VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2014

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER									Letter

CHEMISTRY

Written examination

Tuesday 11 November 2014

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	12	12	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 45 pages.
- A data book.
- Answer sheet for multiple-choice questions.

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Use the following information to answer Questions 1 and 2.

Hydrogen is produced on an industrial scale from methane. The equation for the reaction is

$$2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

Question 1

The expression for the equilibrium constant for the reverse reaction is

A. $K = \frac{[H_2O]^2\ [CH_4]}{[H_2]^4\ [CO_2]}$

B. $K = \frac{[H_2]^4\ [CO_2]}{[H_2O]^2\ [CH_4]}$

C. $K = \frac{[H_2O]\ [CH_4]}{[H_2]\ [CO_2]}$

D. $K = \frac{4[H_2]\ [CO_2]}{2[H_2O]\ [CH_4]}$

Question 2

If an inert gas is added to the equilibrium system at a constant temperature and a constant volume, the concentration of hydrogen will

A. increase.

B. decrease.

C. not change.

D. decrease then increase.

Question 3

Which one of the following statements about 10.0 mL of 0.10 M HCl and 10.0 mL of 0.10 M CH_3COOH solutions is true?

A. Each solution will have the same electrical conductivity.

B. Each solution will react completely with 10.0 mL of 0.10 M NaOH solution.

C. Each solution will react at the same rate with 1.00 g of magnesium ribbon.

D. The concentration of H_3O^+ ions will be greater in the CH_3COOH solution.

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Question 4

If Solution X has a pH of 3 and Solution Y has a pH of 6, we can conclude that

A. $[H^+]$ in Solution X is 1000 times that of $[H^+]$ in Solution Y.

B. $[H^+]$ in Solution X is half that of $[H^+]$ in Solution Y.

C. $[OH^-]$ in Solution Y is twice that of $[OH^-]$ in Solution X.

D. Solution Y must contain a stronger acid than Solution X.

Question 5

The pH of the following acid solutions was measured using a pH meter.

Solution	Volume	Concentration
nitrous acid	10.0 mL	0.10 M
ethanoic acid	20.0 mL	0.10 M
hypobromous acid	5.0 mL	0.10 M
hypochlorous acid	5.0 mL	0.10 M

The acid solution that will have the lowest pH is

A. nitrous acid.

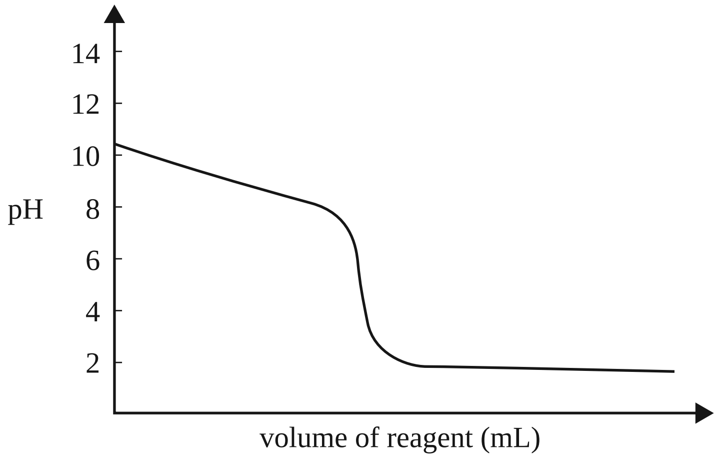
B. ethanoic acid.

C. hypobromous acid.

D. hypochlorous acid.

Question 6

The diagram below represents the titration curve for the reaction between a particular acid and a particular base.



The equation that best represents the reaction described by the titration curve is

A. $HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$

B. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

C. $CH_3COOH(aq) + NH_3(aq) \rightarrow CH_3COONH_4(aq)$

D. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

Question 7

What volume of 0.25 M hydrochloric acid is required to react completely with 40 mL of 0.50 M calcium hydroxide?

