Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper

Total marks – 100

Section I Pages 2–28

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

- Attempt Questions 21–30
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29–39

25 marks

- Attempt ONE question from Questions 31–35
- Allow about 45 minutes for this section

Amendments and additional questions

Section I
75 marks

Part A – 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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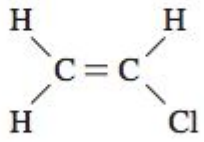
1 What is the name of this compound?



(A) Styrene

(B) Ethylene

(C) Chloroethane

(D) Vinyl chloride

2 Which row of the table correctly matches an ion with its flame colour during a flame test?

	Ion	*Flame colour*
A.	Barium	Orange-red
B.	Calcium	Blue-green
C.	Carbonate	Orange-red
D.	Copper	Blue-green

3 What is the molecular formula of pentanoic acid?

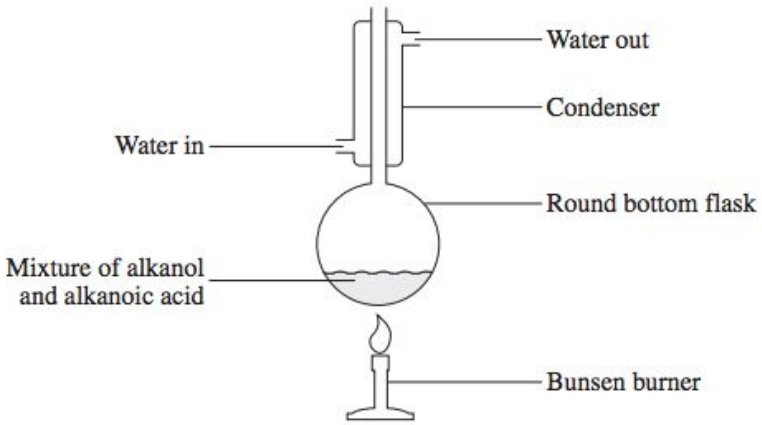
(A) C_5H_9O

(B) $C_5H_{10}O$

(C) $C_5H_{10}O_2$

(D) $C_5H_{11}O_2$

4 Esterification can be carried out in a school laboratory using the equipment shown.



How could the safety of the process shown be improved?

A. Place a stopper on top of the condenser.

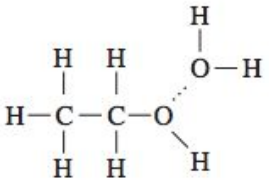
B. Add concentrated sulfuric acid to the flask.

C. Change the direction of water flow through the condenser.

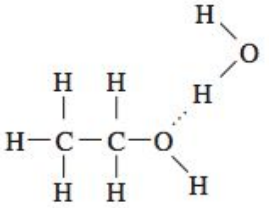
D. Replace the Bunsen burner with an electric heating mantle.

5 Which of the following diagrams best represents the bonding between molecules of water and ethanol?

(A)



(B)



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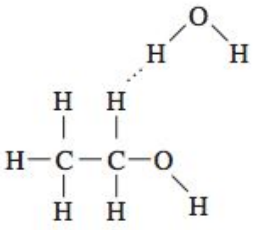
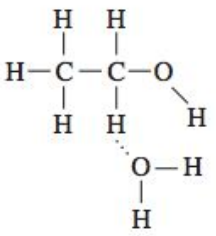


(D)



6 Which combination of equimolar solutions would produce the most basic mixture?

(A) Acetic acid and barium hydroxide

(B) Acetic acid and sodium carbonate

(C) Sulfuric acid and barium hydroxide

(D) Sulfuric acid and sodium carbonate

7 Which indicator in the table would be best for distinguishing between lemon juice (pH = 2.3) and potato juice (pH = 5.8)?

	Indicator	*Colour at different pH*	
(A)	Crystal violet	0.2 – yellow	1.8 – blue
(B)	Methyl orange	3.2 – red	4.4 – yellow
(C)	Bromothymol blue	6.0 – yellow	7.6 – blue
(D)	Phenolphthalein	8.2 – colourless	10.0 – pink

8 There are two unlabelled solutions. One is barium nitrate and the other lead nitrate.

Which of the following could be added to the two unlabelled solutions to distinguish between them?

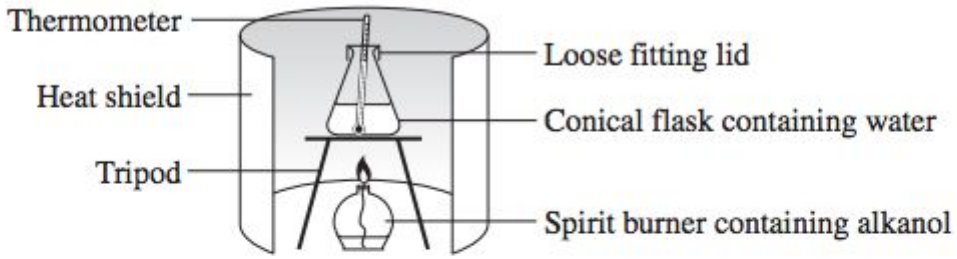
A. Sodium sulfate

B. Sodium nitrate

C. Sodium chloride

D. Sodium carbonate

9 The following equipment was set up to measure the heat of combustion of an alkanol.



Black deposits were observed on the bottom of the conical flask and the heat of combustion measured was lower than the theoretical value.

Which of the following equations could account for these observations?

A. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

B. $C_3H_8O(g) + 4O_2(g) \rightarrow CO_2(g) + CO(g) + 4H_2O(g)$

C. $2C_4H_{10}O(g) + 3O_2(g) \rightarrow 8C(s) + 2H_2(g) + 8H_2O(g)$

D. $2C_2H_6O(g) + 4O_2(g) \rightarrow 2CO_2(g) + 2C(s) + 6H_2O(g)$

10 Which of the following is the conjugate base of the $H_2PO_4^-$ ion?

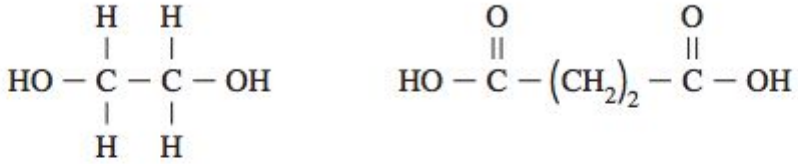
(A) H_3PO_4

(B) H_3PO_3

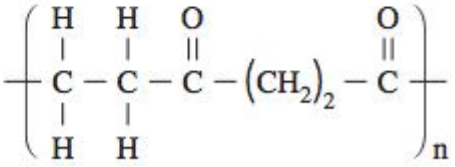
(C) HPO_4^{2-}

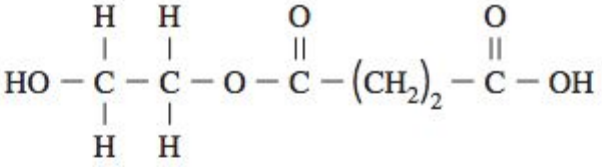
(D) HPO_3^{2-}

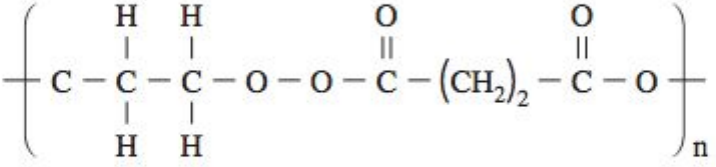
11 Two monomers are shown.

