write a balanced ionic equation for the chemical reaction, including states, and use calculations to determine whether a precipitate will occur when the two solutions are mixed.

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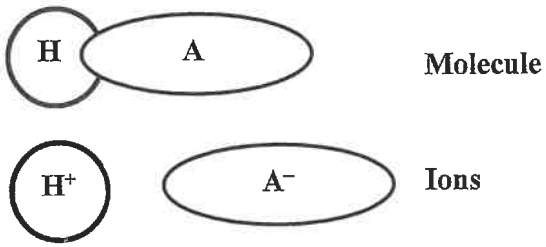
Question 25 (2 marks) **Marks**

The diagrams represent a monoprotic acid molecule, HA and the ions it forms in aqueous solution, H^+ and A^-. **2**



Sketch diagrams to show clear differences between a **strong, concentrated** acid in rectangle 1. and a **weak, dilute** acid in rectangle 2.

1. Strong, concentrated acid

2. Weak, dilute acid

Question 26 (4 marks) **Marks**

Analytical chemistry uses instruments and methods to separate, identify and quantify materials. **4**

Describe TWO significant reasons why scientists apply analytical techniques to monitor the environment. In your answer, outline TWO qualitative tests that could be used to detect the presence of a named ion in solution.

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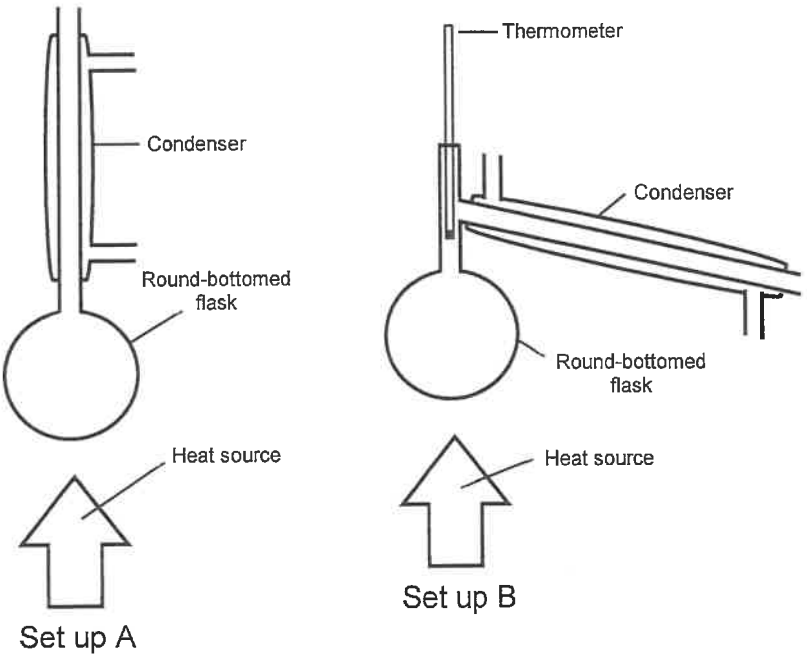
Question 27 (5 marks) **Marks**

The diagrams below show some of the equipment to produce and purify a sample of the ester, butyl acetate (butyl ethanoate).



(a) Write a balanced chemical equation to represent the production of butyl acetate. **1**

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(b) Explain the use of the equipment shown to produce a pure sample of butyl acetate. **4**

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Question 28 (5 marks) **Marks**

Sodium hydroxide (NaOH) is a solid that readily dissolves in water to form a basic solution. An excess amount of this compound is placed into 100 mL of distilled water. **5**

Write a chemical equation for the dissociation of sodium hydroxide in water and account for the way in which this compound undergoes dissolution by drawing a labelled diagram.

Equation:

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Labelled diagram:

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Question 29 (3 marks) **Marks**

While Indigenous Australians were not known to traditionally use the terms 'acid' and base', their use of natural materials indicated an understanding of some important properties of these compounds. **3**

Using a minimum of TWO specific examples, describe how Aboriginal and Torres Strait Islander peoples applied acid-base analysis techniques.

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Question 30 (4 marks) **Marks**

A 3.0 g sample of caustic soda pellets (sodium hydroxide) was dissolved in water and the volume of the solution was diluted to 3.0 L. A 25 mL sample of this solution was then added to 25 mL of 0.021 mol L^{-1} hydrochloric acid solution.

(a) Calculate the concentration of the original sodium hydroxide solution in mol L^{-1}. **1**

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(b) Determine the pH of the final solution. **3**

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STUDENT NUMBER/NAME: .....

Question 31 (3 marks) **Marks**

Nylons are a group of multipurpose synthetic plastics classified as condensation polymers. **3**

Identify the main functional groups contained in the monomers that join to form nylon and explain why nylons are classified as condensation polymers.