A. 40 mL

B. 80 mL

C. 120 mL

D. 160 mL

Question 8

When hydrochloric acid is added to aluminium sulfide, the highly toxic gas hydrogen sulfide is evolved. The equation for this reaction is

$$Al_2S_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2S(g)$$

If excess hydrochloric acid is added to 0.200 mol of aluminium sulfide, then the volume of hydrogen sulfide produced at standard laboratory conditions (SLC) will be

A. 1.63 L

B. 4.90 L

C. 7.35 L

D. 14.7 L

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Question 9

An aerosol can with a volume of 300.0 mL contains 2.80 g of propane gas as a propellant. The warning label says the aerosol may explode at temperatures above 60.0 °C.

What is the pressure in the can at a temperature of 60.0 °C?

A. 5.87×10^{-1} kPa

B. 1.06×10^{2} kPa

C. 5.87×10^{2} kPa

D. 2.58×10^{4} kPa

Question 10

Which one of the reactions of hydrochloric acid below is a redox reaction?

A. $2HCl(aq) + Fe(s) \rightarrow H_2(g) + FeCl_2(aq)$

B. $2HCl(aq) + Na_2S(s) \rightarrow H_2S(g) + 2NaCl(aq)$

C. $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$

D. $2HCl(aq) + K_2CO_3(s) \rightarrow CO_2(g) + 2KCl(aq) + H_2O(l)$

Question 11

Consider the following unbalanced ionic equation.

$$Hg(l) + Cr_2O_7^{2-}(aq) + H^+(aq) \rightarrow Hg^{2+}(aq) + Cr^{3+}(aq) + H_2O(l)$$

When this equation is completely balanced, the coefficient of Hg(l) will be

A. 1

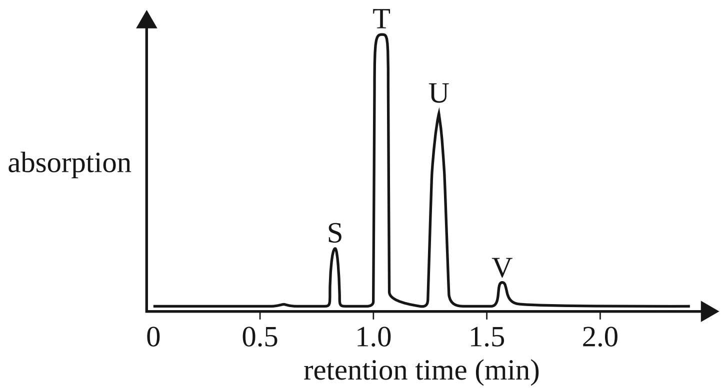
B. 2

C. 3

D. 4

Use the following information to answer Questions 12 and 13.

Four straight chain alkanols, S, T, U, V, with a general formula ROH, were analysed using a gas chromatograph combined with a mass spectrometer. The following chromatogram was produced.



Question 12

What is the order of the alkanols from the highest molar mass to the lowest molar mass?