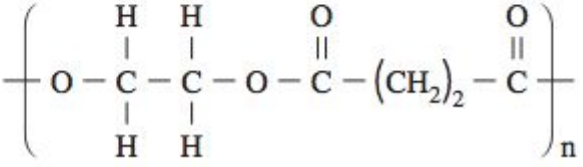


Which of the following shows a condensation polymer that could be formed from the monomers?

(A) 

(B) 

(C) 

(D) 

12 Which of the following could be added to 100 mL of 0.01 mol L^{-1} hydrochloric acid solution to change its pH to 4?

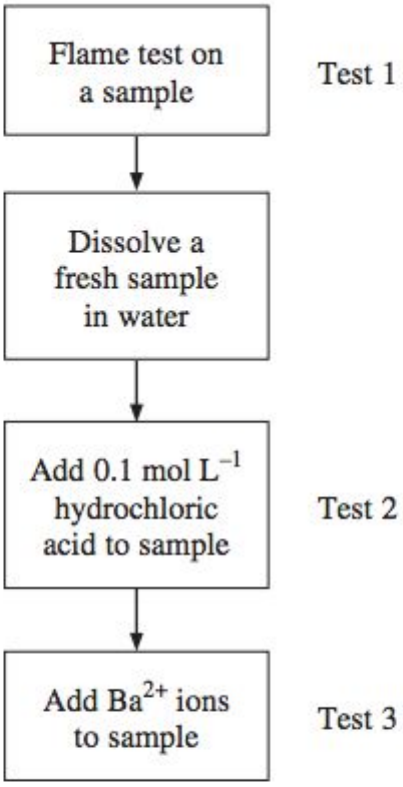
(A) 900 mL of water

(B) 900 mL of 0.01 mol L^{-1} hydrochloric acid

(C) 9900 mL of water

(D) 9900 mL of 0.01 mol L^{-1} hydrochloric acid

13 The flow chart shows the steps used to identify a sample of a substance.



If the substance is sodium sulfate, what should have been observed in Tests 1, 2 and 3?

	Test 1	*Test 2*	*Test 3*
(A)	Bright orange flame	No bubbles	White precipitate formed
(B)	Bright orange flame	Bubbles	No precipitate formed
(C)	Blue-green flame	No bubbles	No precipitate formed
(D)	Blue-green flame	Bubbles	White precipitate formed

14 One litre of an aqueous solution is formed from mixing equal volumes of 0.2 mol L^{-1} hydrochloric acid (HCl) and 0.2 mol L^{-1} sodium chloride (NaCl).

How effective as a buffer is the aqueous solution formed?

A. Ineffective, because HCl is a strong acid

B. Effective, because Cl^- is the conjugate base of HCl

C. Ineffective, because NaCl forms a neutral salt solution

D. Effective, because the pH would change when a solution of NaOH is added

15 The table lists some properties of the straight-chained carbon compounds *W*, *X*, *Y* and *Z*.

Compound	*Reactivity in bromine water*	*Solubility in water*
W	Rapidly decolourises	Insoluble
X	Unreactive	Insoluble
Y	Unreactive	Soluble
Z	Unreactive	Partly soluble

Which row of the following table best identifies the compounds *W*, *X*, *Y* and *Z*?

	W	*X*	*Y*	*Z*
(A)	C_3H_6	C_3H_8	CH_3OH	C_4H_9OH
(B)	C_3H_8	C_3H_6	CH_3OH	C_4H_9OH
(C)	C_3H_6	C_3H_8	C_4H_9OH	CH_3OH
(D)	C_3H_8	C_3H_6	C_4H_9OH	CH_3OH

16 The equation describes an equilibrium reaction occurring in a closed system.

$$X(g) + Y(g) \rightleftharpoons 4Z(g) \qquad \Delta H = +58 \text{ kJ}$$

Under which set of conditions would the highest yield of $Z(g)$ be obtained?

	Temperature (°C)	*Pressure* (kPa)
(A)	50	100
(B)	50	200
(C)	300	100
(D)	300	200

17 What volume of carbon dioxide will be produced if 10.3 g of glucose is fermented at 25°C and 100 kPa?

(A) 1.30 L

(B) 1.42 L

(C) 2.57 L

(D) 2.83 L

Use this information to answer Questions 18–19.

A sample of pond water from a contaminated site was analysed to determine the concentration of lead ions using the following procedure.

- A measuring cylinder was used to collect a 50 mL sample from the pond.
- The sample was placed in a clean dry beaker.
- 25.0 mL of 0.200 mol L^{-1} sodium chloride solution was added to the sample.
- The precipitate of lead(II) chloride that formed was filtered, dried and weighed. It had a mass of 0.13 g.

18 How could the reliability of the analysis of the pond water be improved?

(A) Analyse more samples from the same pond

(B) Use 50 mL of distilled water as a control sample

(C) Analyse samples from different ponds on the site

(D) Remove other contaminants from the sample before the analysis

19 What was the concentration of lead ions in the sample?

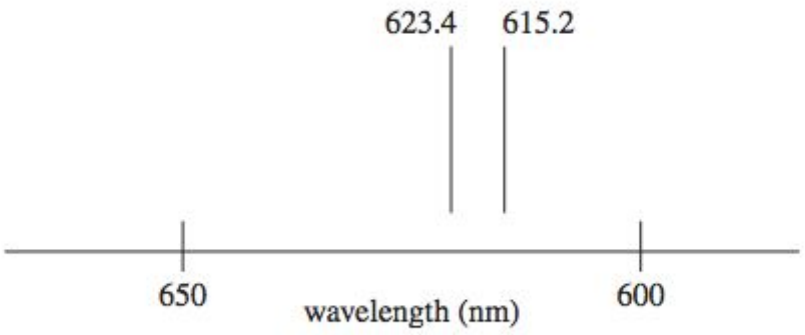
(A) 5.0×10^{-3} mol L^{-1}

(B) 5.8×10^{-3} mol L^{-1}

(C) 9.3×10^{-3} mol L^{-1}

(D) 10.7×10^{-3} mol L^{-1}

20 A section of the emission spectrum of a mercury lamp is shown.



Light at 623.4 nm and 615.2 nm from the mercury lamp was passed through a sample of water containing mercury, and the intensities were then measured by a detector.

I (x nm) = Intensity of light at a wavelength of x nm from the lamp
I_d (x nm) = Intensity of light at a wavelength of x nm at the detector

Which of the following pairs of intensities can be used in the determination of the amount of mercury in the water sample using atomic absorption spectroscopy (AAS)?

(A) I (615.2 nm) and I_d (615.2 nm)

(B) I (615.2 nm) and I_d (623.4 nm)

(C) I (615.2 nm) and I (623.4 nm)

(D) I_d (615.2 nm) and I_d (623.4 nm)

Chemistry

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–30
Allow about 1 hour and 40 minutes for this part

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 on pages 25–27. If you use this space, clearly indicate which question you are answering.

Write your Centre Number and Student Number at the top of this page.