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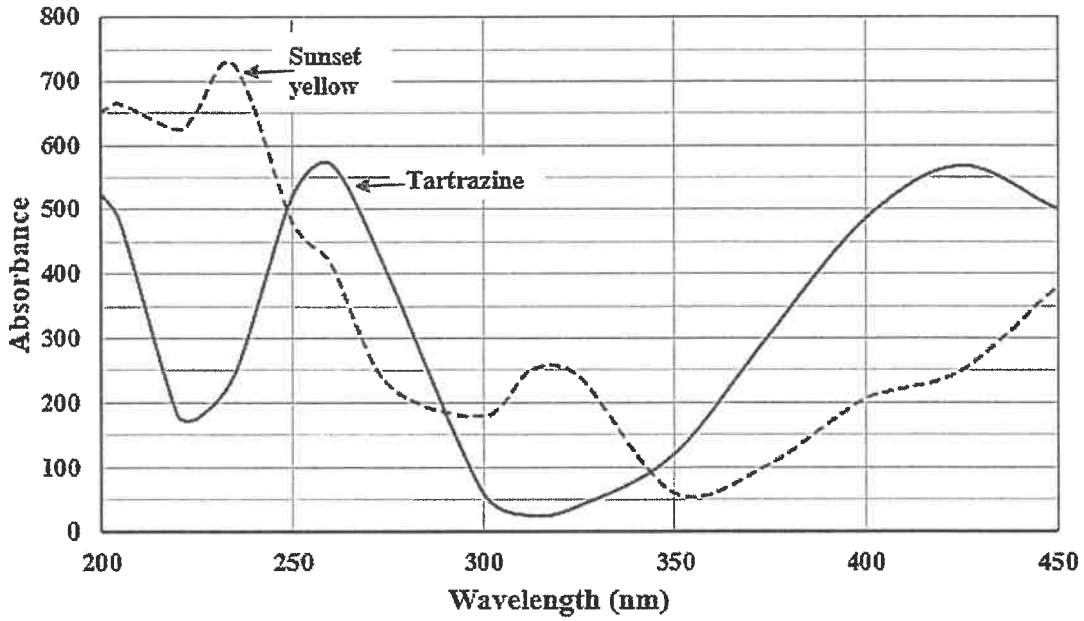
Question 32 (6 marks) **Marks**

Tartrazine and Sunset Yellow are synthetic, organic dyes mostly used as a yellow colouring in food additives. The ultraviolet spectrums of these two chemicals are shown below.



(a) What is the approximate difference between the highest absorbance peak of sunset yellow and the highest absorbance peak of tartrazine? **1**

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(b) Suggest a reason to explain why these two organic compounds have different UV spectra, even though they both have similar formulas and the same number of carbon atoms per molecule. **1**

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Question 32 continues on the next page

Question 32 (continued) **Marks**

(c) Explain why both these food dyes are seen as yellow coloured even though their spectra are in the ultraviolet range of the electromagnetic spectrum. **2**

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(d) Describe how the concentration of tartrazine or sunset yellow can be determined using colourimetry. **2**

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End of Question 32

Question 33 (10 marks) **Marks**

25.0 mL of 0.120 mol L^{-1} standardised sodium hydrogen carbonate, $NaHCO_3$ solution was titrated with nitric acid, HNO_3. The results are recorded in the following table.

Titration	*Volume of nitric acid used (mL)*
1	19.80
2	19.30
3	19.40
4	19.20

(a) Write a balanced equation for the reaction of sodium hydrogen carbonate with nitric acid. **1**

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(b) Calculate the concentration of the nitric acid. **2**

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Question 33 continues on the next page

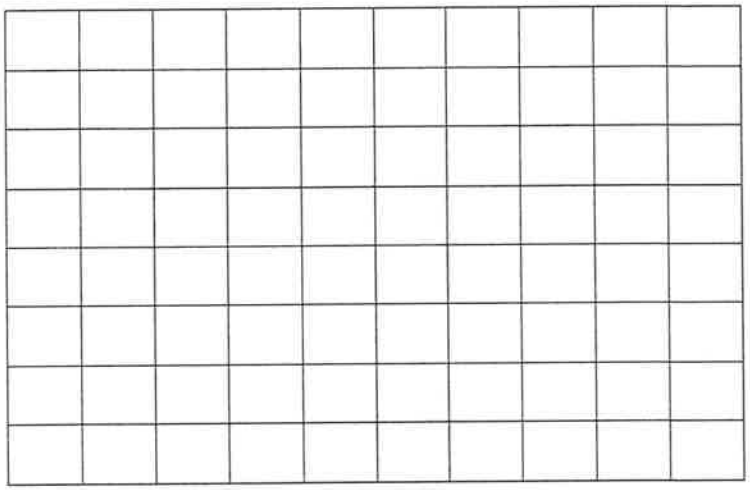
Question 33 (continued) **Marks**

(c) A student placed a pH probe in the sodium hydrogen carbonate solution and measured the change in pH during the titration, as the hydrochloric acid was added from a burette. **3**

The student recorded the following data.

HCl (mL)	20	30	40	45	53	55	60	70	80	90
pH	6.70	6.30	6.00	5.80	5.20	2.60	2.10	1.83	1.78	1.70

Plot this data on the grid below.



(d) Account for the shape of the graph. **2**

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Question 33 continues on the next page

Question 33 (continued) **Marks**

(e) Use at least ONE equation to explain why sodium hydrogen carbonate is considered a Bronsted-Lowry base, but not an Arrhenius base. **2**

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End of Question 33

Question 34 (8 marks) **Marks**

Hydrocarbons are an important resource used to meet many of society's needs. Their uses are greatly influenced by their physical and chemical properties.

(a) Explain THREE physical properties of saturated hydrocarbons in terms of intermolecular bonding. **3**

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(b) With the aid of chemical equations, explain the environmental, economic and sociocultural implications of obtaining and using hydrocarbons from the Earth. **5**

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Question 35 (7 marks) **Marks**

The Haber Process was first developed by the German chemist Fritz Haber in 1908 to manufacture ammonia (NH_3), a raw material used to make fertilisers and explosives. 7

The equation that represents the process is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92.4 \text{ kJ mol}^{-1}$$