A. V, U, T, S

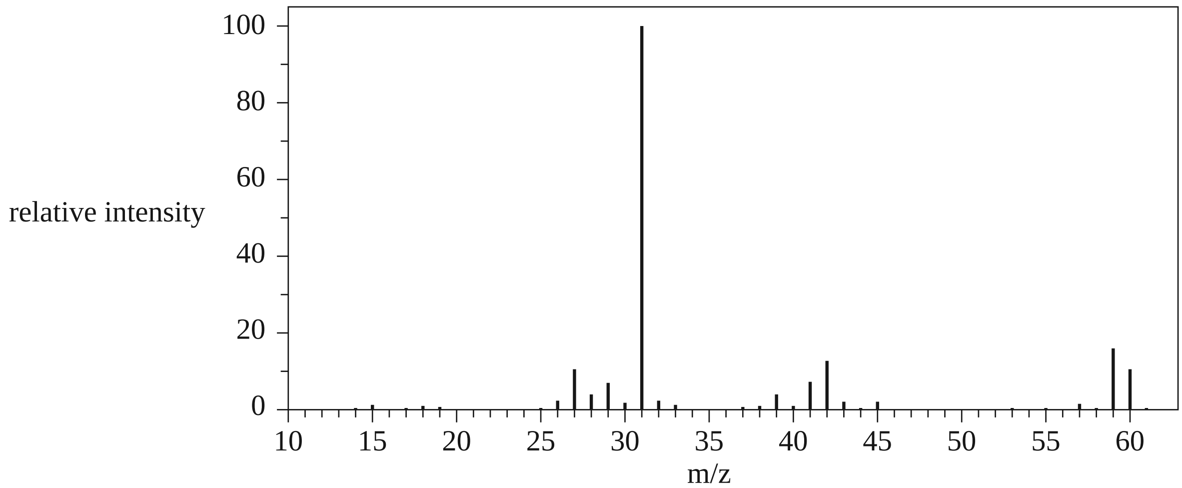
B. T, U, S, V

C. V, S, U, T

D. S, T, U, V

Question 13

The mass spectrum of alkanol T is provided below.



Source: National Institute of Advanced Industrial Science and Technology

What is alkanol T?

A. butan-1-ol

B. ethanol

C. methanol

D. propan-1-ol

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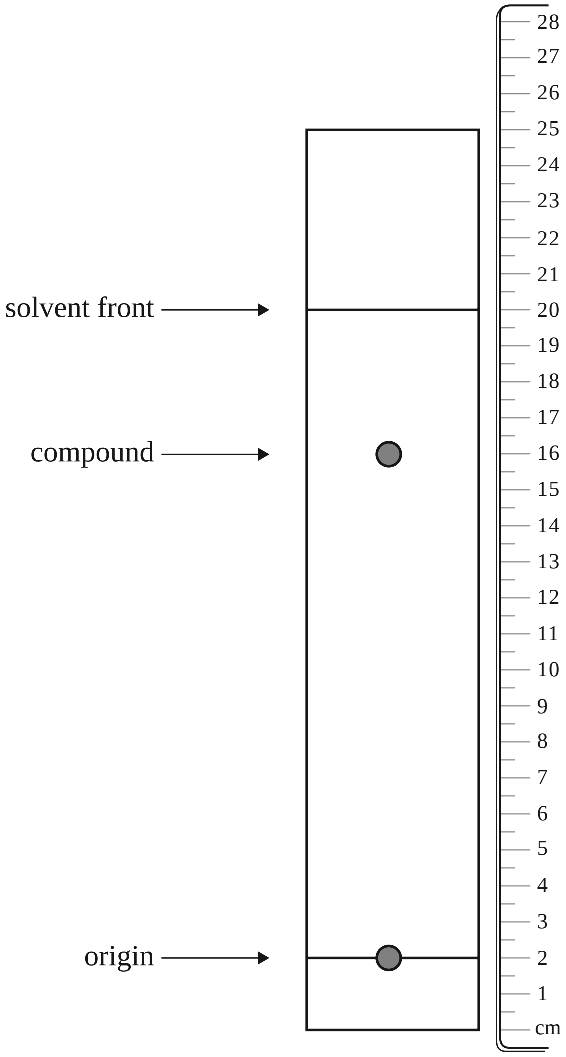
Question 14

A thin layer chromatography (TLC) plate was set up with a non-polar solvent, hexane, and a polar stationary phase, silica gel. The chromatogram below was obtained. A ruler was then placed next to the plate.