Question 21 (4 marks)

(a) Outline a suitable method to prepare a natural indicator. **2**

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(b) How could a natural indicator be tested? **2**

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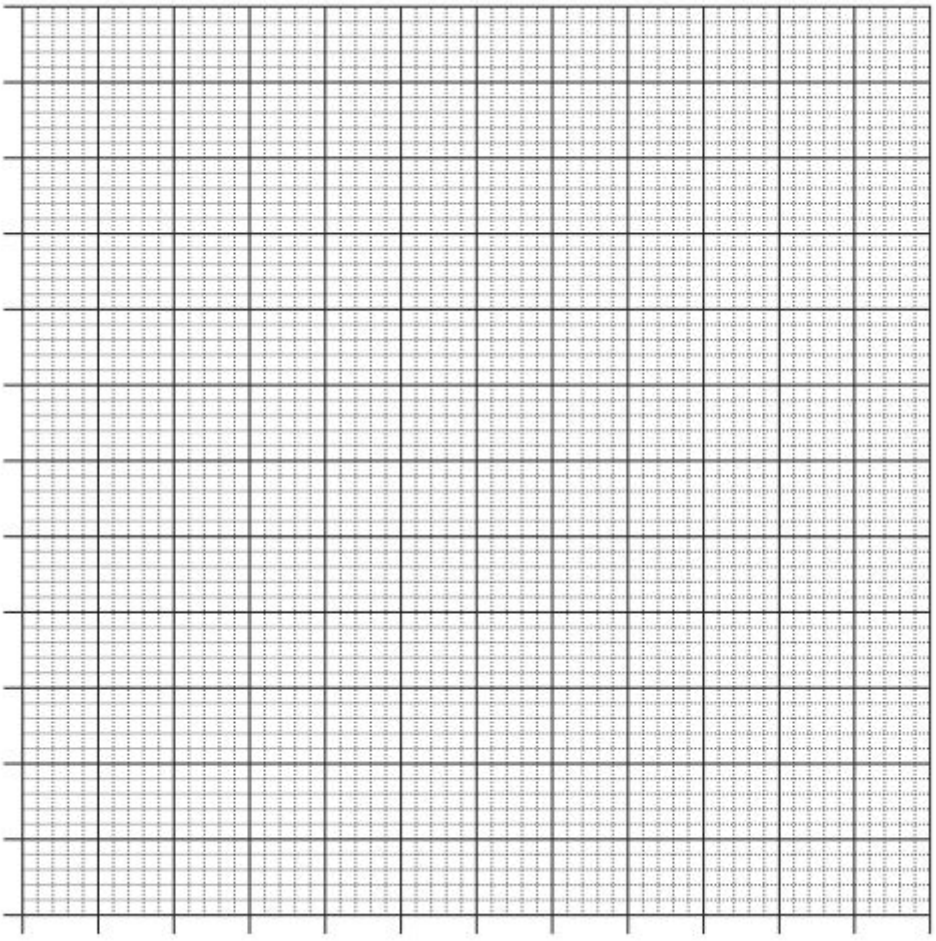
Question 22 (7 marks)

The table shows data for ozone concentrations over 50 years in the upper atmosphere above Antarctica.

Year	*Ozone Concentration* (Dobson Units)
1955	320
1960	300
1970	300
1980	260
1995	130
2000	130
2005	150

(a) Draw a line graph of the data on the grid provided. **4**



(b) Describe a method by which this data could have been measured. **3**

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End of Question 22

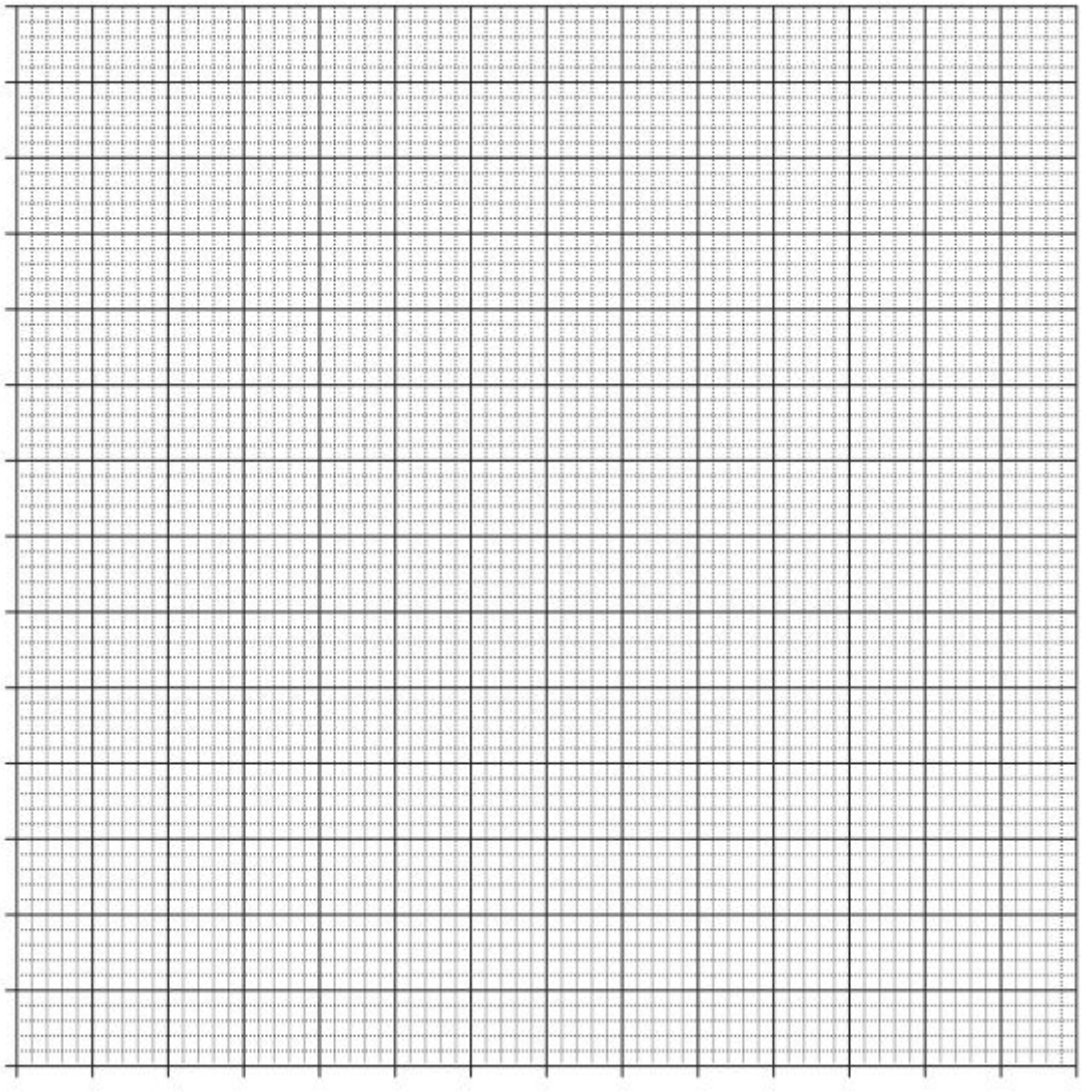
Question 23 (6 marks)

A spirit burner containing ethanol was used to heat water in a conical flask for three minutes to measure the molar heat of combustion of ethanol.

The results from the investigation are shown.

Time (min)	0	0.5	1.5	2.0	2.5	3.0	3.5	4.5	5.0
Temperature of water (°C)	18.5	20.5	25.0	27.0	29.5	31.0	30.5	28.5	27.5

(a) On the grid, draw a line graph to represent the data contained in the table. **3**



(b) The following values were also recorded during the investigation: **3**

Initial mass of spirit burner = 236.14 g

Final mass of spirit burner = 235.56 g

Calculated experimental molar heat of combustion of ethanol = –827 kJ mol^{-1}.

Using information from the previous page and the above values, determine the mass of water that was in the conical flask.

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End of Question 23

Question 24 (5 marks)

(a) Explain why the salt, sodium acetate, forms a basic solution when dissolved in water. Include an equation in your answer. **2**

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(b) A solution is prepared by using equal volumes and concentrations of acetic acid and sodium acetate. **3**

Explain how the pH of this solution would be affected by the addition of a small amount of sodium hydroxide solution. Include an equation in your answer.