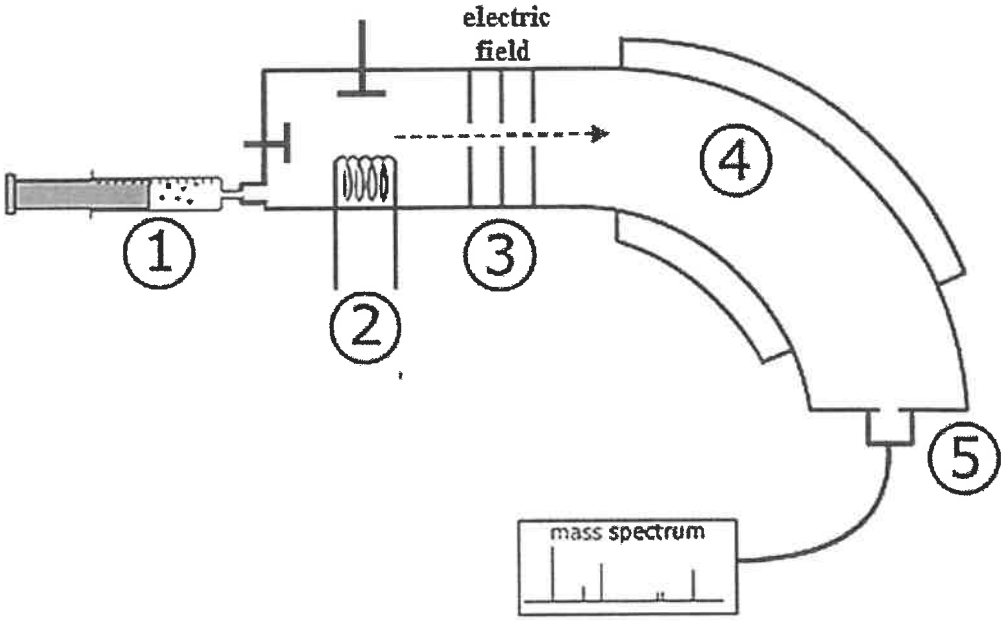
Explain the conditions that improve the yield of ammonia for this reaction.

Your answer should reference collision theory and heat of reaction.

STUDENT NUMBER/NAME: .....

Question 36 (8 marks) **Marks**

Explain the operation of a mass spectrometer using steps 1 to 5 in the diagram. Relate this information to the production of a mass spectrum and the identification of organic compounds. 8



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

Question 36 (continued)

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Section II extra writing space

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

NSW INDEPENDENT TRIAL EXAMS – 2021
CHEMISTRY TRIAL HSC EXAMINATION
MARKING GUIDELINES

Section I

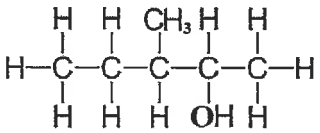
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	D	C	B	B	D	D	B	C	A	C	B	A	C	A	B	A	C	B	D

Section II

Question 21(a)

Criteria	Mark
• Provides a correct structural formula	1

Sample answer:



Question 21(b)

Criteria	Mark
• Thoroughly explains the observations in the THREE test tubes • Clearly identifies the TWO organic products of the reactions	3
• Explains the observations in at least TWO of the three test tubes • Identifies at least ONE of the organic products of the reactions	2
• Explains the observations in ONE of the three test tubes OR • Identifies ONE of the organic products of the reactions	1

Sample answer: Acidified potassium permanganate is a strong oxidising agent. The change in its purple colour indicates that the potassium permanganate has oxidised the organic contents in the test tube. Primary and secondary alcohols can be oxidised by acidified potassium permanganate, while tertiary alcohols cannot. Hence two of the test tubes (containing the primary and the secondary alcohols) showed a colour change while the third (containing the tertiary alcohol) remained unchanged in colour.

A primary alcohol oxidises to produce an alkanoic acid. A secondary alcohol oxidises to produce a ketone (alkanone).

Question 22(a)

Criteria	Mark
• Indicates a logical advantage and a logical disadvantage of locating the vanadium processing plant near the mining site even though the mining site is in a remote area	2
• Indicates a logical advantage or a logical disadvantage of locating the vanadium processing plant near the mining site even though the mining site is in a remote area	1

Sample answer: Vanadium is a relatively rare metal and so transporting the metal ore, along with a large amount of waste a long way to a processing plant, would not be economically viable. A disadvantage would be that being in a remote area, transport, workforce accommodation and other infrastructure would need to be constructed at a relatively high cost.

Question 22(b)

Criteria	Mark
• Outlines TWO environmental considerations relevant to the location of the vanadium processing plant at Murchison	2
• Outlines ONE environmental consideration relevant to the location of the vanadium processing plant at Murchison	1

Sample answer: Significant wastes and runoff containing metals and other chemicals, would need to be prevented from entering any local water systems. Any gaseous emissions from the processing plant would need to be monitored and filtered accordingly. Any disused mined areas would need to be rehabilitated.

Question 23

Criteria	Mark
• Calculates the correct concentration of HI(g) • Calculates the correct value of the equilibrium quotient • Justifies that equilibrium has been achieved	3
• Calculates a concentration of HI(g) • Calculates a value for the equilibrium quotient • Justifies if equilibrium has been achieved	2
• Calculates the correct concentration of HI(g) OR • Provides a correct method of calculating an equilibrium quotient	1

Sample answer: For $H_2(g) + I_2(g) \rightarrow 2HI(g)$

	$[H_2]$	$[I_2]$	$[HI]$
I	1.5	1.0	0.0
C	–0.9	–0.9	1.8
E	0.6	0.1	1.8

Therefore $[HI] = 1.8$ mol L^{-1} at equilibrium
Now $K_Q = [HI]^2/[H_2] \times [I_2] = (1.8)^2 / 0.6 \times 0.1 = 54.0$
Since $K_Q = Keq$ then equilibrium has been achieved

Question 24

Criteria	Mark
• Writes a correct ionic equation including states • Calculates the correct concentration of ions in the total solution • Calculates the correct solubility product quotient • Makes a correct prediction by comparing the Q_{sp} with the K_{sp}	4
• Writes a correct ionic equation • Uses some correct calculations • Makes a prediction by comparing the Q_{sp} with the K_{sp}	2–3
• Provides a prediction about whether a precipitation will occur based on a correct process	1

Sample answer:

$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$

$n\ I^- = c \times V = 0.001 \times 0.1 = 0.0001$

$n\ Pb^{2+} = c \times V = 0.001 \times 0.1 = 0.0001$

The two 100.0 mL solutions are mixed so that the new total volume is 200.0 mL

Hence $[I^-] = 0.0001/0.2 = 0.0005$ mol L^{-1} and $[Pb^{2+}] = 0.0001/0.2 = 0.0005$ mol L^{-1}