The R_f value for the compound would be

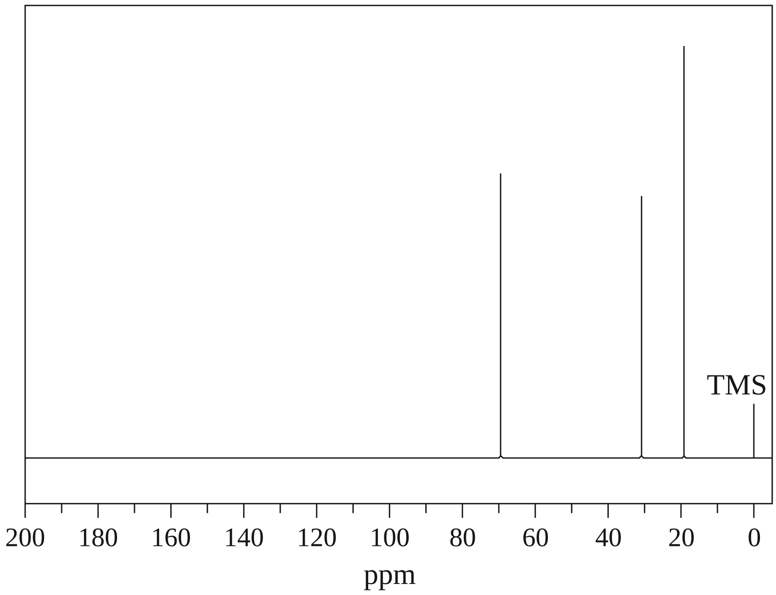
A. 0.80

B. 0.78

C. 0.64

D. 0.61

Question 15



Source: National Institute of Advanced Industrial Science and Technology

The ^{13}C NMR spectrum above corresponds to which one of the following compounds?

A. propane

B. 2-methylbutane

C. 2-methylpropan-1-ol

D. 2-methylpropan-2-ol

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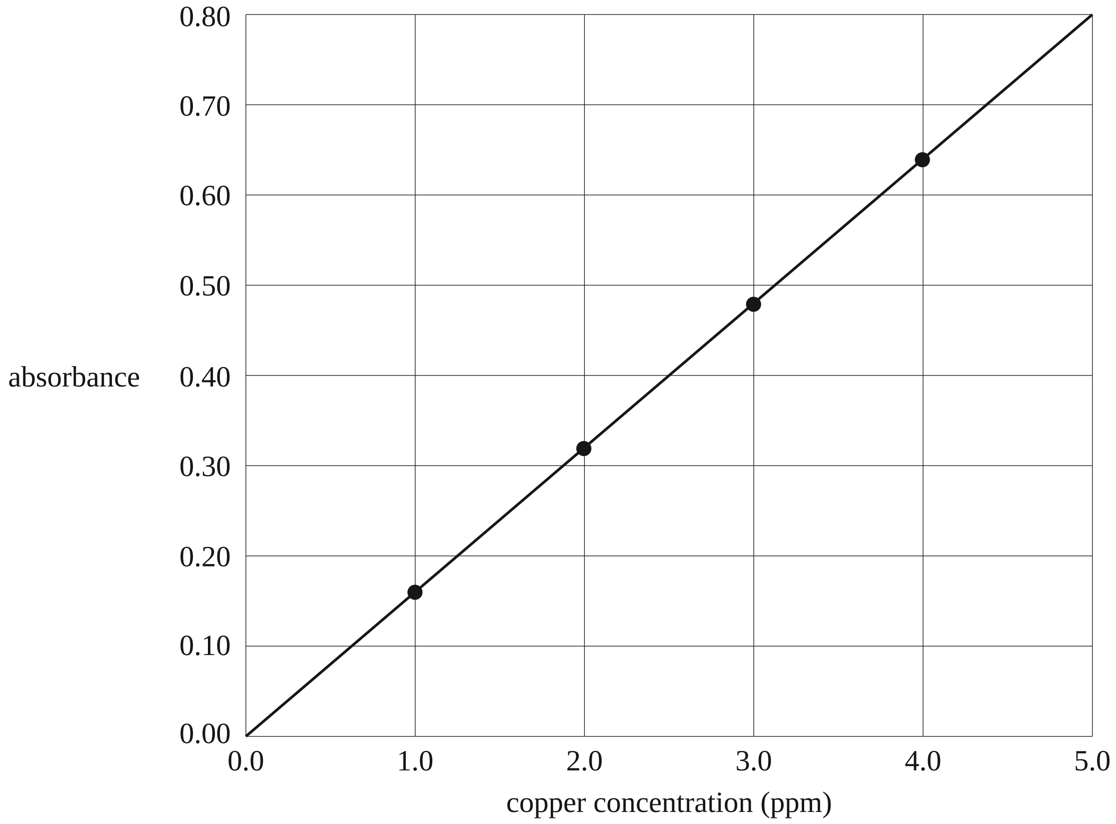
Use the following information to answer Questions 16 and 17.