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Question 25 (4 marks)

An unattended car is stationary with its engine running in a closed workshop. The workshop is 5.0 m × 5.0 m × 4.0 m and its volume is 1.0×10^5 L. The engine of the car is producing carbon monoxide in an incomplete combustion according to the following chemical equation: **4**

$$C_8H_{18}(l) + \tfrac{17}{2}O_2(g) \rightarrow 8CO(g) + 9H_2O(l)$$

Exposure to carbon monoxide at levels greater than 0.100 g L^{-1} of air can be dangerous to human health.

6.0 kg of octane was combusted by the car in this workshop.

Using the equation provided, determine if the level of carbon monoxide produced in the workshop would be dangerous to human health. Support your answer with relevant calculations.

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Question 26 (7 marks)

A sodium hydroxide solution was titrated against citric acid ($C_6H_8O_7$) which is triprotic.

(a) Draw the structural formula of citric acid (2–hydroxypropane–1,2,3–tricarboxylic acid). **1**

(b) How could a computer-based technology be used to identify the equivalence point of this titration? **2**

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(c) The sodium hydroxide solution was titrated against 25.0 mL samples of 0.100 mol L^{-1} citric acid. The average volume of sodium hydroxide used was 41.50 mL. **4**

Calculate the concentration of the sodium hydroxide solution.

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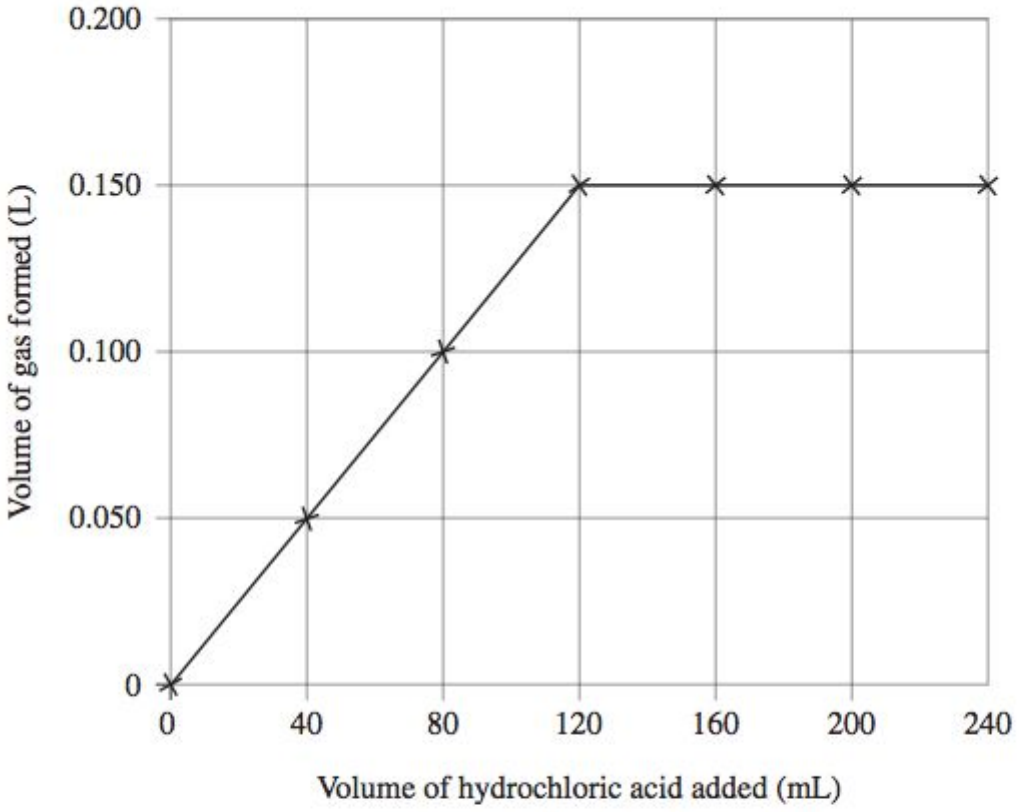
End of Question 26

Question 27 (4 marks)

The volume of gas formed at 25°C and 100 kPa as hydrochloric acid was added to a pure sample of aluminium is shown in the graph. **4**



Calculate the original mass of the aluminium sample used in the reaction.

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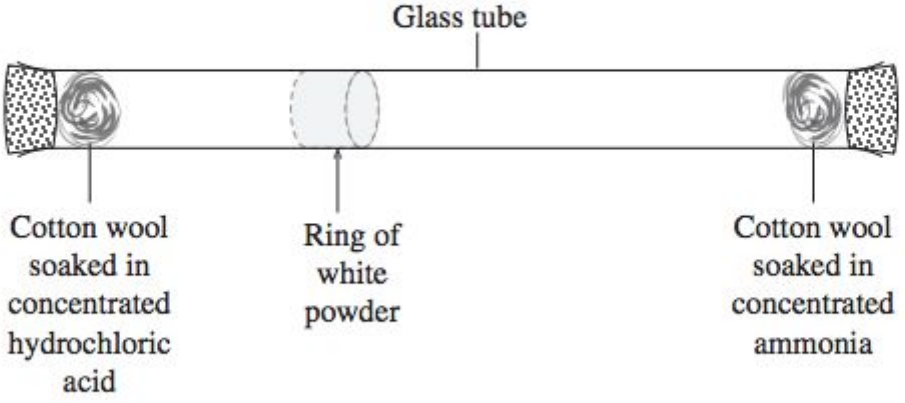
Question 28 (3 marks)

The equipment shown is set up. After some time a ring of white powder is seen to form on the inside of the glass tube.



(a) Why would this NOT be an acid–base reaction according to Arrhenius? **1**

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(b) Explain why this would be considered a Brönsted–Lowry acid–base reaction. Include an equation in your answer. **2**

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Question 29 (6 marks)

A solution of hydrochloric acid was standardised by titration against a sodium carbonate solution using the following procedure.

- All glassware was rinsed correctly to remove possible contaminants.
- Hydrochloric acid was placed in the burette.
- 25.0 mL of sodium carbonate solution was pipetted into the conical flask.

The titration was performed and the hydrochloric acid was found to be 0.200 mol L^{-1}.

(a) Identify the substance used to rinse the conical flask and justify your answer. **2**

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(b) Seashells contain a mixture of carbonate compounds. The standardised hydrochloric acid was used to determine the percentage by mass of carbonate in a seashell using the following procedure. **4**

- A 0.145 g sample of the seashell was placed in a conical flask.
- 50.0 mL of the standardised hydrochloric acid was added to the conical flask.
- At the completion of the reaction, the mixture in the conical flask was titrated with 0.250 mol L^{-1} sodium hydroxide.

The volume of sodium hydroxide used in the titration was 29.5 mL.

Calculate the percentage by mass of carbonate in the sample of the seashell.

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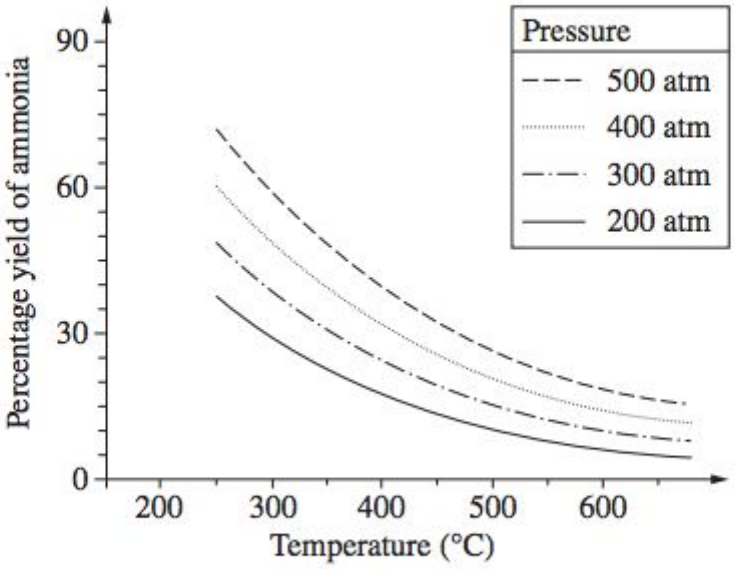
Question 30 (6 marks)

The graph shows the percentage yield of ammonia produced from nitrogen and hydrogen at different temperatures and pressures. **6**



The Haber process is the main industrial procedure for the production of ammonia. Explain the conditions used in the Haber process with reference to the graph.