Now $Q_{sp} = [I^-]^2 \times [Pb^{2+}] = (0.0005)^2 \times (0.0005) = 1.25 \times 10^{-10}$

At 25°C the K_{sp} for lead II iodide is 9.8×10^{-9} (from data sheet)

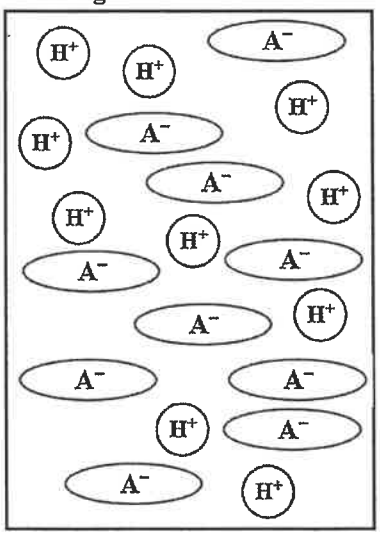
Since $Q_{sp} < K_{sp}$, no precipitate will form

Question 25

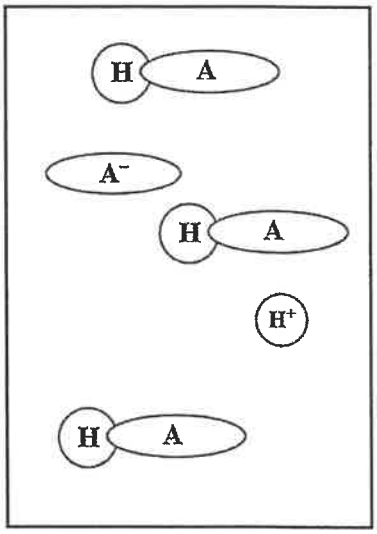
Criteria	Mark
• Draws appropriate diagrams that show many completely dissociated ions in diagram 1 and fewer and less dissociated ions in diagram 2	2
• Provides some information that shows a distinction between strong and weak acids OR between concentrated and dilute acids	1

Sample answer:

1. Strong and concentrated acid



2. Weak and dilute acid



Question 26

Criteria	Mark
• Describes TWO significant reasons why scientists apply analytical techniques to monitor the environment • Outlines TWO relevant qualitative tests that could be used to detect the presence of a named ion in solution	4
• Describes ONE or TWO significant reasons why scientists apply analytical techniques to monitor the environment • Outlines ONE or TWO relevant qualitative tests that could be used to detect the presence of a named ion in solution	2–3
• Provides some information about why scientists monitor the environment, relevant to a qualitative test, to detect the presence of an ion in solution	1

Sample answer: Scientists apply analytical techniques to monitor the environment to ensure that freshwater is suitable for plants and animals and drinking water is of a suitable quality for humans. This water must be monitored to ensure it is either free of toxic substances such as heavy metals or that they are below certain concentration limits. Scientists also monitor air quality to test for excessive levels of pollutants (e.g. carbon dioxide, nitrogen oxides and particulates) as they may cause respiratory difficulties and general health concerns in humans and other living things.

The presence of barium ions, Ba^{2+} can be detected in solution using a flame test. A sample of the solution is placed in a Bunsen burner flame. Barium ions are identified if a pale green (apple green) colour is observed. Barium ions can also be detected as they easily form a white precipitate with sulfate ions, SO_4^{2-}, provided carbonate ions and phosphate ions have first been eliminated.

Question 27(a)

Criteria	Mark
• Writes a correct and balanced chemical equation	1

Sample answer: $CH_3COOH + C_4H_9OH \rightleftharpoons CH_3COOC_4H_9 + H_2O$
OR $CH_3COOH + CH_3CH_2CH_2CH_2OH \rightleftharpoons CH_3COOCH_2CH_2CH_2CH_3 + H_2O$

Question 27(b)

Criteria	Mark
• Clearly explains the use of BOTH equipment set ups in term of reflux and distillation	4
• Explains the use of ONE of the equipment set ups and outlines the use of the other	3
• Outlines the use of BOTH equipment set ups OR • Explains the use of ONE of the equipment set ups	2
• Provides some relevant information about ONE or both of the set ups	1

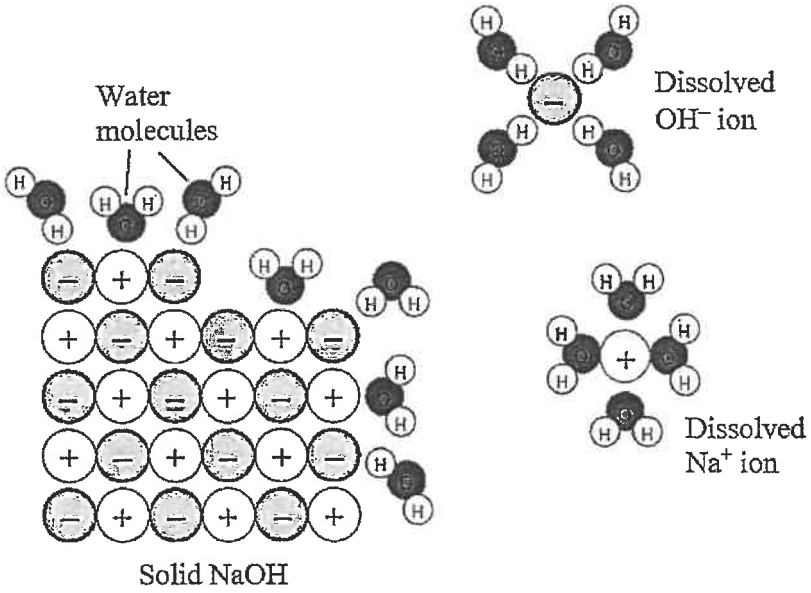
Sample answer: Equipment A is a reflux apparatus. It is used because esterification is a very slow reaction, so the reactants need to be heated to speed up the production of the ester. In addition, the reactants and the ester product are volatile and so would be quickly lost to evaporation if heated in an open container. The condenser is placed in a vertical position so that during heating, any vapours formed are cooled and condensed and then drip back into the reaction flask. Heating can therefore be continued over an extended period of time without the loss of reactants or of any product formed.