An atomic absorption spectrometer can be used to determine the level of copper in soils. The calibration curve below plots the absorbance of four standard copper solutions against the concentration of copper ions in ppm.

The concentrations of copper ions in the standard solutions were 1.0, 2.0, 3.0 and 4.0 mg L^{-1}. (1 mg L^{-1} = 1 ppm)

Copper calibration curve



Question 16

The concentration of copper in a test solution can be determined most accurately from the calibration curve if it is between

A. 0.0 ppm and 5.0 ppm.

B. 0.0 ppm and 4.0 ppm.

C. 1.0 ppm and 4.0 ppm.

D. 1.0 ppm and 5.0 ppm.

Question 17

If the test solution gave an absorbance reading of 0.40, what would be the concentration of copper ions in the solution in mol L^{-1}?

A. 2.5

B. 3.9×10^{-2}

C. 3.9×10^{-5}

D. 2.5×10^{-6}

Question 18

To determine the amount of phosphate in a sample of polluted water, a coloured solution is produced by adding excess molybdovanadate reagent to the water sample.

Which technique would be used to determine the concentration of phosphate in the water?

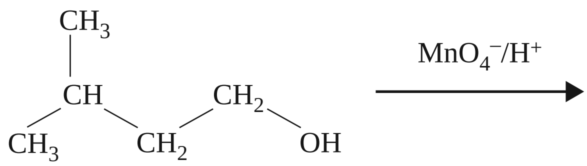
A. atomic absorption spectroscopy

B. gas chromatography

C. high-performance liquid chromatography

D. ultraviolet – visible spectroscopy

Question 19



What is the systematic name for the product of the reaction above?

A. 2-methylpentanoic acid

B. 4-methylpentanoic acid

C. 2-methylbutanoic acid

D. 3-methylbutanoic acid

Question 20

Thymine makes up 27% of the number of bases in a double strand of wheat DNA.

Wheat DNA also contains

A. 23% adenine.

B. 23% cytosine.

C. 27% guanine.

D. 46% guanine.

Question 21

Maltotriose is a trisaccharide that is formed when three glucose molecules link together. The molar mass of glucose, $C_6H_{12}O_6$, is 180 g mol^{-1}.

The molar mass of maltotriose is

A. 472 g mol^{-1}

B. 486 g mol^{-1}

C. 504 g mol^{-1}

D. 540 g mol^{-1}

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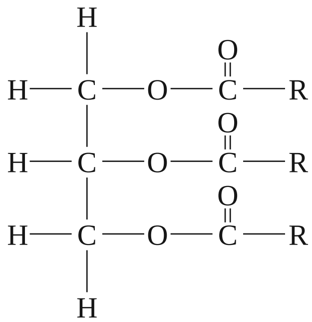
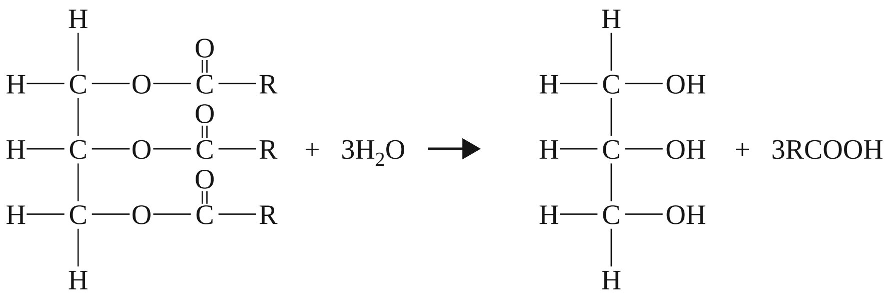
Question 22

The general formula of a triglyceride can be represented as follows.