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Question 31

(c) (i) Methane and water vapour react to form carbon monoxide and hydrogen in a closed container as shown. **3**

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206 \text{ kJ}$$

Compare the impact on the equilibrium system of a decrease in volume of the container to the impact of a decrease in temperature. Refer to the equilibrium constant in your answer.

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(ii) Solid ammonium hydrogen sulfide (NH_4HS) decomposes to form ammonia gas and hydrogen sulfide gas (H_2S). **4**

2.00 moles of ammonium hydrogen sulfide were placed in a sealed 3.00 L container and the system was allowed to reach equilibrium. At equilibrium, there were 0.0328 moles of ammonia gas.

Calculate the equilibrium constant for this reaction.

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Question 32 (6 marks)

In order to find the sulfate content of a lawn fertiliser, a student weighed out some fertiliser in a beaker and mixed it with 100 mL of 1 molar hydrochloric acid. She heated the mixture to boiling while stirring, then filtered the mixture rinsing the residue with small quantities of water. Next she added barium chloride solution to the filtrate until no more precipitate formed. She filtered the precipitate using a pre-weighed filter paper, then rinsed the residue in the filter paper with a few millilitres of water. She placed the filter paper with the precipitate into a drying oven overnight, then weighed them.

Here are her results:

Mass of beaker (g)	108.45
Mass of the beaker plus fertiliser (g)	112.45
Mass of filter paper (g)	0.97
Mass of filter paper plus precipitate (g)	6.61

(a) Explain with the help of equations the reason for adding hydrochloric acid. **2**

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(b) The molar mass of barium sulfate is 233.4 g mol^{-1}. Calculate the mass percentage of sulfate in this fertiliser. **4**

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Question 33 (5 marks)

"According to the work of Davy and Arrhenius on the theory of acids, all acids contain hydrogen atoms. However, there are many compounds which contain hydrogen atoms which are not classified as acids".

Use the following examples to explain this statement:

- Methane, CH_4
- Ethanoic acid, CH_3COOH
- Hydrogen chloride, HCl (g)

Relate your answer to the bonding of the hydrogen atoms in the THREE compounds. **5**

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Question 34 (2 marks)

Explain why esters have lower boiling points than alcohols or acids of the same molecular mass. **2**

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Question 35 (5 marks)

(a) Identify a heavy metal that can be found in the environment due to pollution. **1**

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(b) Explain the effects of this heavy metal on the environment. **2**

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(c) Explain why analytical laboratories now use atomic absorbance spectroscopy (AAS) rather than precipitation reactions for identification and measurement of lead (II) ions in water samples. **2**

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END OF PAPER

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Multiple Choice Answer Sheet

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

ANSWERS

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

QUESTION 21

Question 21 (a)

Criteria	Marks
• Correctly outlines all steps	2
• Identifies some steps	1

Sample answer:

- Collect some coloured plant material such as red cabbage. Select the coloured parts and cut into small pieces
- Place them in a beaker with water and boil until the water becomes coloured
- Cool mixture
- Decant the liquid into a container, leaving the solid behind.

Question 21 (b)

Criteria	Marks
• Outlines a suitable activity using a natural indicator to show the different colours in acidic and basic solutions	2
• Identifies a suitable activity for testing a natural indicator	1

Sample answer:

Add some of the indicator to separate test tubes of a known acid and base.

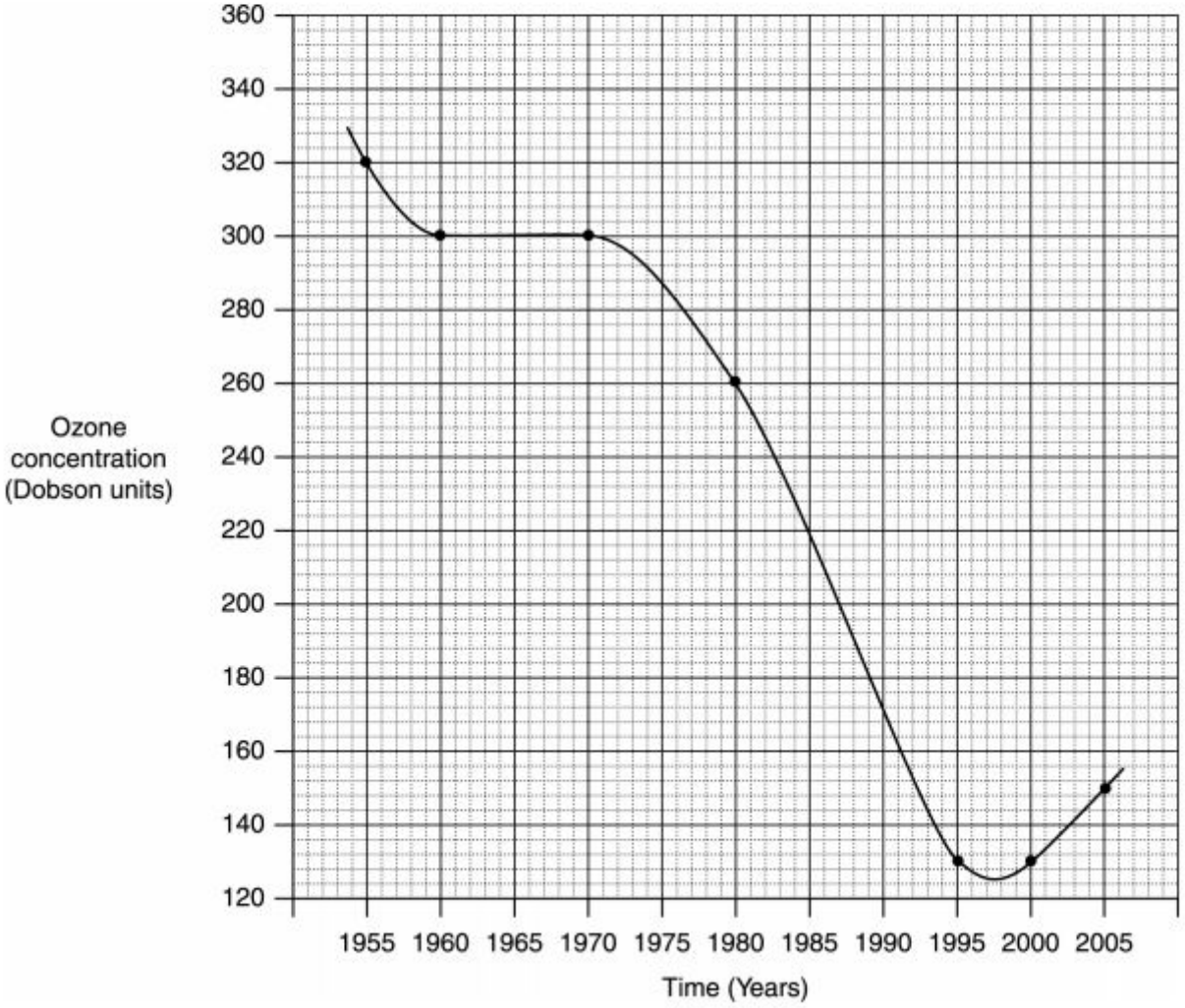
Record the natural indicator colour in the acid and base.