Over time, the esterification reaction establishes an equilibrium resulting in a mixture of both reactants and products in the reaction flask. To obtain a pure sample of the ester produced, it needs to be separated from the other contents in the equilibrium mixture. Equipment B is a distillation apparatus and can separate each substance present in the mixture based on its own specific boiling point. The thermometer records the temperature of the vapour passing into the condenser. Each compound's vapour is condensed from the mixture and removed in a separate container. In this way, a relatively pure sample of the ester can be obtained.

Question 28

Criteria	Mark
• Writes a correctly balanced equation • Accounts for the process of dissolution of NaOH in some detail • Provides a suitable and well-labelled diagram	5
• Writes a correctly balanced equation • Incomplete account of the process of dissolution of NaOH • Provides a suitable and labelled diagram	3–4
• Writes a correctly balanced equation and describes the process of dissolution of NaOH OR • Writes a correctly balanced equation and provides a suitable diagram OR • Describes the process of dissolution of NaOH and provides a suitable diagram	2
• Writes a correctly balanced equation OR describes a process of dissolution OR provides a suitable diagram	1

Sample answer: $NaOH(s) \rightleftharpoons Na^+(aq) + OH^-(aq)$



Sodium hydroxide (NaOH) is very soluble in water because it is an ionic compound and forms strong bonds with polar water molecules. The relatively negative side of several water molecules (O^- side) become attracted to the positive Na^+ ions and the relatively positive side of other water molecules (H^+ side) become attracted to the negative OH^- ions.

In this way, strong ion-dipole attractions occur and ionic bonds within the sodium hydroxide structure are broken. Ions are gradually removed from the solid and become stabilised as each ion is surrounded by a number of water molecules.

The solid NaOH dissociates into its respective independent cations and anions, Na^+ and OH^- until an equilibrium is formed.

Question 29

Criteria	Mark
• Uses TWO specific examples to describe how Aboriginal and Torres Strait Islander peoples applied relevant acid-base analysis techniques	3
• Uses TWO specific examples to describe how Aboriginal and Torres Strait Islander peoples applied relevant acid-base analysis techniques OR • Uses ONE specific example to describe how Aboriginal and Torres Strait Islander peoples applied relevant acid-base analysis techniques	2
• Provides some specific information about the use of an acid-base analysis technique by Aboriginal and Torres Strait Islander peoples	1

Sample answer: Many plants were used by Indigenous peoples to treat a variety of ailments from wounds and stings to tooth ache. In Queensland, Aboriginal peoples sometimes used the juice from chewed leaves of the hop-bush (*D. viscosa*) to put on stings caused by stingrays and stonefish etc. This juice has been analysed. It contains a large range of chemicals including some alkaline substances and shows analgesic (painkilling) and antibacterial properties.

Aboriginal and Torres Strait Islander peoples used ochres, not only as paint, but also for medicine and food preservation. The colours of ochre are due to iron oxides or iron hydroxides (bases) and white kaolin clay contains hydroxides of aluminium. Ochres could be applied to the skin or ingested to cure rashes and digestive infections. The alkaline compounds in ochre helped neutralise excess stomach acid and so it was used like a modern day antacid. Iron in these clays may have added an essential mineral, lacking in some diets.

Question 30(a)

Criteria	Mark
• Calculates the correct concentration of the sodium hydroxide solution in mol L^{-1}	1

Sample answer:
n NaOH = m/M = 3.0/(22.99 +16 + 1.008) = 0.075004
$\therefore$ [NaOH] = n/V = 0.075004/3 = 0.025 mol L^{-1}

Question 30(b)

Criteria	Mark
• Determines the correct pH of the final solution	3
• Uses correct processes to determine a final pH of the solution including an understanding of a limiting reagent	2
• Provides some correct processes to determine a final pH of the solution	1

Sample answer:
$NaOH + HCl \rightarrow NaCl + H_2O$
n NaOH = c × V= 0.025 × 0.025 = 6.25×10^{-4}
n HCl = c × V= 0.021 × 0.025 = 5.25×10^{-4} (limiting reagent)
$\therefore$ Excess mol NaOH = $(6.25 \times 10^{-4}) - (5.25 \times 10^{-4}) = 1.0 \times 10^{-4}$ in 50 mL
$\therefore$ [NaOH] = n/V = $1.0 \times 10^{-4}/0.05 = 2.0 \times 10^{-3}$
pOH = $-\log 2.0 \times 10^{-3} = 2.7$
$\therefore$ pH = 14 – 2.7 = 11.3

Question 31

Criteria	Mark
• Identifies the main functional groups in the monomers that join to form nylon • Explains why nylons are classified as condensation polymers	3
• Identifies the main functional groups in the monomers that join to form nylon OR • Explains why nylons are classified as condensation polymers	2
• Provides some relevant information about the structure of nylon	1

Sample answer: Nylon monomer units contain amine and carboxylic acid functional groups.

Polymers such as nylon are produced when many of these smaller monomer units join together to form long-chained molecules.

Condensation polymers are those in which a small molecule, usually water, is removed when each monomer unit is joined to the polymer chain.

When these units join to form a link between them water is produced and eliminated. Hence nylons are classified as condensation polymers.

Question 32(a)

Criteria	Mark
• Calculates the difference between the absorbance peaks within a margin of +/–10	1

Sample answer: Difference = 730 – 575 = 155

Question 32(b)

Criteria	Mark
• Suggests a logical reason to explain why these two organic compounds have different UV spectra based on their functional groups or structure	1

Sample answer: Organic compounds containing unsaturated functional groups absorb in the UV wavelength range. So, even though their formulae are similar, they each may have different numbers or types of unsaturated functional groups (e.g. –C=C–).