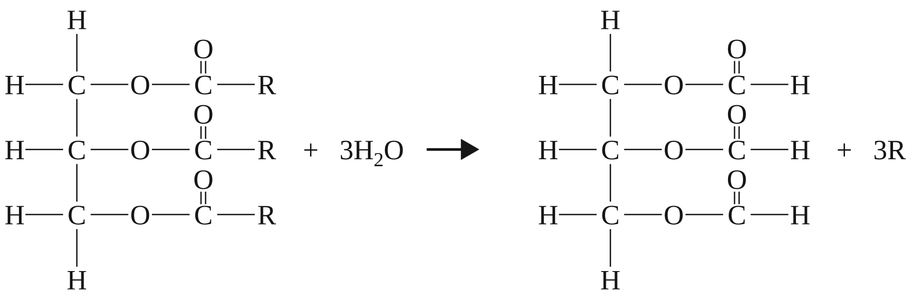


Which one of the following equations represents the hydrolysis of a triglyceride?

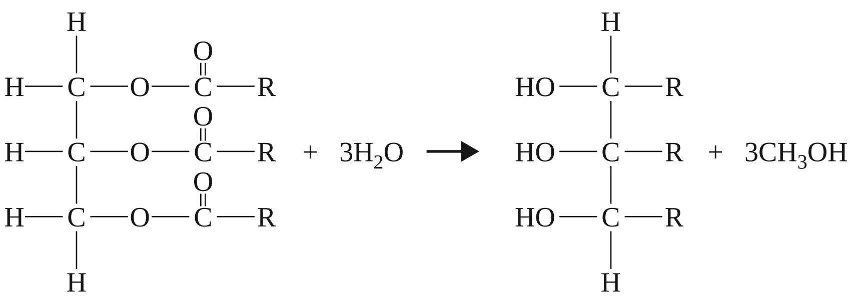
A.



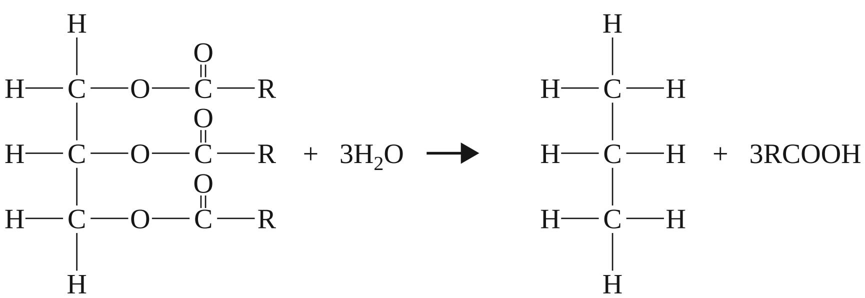
B.



C.



D.



Question 23

Large deposits of methane hydrate have been discovered deep under the sediment on the ocean floor. It has been suggested that methane hydrate deposits could be commercially mined to provide a clean fuel once the trapped methane is extracted.

Methane hydrate has a complex structure. The simplified formula for methane hydrate is $CH_4.6H_2O$.

The amount of energy released by the complete combustion of methane extracted from a 1.00 kg sample of methane hydrate at SLC is

A. 8.89×10^2 kJ

B. 7.17×10^3 kJ

C. 4.30×10^4 kJ

D. 5.56×10^4 kJ

Question 24

Methane gas may be obtained from a number of different sources. It is a major component of natural gas. Methane trapped in coal is called coal seam gas and can be extracted by a process known as fracking. Methane is also produced by the microbial decomposition of plant and animal materials. In addition, large reserves of methane were trapped in ice as methane hydrate in the ocean depths long ago.