QUESTION 22

Question 22 (a)

Criteria	Marks
• Provides a correct graph that includes labelled axes, units, appropriate scales, plotted points and a smooth line of best fit	4
• Provides a substantially correct graph	3
• Provides a graph that includes a scale	2
• Provides some relevant information	1

Sample answer:



Question 22 (b)

Criteria	Marks
• Describes how a ground-based technique or instrument launched into the upper atmosphere can be used to measure ozone levels	3
• Outlines an instrument and/or a technique that can be used to measure ozone levels	2
• Identifies an instrument or a technique that can be used to measure ozone levels	1

Sample answer:

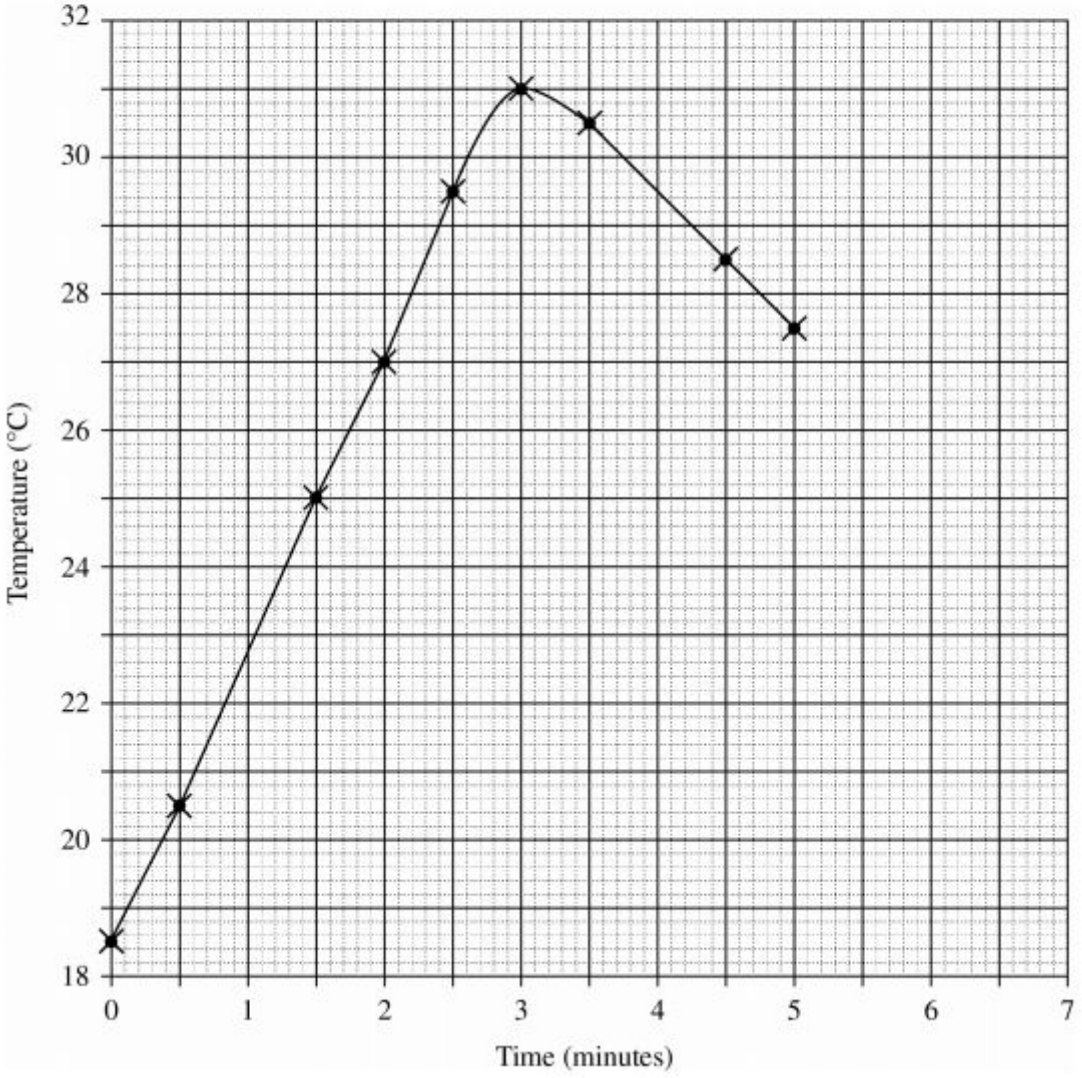
The information could be measured by a ground-based UV spectrophotometer. This analyses UV light intensity at a wavelength at which ozone absorbs, and compares the intensity to a nearby wavelength of UV that ozone does not absorb. The amount of absorption by ozone provides information about ozone concentrations. Similar measurements over time allow ozone concentrations to be monitored.

QUESTION 23

Question 23 (a)

Criteria	Marks
• Labels axes appropriately • Provides correct units • Plots data correctly • Draws curve of best fit	3
• Provides a substantially correct graph	2
• Provides a partially correct graph	1

Sample answer:



Question 23 (b)

Criteria	Marks
• Provides a correct answer with relevant working and includes appropriate unit (sig figs not required)	3
• Provides a correct answer without units OR • Provides a substantially correct answer	2
• Includes a correct step	1

Sample answer:

From graph, $\triangle T = 31.0 - 18.5 = 12.5°C$

Mass of ethanol burnt = 236.14 – 235.56 = 0.58 g

$$\text{moles ethanol} = \frac{m}{M} = \frac{0.58}{(2\times 12.01 + 6\times 1.008 + 16.00)} = 0.0126\,\text{mol}$$

$$\text{energy released} = n \times 827 = 0.0126 \times 827 = 10.420\,\text{kJ}$$
$$= 10420\,\text{J}$$

$$\triangle H = mC\triangle T \quad m = \frac{\triangle H}{C\triangle T} = \frac{10420}{4.18\times 10^3 \times 12.5}$$
$$= 0.199\,\text{kg}$$

QUESTION 24

Question 24 (a)

Criteria	Marks
• Recognises that the salt produces hydroxide ions and relates this to the formation of a basic solution • Includes a relevant equation	2
• Recognises that hydroxide ions are produced OR • Includes a relevant equation	1

Sample answer:

$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

The presence of OH^- ions produced by the hydrolysis of CH_3COO^- increases the pH of the solution and results in a basic pH.

Question 24 (b)

Criteria	Marks
• Explains how an increase in $[OH^-]$ will affect the reaction • Relates to minimal change in pH • Includes a relevant equation	3
• Provides some explanation and/or description of how the pH would be affected • Links the reaction of OH^- to the equilibrium reaction	2
• Provides some relevant information	1

Sample answer:

$CH_3COO^-(aq) + H_3O^+(aq) \rightleftharpoons CH_3COOH(aq) + H_2O(l)$

The addition of OH^- ions will cause reaction with H_3O^+ ions, reducing their concentration in the equilibrium mixture. This will force the reaction to the left to increase the $[H_3O^+]$, thus minimising the change in pH.

QUESTION 25

Question 25

Criteria	Marks
• Justifies whether the level of CO is dangerous with relevant calculations (sig figs not required)	4
• Provides a substantially correct CO level and calculations OR • Provides a correct CO level and justification but no working	3
• Provides some correct steps in the calculation of CO level	2
• Provides some relevant information	1

Sample answer:

Volume of garage is 1.0×10^5 L = 100000 L

6.0 kg octane = 6000 g $n = \frac{m}{M} = \frac{6000}{114.224} = 52.53$ moles

Molar ratio from equation is 1 : 8 $\therefore 8 \times 52.53$ moles of carbon monoxide are produced = 420.23 moles.