Question 32(c)

Criteria	Mark
• Explains why both these food dyes are seen as yellow coloured by referring to the visible part of the spectrum	2
• States a logical reason why both these food dyes are seen as yellow	1

Sample answer: Although both compounds absorb in the UV part of the spectrum, they also absorb the complimentary colour to yellow (blue-violet) in the visible part of the spectrum (400 to 700 nm). The colour not absorbed is yellow.

Question 32(d)

Criteria	Mark
• Describes how the concentration of ONE of these dyes can be determined using colourimetry	2
• Provides some relevant information about how the concentration of a dye is determined	1

Sample answer:

1. Using a UV spectrophotometer, a wavelength filter is selected that corresponds to a wavelength of light that is most strongly absorbed by the sample dye solution.
2. The absorbance of a series of 'standard' solutions is measured.
3. A calibration curve of absorbance versus concentration is drawn for the standard solutions.
4. The calibration curve is used to measure the eoncentration of the sample dye solution (accounting for any previous dilution).

Question 33(a)

Criteria	Mark
• Correctly writes a balanced equation for the reaction of sodium hydrogen carbonate with nitric acid	1

Sample answer: $NaHCO_3(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) + CO_2(g)$

Question 33(b)

Criteria	Mark
• Calculates the correct concentration of the nitric acid to three significant figures	2
• Calculates a concentration of nitric acid using some correct processes	1

Sample answer:

n $NaHCO_3$ = c × V = 0.12 × 0.025 = 0.003

∴ n HNO_3 = 0.003

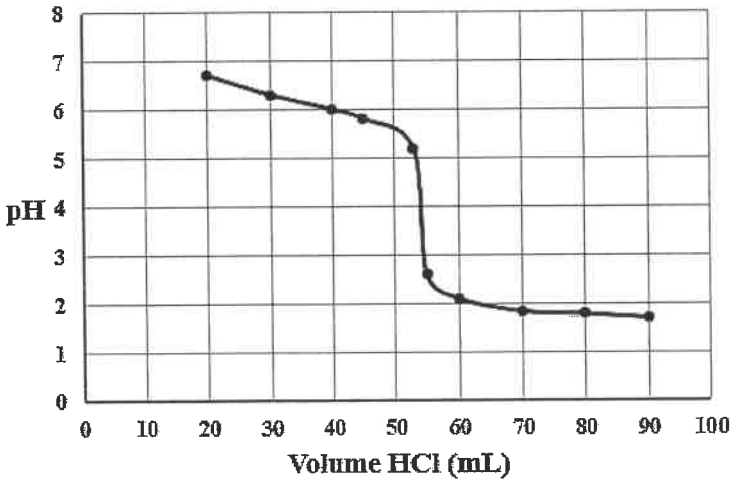
Av titre HNO_3 = (19.3 + 19.4 + 19.2)/3 = 19.3 mL

∴ $[HNO_3]$ = n/V = 0.003/0.0193 = 0.155 mol L^{-1} (to 3 significant figures)

Question 33(c)

Criteria	Mark
• Provides accurately plotted data • Scales are appropriate • Scales are appropriately labelled with names and units	3
• Provides accurately plotted data AND • Scales are appropriate OR • Scales are appropriately labelled with names and units	2
• A graph is plotted that shows some appropriate information	1

Sample answer:



Question 33(d)

Criteria	Mark
• Accounts for the shape of the graph	2
• Makes a correct statement that partly accounts for the shape of the graph	1

Sample answer: The shape of this graph is typical of the reaction between a strong acid and a weak base. The equivalence point is not neutral but occurs below pH = 7 because the CO_2 produced in the reaction dissolves in water and produces some H^+ ions.

The graph starts at pH just above 7 as $NaHCO_3$ is weakly alkaline. As more acid is added the pH decreases until at about the 54 mL mark, a steep decrease occurs as equivalence is reached. After this, as more acid is added, the pH again decreases, but less steeply as no further reaction takes place.

Question 33(e)

Criteria	Mark
• Explains why sodium hydrogen carbonate solution is a Bronsted-Lowry base but not an Arrhenius base • Explanation involves a relevant equation	2
• Explains why sodium hydrogen carbonate solution is a Bronsted-Lowry base but not an Arrhenius base	1

Sample answer: Sodium hydrogen carbonate can act as a Bronsted-Lowry base because in solution it dissociates to form hydrogen carbonate ions which can accept a proton from water to form an equilibrium.

$$NaHCO_3(s) \rightarrow Na^+(aq) + HCO_3^-(aq)$$
$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$

Arrhenius theory does not account for substances that do not contain hydroxide ions, OH^- in their formulas and do not ionise directly to form hydroxide ions.

Bronsted-Lowry can account for substances that do not contain OH^- in their formulas. Any ion that can accept a proton can be considered a base. This theory helps explain and why some salts, like $NaHCO_3$, are basic.

Question 34(a)

Criteria	Mark
• Explains at least THREE physical properties of saturated hydrocarbons in terms of intermolecular bonding	3
• Explains at least TWO physical properties of saturated hydrocarbons in terms of intermolecular bonding	2
• Explains a physical property of hydrocarbons in terms of intermolecular bonding	1

Sample answer: The molecules of saturated hydrocarbons are non-polar and so only weak dispersion forces exist between the molecules. These weak forces allow intermolecular bonds to be easily broken and result in these hydrocarbons having relatively low melting and boiling points. Small-chained molecules are therefore gaseous at room temperature. As chain length increases the strength of the dispersion forces increases, hence longer chained molecules can be liquids or soft solids at room temperature.