$m = n \times M = 420.23 \times 28.01 = 11771$ g

$[CO] = \frac{11771}{100000} = 0.118 \text{ g L}^{-1}$

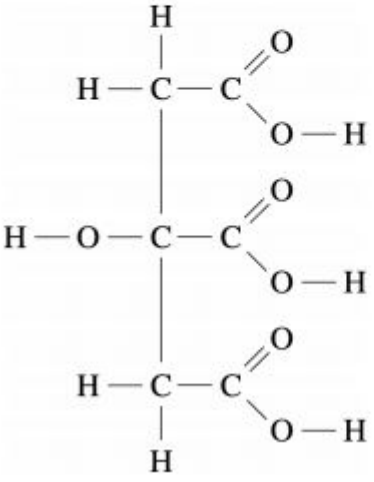
Therefore the level of carbon monoxide is dangerous as it is more than 0.100 g L^{-1}.

QUESTION 26

Question 26 (a)

Criteria	Marks
• Draws a correct structural formula for citric acid	1

Sample answer:



Question 26 (b)

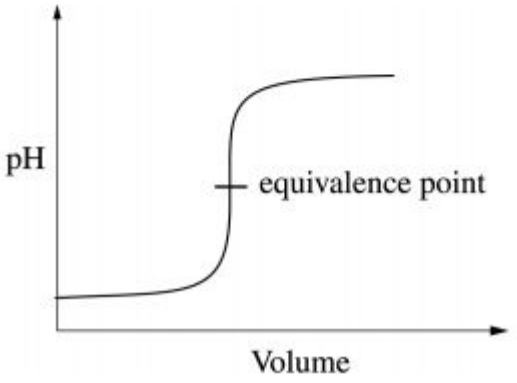
Criteria	Marks
• Outlines how a computer-based technology could be used to identify the equivalence point	2
• Provides some relevant information	1

Sample answer:

A digital pH probe was used to collect appropriate data to plot a graph of pH vs volume of sodium hydroxide.

The equivalence point was identified from the graph obtained from the data collected by the pH probe.

Answer could include:



Question 26 (c)

Criteria	Marks
• Correctly calculates the concentration of sodium hydroxide • States answer to three significant figures	4
• Correctly calculates the concentration of sodium hydroxide	3
• Applies correct steps to calculate the concentration of the sodium hydroxide solution OR • Correctly calculates moles of citric acid and moles of sodium hydroxide with correct equation	2
• Substitutes into a relevant formula OR • Provides a relevant equation OR • Shows a basic understanding of the calculation required	1

Sample answer:

$n = cV = 0.100 \times 0.0250$
Moles citric acid = 0.00250

$C_6H_8O_7 + 3NaOH \rightarrow C_6H_5O_7Na_3 + 3H_2O$

41.50 mL NaOH must contain 3×0.00250 moles
= 0.00750 moles

$$c = \frac{n}{V} = \frac{0.00750}{0.04150} = 0.18072$$

$= 0.181 \text{ mol } L^{-1}$ (3 significant figures)

QUESTION 27

Question 27

Criteria	Marks
• Provides correct answer with THREE significant figures	4
• Provides correct answer with incorrect significant figures OR • Provides substantially correct answer with THREE significant figures	3
• Provides some relevant steps	2
• Provides a relevant step	1

Sample answer:

$$Al + 3HCl \rightarrow AlCl_3 + \frac{3}{2}H_2$$

$$\text{Moles gas} = \frac{0.150}{24.79} = 6.05 \times 10^{-3}\ \text{mol}\ H_2\ \text{gas}$$

$$H_2{:}Al = \frac{3}{2}:1 \quad \therefore \frac{2}{3} \times 6.05 \times 10^{-3}\ \text{mol Al}$$

$$\text{Mass Al} = n \times M = \frac{2}{3} \times 6.05 \times 10^{-3} \times 26.98 = 0.109\ \text{g (3 sig figs)}$$

2Al + 6HCl --> 2AlCl3 + 3H2

Moles of gas = 0.150/24.79 = 0.00605083
H2:Al = 1.5:1 ratio
Therefore - 0.00605083 / 1.5 = 0.00403389
Mass of Al = n x M
= 0.00403389 x 26.98
= 0.10883426 = 0.109 (3 sig fig)

QUESTION 28

Question 28 (a)

Criteria	Marks
• Correctly shows why this would not be considered an Arrhenius acid-base reaction	1

Sample answer:

This reaction does not occur in aqueous solution.

Question 28 (b)

Criteria	Marks
• Provides a valid reason • Includes a relevant equation	2
• Provides some relevant information	1

Sample answer:

It involves proton transfer.

$HCl(g) + NH_3(g) \rightarrow NH_4^+ + Cl^-$

QUESTION 29

Question 29 (a)

Criteria	Marks
• Provides correct reason and substance used	2
• Provides correct substance	1

Sample answer:

Water should be used to rinse the conical flask as this will not change the number of moles of Na_2CO_3 placed in it.

Question 29 (b)

Criteria	Marks
• Provides correct answer with relevant working	4
• Provides a substantially correct answer with relevant working	3
• Provides some relevant steps	2
• Provides a relevant step	1

Sample answer:

$HCl + NaOH \rightarrow H_2O + NaCl$

$n(NaOH) = cV$

$= 0.250 \times 0.0295$

$= 7.375 \times 10^{-3}$ $\therefore n(HCl) = 7.375 \times 10^{-3}$ after reaction with seashell

$$\begin{aligned} \text{Original HCl} &= cV \\ &= 0.200 \times 0.0500 = 0.0100 \text{ moles} \\ \therefore \text{HCl used} &= 0.0100 - 7.375 \times 10^{-3} \\ &= 2.625 \times 10^{-3} \text{ moles used} \end{aligned}$$

$2HCl + CO_3^{2-} \rightarrow H_2O + CO_2 + 2Cl^-$

$HCl : CO_3^{2-} = 2 : 1$

$$\therefore n\,CO_3^{2-} = \frac{2.625 \times 10^{-3}}{2}$$

$$= 1.3125 \times 10^{-3}$$

$$m = 1.3125 \times 10^{-3} \times 60.01$$

$$= 0.07876 \text{ g}$$

$$= \frac{0.07876 \text{ g}}{0.145 \text{ g}} \times 100\% = 54.3\%.$$

QUESTION 30

Question 30

Criteria	Marks
• Relates the conditions used in the Haber process to yield and rate considerations and Le Chatelier's principle • Relates information in the graph to these conditions • Provides a logical response with no extraneous information	6
• Links conditions used in the Haber process to yield, rate and Le Chatelier's principle • Links the graph to temperature and pressure	5
• Links conditions used in the Haber process to yield/rate and Le Chatelier's principle • Refers to the graph	4
• Links conditions used in the Haber process to Le Chatelier's principle and/or yield and/or rate and/or the graph	3
• Identifies condition(s) used in the Haber process and/or yield and/or rate and/or the graph and/or feature(s) of Le Chatelier's principle	2
• Provides some relevant information	1

Sample answer:

In the Haber process, ammonia is produced from nitrogen and hydrogen in the following exothermic reaction.