Saturated hydrocarbons are insoluble in water as the strong hydrogen bonding and dipole-dipole attraction between water molecules cannot be disrupted by attractions to the non-polar hydrocarbon molecules.

Question 34(b)

Criteria	Mark
• Provides an explanation that demonstrates an extensive understanding of a wide range of both positive and negative environmental, economic and sociocultural impacts of obtaining and using hydrocarbons from the Earth • Provides relevant and correctly balanced chemical equations	5
• Demonstrates a thorough understanding of a range of environmental, economic and sociocultural impacts of obtaining and using hydrocarbons from the Earth • Provides a relevant and correctly balanced chemical equation	4
• Demonstrates a sound understanding of a range of environmental, economic and/or sociocultural impacts of obtaining and using hydrocarbons from the Earth • Provides a relevant chemical equation	3
• Demonstrates a sound understanding of some environmental, economic and/or sociocultural impacts of obtaining and using hydrocarbons from the Earth	2
• Provides some relevant and correct information relating to the impacts of obtaining and using hydrocarbons	1

Sample answer: The obtaining and use of hydrocarbons from the Earth has had many positive and negative implications over time.

Economically it has improved the living standards in many countries around the world by providing a cheap and reliable resource for fuels for transport of people and goods, lubricants and for the production of many other materials and goods.

Hydrocarbons obtained from crude oil are used to produce ethylene which can then be used to produce a wide range of synthetic plastics (e.g., polyethylene) and other petrochemicals.

$$\underset{\text{ethylene}}{nCH_2 = CH_2} \longrightarrow \underset{\text{polyethylene}}{-[CH_2 - CH_2]_n-}$$

Hydrocarbons have also been used to produce refrigerants (e.g., CFC's) which has greatly benefited the transport and storage of food and medical supplies.

Negative economic impacts of hydrocarbon use include the huge cost to society of the health issues, environmental damage and sociocultural change that has been caused.

While some environmental impacts have been positive, many are negative.

Question 34(b) continues on the next page

Question 34(b) continued

Oils obtained from the Earth have reduced the need for oils from other sources such as whale oil, helping conserve whale populations. Oils for fuels reduce the need for land clearing to grow crops to produce alternative fuels such as ethanol.
When oils are combusted in air, CO_2 gas, an atmospheric greenhouse gas, is produced.

Example: $C_8H_{18} + 25/2O_2(g) \longrightarrow 8\ CO_2(g) + 9H_2O(l)$

Being a non-renewable resource, this release of CO_2 gas from the widespread use of oil fuels around the world is increasing in its concentration in the atmosphere, causing global warming and thus, having a negative impact on Earth's climate.

Combustion also greatly increases air pollution by releasing unburned hydrocarbons, soot and aiding the production of smog, ozone and acid rain.

Toxic effects from oil spills and waste disposal of hydrocarbon-based chemicals and materials are also a major problem.

CFCs are refrigerants produced using hydrocarbons which, when released into the atmosphere, release chlorine atoms and have a destructive effect on the stratospheric ozone layer which protects living things from solar UV radiation.

$$CF_2Cl_2 \longrightarrow CF_2Cl + Cl \qquad Cl + O_3 \longrightarrow O_2 + OCl$$

While the oil industry has supplied many people with employment, hydrocarbon use has had many negative sociocultural impacts, degrading traditional lands through pollution, increasing urbanisation with populations concentrating in cities, replacing many traditional materials and jobs, hence changing many cultural practices.

Question 35

Criteria	Mark
• Identifies that the reaction is an equilibrium involving gases • Accounts for any changes to the equilibrium by referring to Le Chatelier's Principle • Explains the impact of increasing the pressure on the system in terms of collision theory • Explains explains the impact of a change in temperature on the system in terms of heat of reaction or collision theory • Demonstrates the thorough use of scientific language	7
• Identifies that the reaction is an equilibrium involving gases • Accounts for any changes to the equilibrium by referring to Le Chatelier's Principle • Outlines the impact of increasing the pressure on the system in terms of collision theory • Outlines the impact of a change in temperature on the system in terms of heat of reaction or collision theory • Demonstrates the use of scientific language	5–6
• Identifies that the reaction is an equilibrium involving gases • Accounts for any changes to the equilibrium by referring to Le Chatelier's Principle AND • Outlines the impact of increasing the pressure on the system in terms of collision theory OR • Outlines the impact of a change in temperature on the system in terms of heat of reaction or collision theory	3–4
• Provides some correct information about the conditions that would have to be considered to improve the yield of ammonia for this reaction	1–2

Sample answer: The reaction involves gases and the double arrows for the equation indicate that it is an equilibrium reaction, so that it must be sustained in a closed system. Consequently, Le Chatelier's Principle can be used to help explain why a change in factors can affect an equilibrium so that it favours the production of more ammonia.

Collision theory dictates that higher temperatures in the system will increase the reaction rate as the reacting molecules will have more energy to collide, break bonds, and form the product. However, the process is exothermic in the forward direction and produces a significant amount of heat energy. A higher temperature would reduce the yield of the ammonia gas as, according to Le Chatelier's Theory it would drive the reaction in the reverse direction and produce a lower yield. Therefore, even though a higher temperature would increase the reaction rate, a lower, more moderate temperature would be a compromise to ensure both a reasonable yield and at a reasonable speed. A suitable catalyst could be used to lower the activation energy required and allow the equilibrium to be achieved more quickly and at a lower temperature.

A high gas pressure would increase the reaction rate because it would increase the concentration of all gases and provide more opportunity for the reacting gas molecules to collide. The high pressure forces the equilibrium to the right because there are relatively more gas particles on the left. Equilibrium is regained by a decrease in the number of gaseous molecules. Pressure and temperature must be monitored so that the yield of ammonia does not drop and the reaction vessel safety is maintained.

The ratio of reactant gases must be monitored to keep it at 3:1 because this is the ratio at which these gases react. If this ratio is not adhered to the rate of reaction may be slowed and/or the yield reduced.

Question 36

Criteria	Mark
• Identifies the function of a mass spectrometer • Explains the operation of a mass spectrometer using steps ONE–FIVE in the diagram • Provides a correct description of a mass spectrum • Outlines how the mass spectrum was obtained from the spectrometer • Outlines how a spectrometer and the mass spectrum can be used to identify an organic compound	**8**
• Identifies the function of a mass spectrometer • Outlines the operation of a mass spectrometer using at least FOUR of the steps in the diagram • Provides a correct description of a mass spectrum • Outlines how the mass spectrum was obtained from the spectrometer • Outlines how a spectrometer and the mass spectrum can be used to identify an organic compound	**6–7**
• Outlines the operation of a mass spectrometer using at least THREE of the steps in the diagram • Provides a correct description of a mass spectrum • States how the mass spectrum was obtained from the spectrometer • States how a spectrometer OR the mass spectrum can be used to identify an organic compound	**4–5**
• Outlines the operation of a mass spectrometer using at least TWO of the steps in the diagram • States how the mass spectrum was obtained from the spectrometer OR how a spectrometer can be used to identify an organic compound	**2–3**
• Provides some relevant information relating to the diagram and the identification of an organic compound	**1**

Sample answer: A mass spectrometer is an apparatus that measures the mass-to-charge ratio (m/z) of one or more molecules present in a sample. By doing this the exact molecular weight, identity and structure of a molecule can be determined.

Description and explanation of steps 1 to 5.

1. Injection	The sample is injected into the vaporisation chamber.
2. Ionisation	If the injected sample was not a vapour, it is vaporised. The sample is bombarded by electrons which come from a heated filament. The electrons run in a stream between the cathode and anode. When the sample passes through the electron stream, the high energy electrons in the stream knock electrons out of the sample to form ions.
3. Acceleration	The ions shoot out from the vacuum chamber into an electric field which makes them accelerate. The more highly charged ones are accelerated most.
4. Deflection	A magnetic field deflects lighter ions more than heavier ions. The ions split into a spectrum, with each different type of ion bent a different amount according to its mass and its electrical charge.
5. Detection	As the magnetic field is varied by a controller, ions with different masses are accurately detected and recorded.

Question 36 continues on the next page

Question 36 continued

In spectrometers, the magnetic field is slowly varied so each separate ion beam hits the detector in turn. A computerised, electrical detector records a spectrum pattern showing how many ions arrive for each mass/charge ratio. This can be used to identify the atoms or molecules in the original sample.

This data is represented graphically as a mass spectrum showing the relative abundance of all of the particles produced by the stream of electrons as well as their exact masses (compared to their charge). The mass spectrum is produced because electron bombardment causes molecules to break apart into fragments of ions. The most abundant ion fragment forms the 'base ion peak' but the most important abundance line is called the 'molecular ion' and is caused by the molecule itself losing only one electron before going to the detector. All other lines represent the abundance of various other fragments.

The mass to charge (m/z) value of the molecular ion can be measured to a high degree of accuracy and its mass is the same as the relative molecular mass of the molecule. For example – ethanoic acid:

m/z = 60.052 : 1
relative molecular mass = 60.052

This process can also be used to determine the exact number of each type of atom within the molecule. In addition, a careful analysis of the fragment ions provides information about the structure of the sample molecule. For example, a loss of a CH_3 fragment from an ethanoic acid molecular ion would produce a m/z of 45 which is equal to the mass of the $COOH^+$ ion. Consequently, if the general formula of a compound is known then obtaining its molecular mass from a mass spectrum can help deduce its identity.

Often, mass spectra are compared to a library of mass spectra to help determine the identity of a compound. In addition, other analytical techniques such as infrared spectrometry may also be used to determine a compound's identity.

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CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID

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

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MAPPING GRID

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section II				
21(a)	1	Mod 7 Nomenclature Mod 7 Alcohols	12-7, 12-14	2-3
21(b)	3	Mod 7 Alcohols	12-6, 12-7, 12-14	4
22(a)	2	Mod 8 Chemical synthesis and design	12-15	3
22(b)	2	Mod 8 Chemical synthesis and design	12-7, 12-15	2-3
23	3	Mod 5 Calculating the equilibrium constant	12-4, 12-5, 12-12	3-4
24	4	Mod 5 Solution equilibria	12-6, 12-12	3-5
25	2	Mod 6 Using Bronsted-Lowry Theory Mod 6 Quantitative analysis	12-4, 12-7, 12-13	4-5
26	4	Mod 8 Analysis of inorganic substances	12-2, 12-15	2-4
27(a)	1	Mod 7 Reactions of organic acids and bases	12-7, 12-14	4
27(b)	4	Mod 7 Reactions of organic acids and bases	12-2 ,12-7, 12-14	3-4
28	5	Mod 5 Solution equilibria	12-7, 12-12	3-5
29	3	Mod 6 Properties of acids and bases Mod 6 Quantitative analysis	12-7, 12-13	4-6
30(a)	1	Mod 6 Properties of acids and bases Mod 6 Using Bronsted-Lowry Theory	12-6, 12-13	3
30(b)	3	Mod 6 Using Bronsted-Lowry Theory	12-6, 12-13	4-6
31	3	Mod 7 Polymers	12-7, 12-14	4-5
32(a)	1	Mod 8 Analysis of inorganic substances	12-5, 12-15	2
32(b)	1	Mod 8 Analysis of inorganic substances	12-6, 12-15	4
32(c)	2	Mod 8 Analysis of inorganic substances	12-6, 12-7, 12-15	5
32(d)	2	Mod 8 Analysis of inorganic substances	12-2, 12-15	4-5
33(a)	1	Mod 6 Properties of acids and bases Mod 6 Quantitative analysis	12-7, 12-13	4-5
33(b)	2	Mod 6 Quantitative analysis	12-4, 12-6, 12-13	5
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