$N_2(g) + 3H_2(g) \quad 2NH_3(g) \quad \Delta H = -92$ kJ

Being exothermic, yield is increased by lowering the temperature of the reaction mixture, which would drive the reaction to the right, as according to Le Chatelier's principle, the reaction would be favoured that produced heat. On the graph, this is clearly shown, as for each pressure, the yield increased at lower temperatures. Maximum yield could be obtained at very low temperatures, however, the rate of ammonia formation would be compromised at low temperatures, hence, in the Haber process, a temperature of about 450°C is used. This produces an acceptable yield. A catalyst of Fe_3O_4 is used to maintain an acceptable rate of reaction at this low industrial temperature. In the reaction above, there is a 4:2 ratio of gaseous reactants to products, so higher pressures will drive the reaction to the right to reduce moles of gas, which reduces the pressure. Ideally as shown on the graph, extreme pressures would increase the yield. However, in the Haber process, the cost of maintaining high-pressure reaction vessels is prohibitive, so a pressure of 300 atm is used which is an acceptable compromise.

QUESTION 31

Question 31 (c) (i)

Criteria	Marks
• Links pressure and temperature changes correctly to change in equilibrium position • Identifies impact on K value	3
• Relates changes in equilibrium to Le Chatelier's principle	2
• Provides some relevant information	1

Sample answer:

Decrease in volume (causes increase in pressure)	*Decrease in temperature*
• System adjusts to decrease pressure by Le Chatelier's principle • Equilibrium moves to reactant side as less moles of gas will reduce pressure • No change to K when equilibrium re-established	• Systems adjusts to increase temperature by Le Chatelier's principle • Equilibrium moves to reactant side to produce more heat • K will be lower when the new equilibrium is established

Question 31 (c) (ii)

Criteria	Marks
• Provides correct answer and working (significant figures not required)	4
• Provides substantially correct answer with working	3
• Provides some relevant steps	2
• Provides a relevant step	1

Sample answer:

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

$$n\ NH_3 = 0.0328 = n\ H_2S$$

$$[NH_3] = [H_2S] = \frac{0.0328}{3}$$

$$= 0.0109$$

$$K = [NH_3][H_2S]$$

$$= 0.0109 \times 0.0109$$

$$= 1.20 \times 10^{-4}$$

QUESTION 32

QUESTION 34 a

Criteria	Marks
• Explains fully • Writes at least two correct equations	2
• Explains fully • OR • Writes an explanation that demonstrates some understanding • Writes one correct equation	1

Sample answer

The acid can remove other cations (carbonate, hydroxide and phosphate) which, if present in the fertiliser, would precipitate with the barium. (In high enough concentration soluble barium hydroxide becomes insoluble.)

$2H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

$2H^+_{(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow H_2PO_4^-{}_{(aq)}$

QUESTION 34 b

Criteria	Marks
• Correctly calculates mass of fertiliser • Correctly calculates mass of barium sulfate precipitate • Correctly calculates number of moles of barium sulfate • Correctly calculates mass of sulfate • Correctly calculates mass percentage of sulfate	4
• Four of the above	3
• Three of the above	2
• Two of the above	1

Sample answer

mass of fertiliser = 112.45 - 108.45 = 4.00 g

mass of barium sulfate precipitate = 6.61 - 0.97 = 5.64 g

number of moles of barium sulfate = n/MM = 5.64/233.4 = 0.0242 mol

mass of sulfate (SO_4^{2-}) = n x MM = 0.0242 x (32.06 + 4 x 16.00) = 2.32 g

mass % of sulfate = mass of sulfate x 100/mass of fertiliser = 2.32 x 100/4.00 = 58%

QUESTION 33

Outcomes Assessed: H2, H6, H8 *Targeted Performance Bands: 2-6*

Criteria	Marks
• Thorough explanation of the statement using the THREE examples in the explanation AND • Correctly relates the classification of acids to the polarity of bonding of hydrogen atoms	5
• Sound explanation of the statement using the THREE examples in the explanation (methane and hydrogen chloride are gases) AND • Correctly links acidic properties to the polarity of bonding of hydrogen atoms	3-4
• Some correct information about classification of the THREE examples (identifies acetic acid as a weak acid) OR • Correctly links acidic properties to the polarity of bonding of hydrogen atoms	1-2

Sample answer

The Lowry-Brönsted theory defines acids as proton donors. As a result, only those compounds containing hydrogen atoms which are bonded to an electronegative element can potentially be classified as acids. The bond between hydrogen and the electronegative atom must be sufficiently polar for the hydrogen to be donated as a proton (H^+) to the electron pair of a base and hence for the substance to be classified as an acid by the Lowry-Brönsted theory.

Methane contains 4 hydrogen atoms but these are not acidic, in that the bonds to the central carbon are non-polar (since carbon and hydrogen have identical electronegativity) – so methane is not classified as an acid.

Ethanoic acid has 3 hydrogen atoms (those bonded in the methyl $-CH_3$ group) which are not acidic because these bonds are non-polar, as in methane. However, the O–H bond in ethanoic acid (part of the -COOH carboxylic acid functional group) is polar, with the electrons in the bond attracted to the very electronegative oxygen atom. This hydrogen atom can be lost as a proton, so ethanoic acid is classified as a monoprotic acid, in that it can lose 1 of its 4 hydrogens.

Hydrogen chloride gas is also classified as a Lowry-Brönsted acid, as it is capable of donating a proton, even in the gaseous state. The H–Cl bond is polar, with the electrons attracted strongly to the electronegative chlorine atom. The hydrogen is lost as H^+ to a base, such as ammonia – so hydrogen chloride is classified as an acid.

QUESTION 34

Question 24 (2 marks)

Outcomes Assessed: H9 ***Targeted Performance Bands: 3-5***

Criteria	Marks
• Correct explanation in terms of intermolecular forces in esters AND alcohols OR acids	2
• Some correct information about the intermolecular forces in esters OR alcohols OR acids	1

Sample answer

Esters are polar molecules but they do not have hydrogen bonding (only weaker dipole-dipole forces) between neighbouring molecules. Alcohols and acids have stronger hydrogen bonding between neighbouring molecules. Hence if esters, alcohols and acids of the same (or similar) molecular mass are heated, the esters will boil at lower boiling points than alcohols and acids, as less energy needs to be applied to separate the molecules and change the state.

QUESTION 35

28 (a) (1 mark)

Outcomes Assessed: H11, H13 ***Targeted Performance Bands: 3-5***

Criteria	Marks
• Correct identification of a heavy metal	1

Sample answer

Heavy metals are metals of high atomic weight that are toxic to humans in relatively low concentrations.

Heavy metals include the transition metals, plus lead and the semi-metal arsenic. The heavy metals that are of concern because of their detrimental health effects are mercury, lead, cadmium, chromium and arsenic.

28 (b) (2 marks)

Outcomes Assessed: H11, H13 ***Targeted Performance Bands: 3-5***

Criteria	Marks
• Two effects OR One effect and a consequence	2
• One effect Or a consequence	1

Sample answer

Contamination of water supplies and natural waterways by mercury, lead, cadmium, chromium and arsenic are of concern because of their detrimental health effects on humans and animals. Many metal ions (like mercury) bioaccumulate and can pass up the food chain.

Lead is a poison. It retards intellectual development in children, causes brain damage and can lead to neurological disorders. Lead can cause neurological disorders even in low concentrations.

Mercury is a serious pollutant of water due to its toxic and bio-accumulative properties. It damages the nervous system and can cause death of fish and other animals up the food chain who depend on fish for their diets. Unborn children are most at risk of nervous disorders if their mothers eat contaminated fish. In aquatic systems, mercury is often converted by bacteria to methylmercury (the organic form of mercury) which can be magnified up the aquatic food chain hundreds of thousands of times, posing a potential risk to humans and wildlife that consume fish.