Methane is a renewable energy source when it is obtained from

A. natural gas.

B. coal seam gas.

C. methane hydrate.

D. microbial decomposition.

Question 25

Consider the following information about the reaction of Ru^{2+} with various reagents.

$$Ru^{2+}(aq) + Fe^{2+}(aq) \rightarrow \text{no observed reaction}$$

$$Ru^{2+}(aq) + Ni(s) \rightarrow Ru(s) + Ni^{2+}(aq)$$

$$Ru^{2+}(aq) + Ag(s) \rightarrow \text{no observed reaction}$$

$$Ru^{2+}(aq) + Cu(s) \rightarrow Ru(s) + Cu^{2+}(aq)$$

Where would the following reaction be placed in the electrochemical series if the above tests were carried out under standard conditions?

$$Ru^{2+}(aq) + 2e^- \rightarrow Ru(s)$$

A. below –0.23 V

B. between –0.44 V and –0.23 V

C. between 0.77 V and 0.34 V

D. above 0.77 V

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Question 26

Consider the following experiments that are carried out under standard conditions.

Beaker I	A strip of nickel metal is placed into a 1.0 M silver nitrate solution.
Beaker II	A 1.0 M copper(II) sulfate solution is added to a 1.0 M sodium iodide solution.
Beaker III	Chlorine gas is bubbled through a 1.0 M potassium iodide solution.

It would be predicted that a reaction will occur in

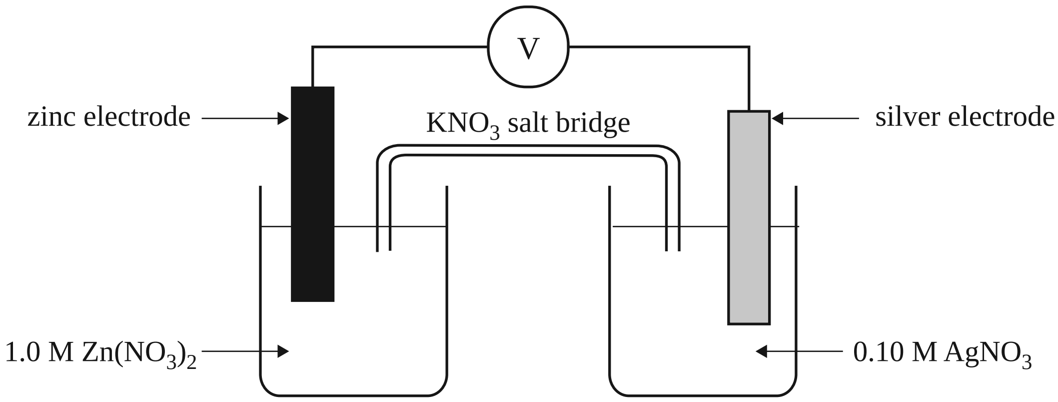
A. Beaker I only.

B. Beaker II only.

C. Beakers I and III only.

D. Beakers II and III only.

Use the following information to answer Questions 27 and 28.



Question 27

Which one of the following statements about the cell above is true as the cell discharges?

A. The silver electrode is the anode.

B. The concentration of Zn^{2+} ions will increase.

C. The maximum voltage delivered by this cell will be 1.56 V.

D. Electrons in the external circuit will flow from the silver electrode to the zinc electrode.

Question 28

What should be observed at the zinc electrode as the cell discharges?

A. No change will be observed at this electrode.

B. The electrode will become thinner and pitted.

C. Crystals will form over the surface of the electrode.

D. Bubbles of gas will form over the surface of the electrode.

Question 29

A hydrogen-oxygen fuel cell uses 1.00×10^{-5} mol of hydrogen gas per second of operation.

The current produced by this cell is

A. 0.483 A

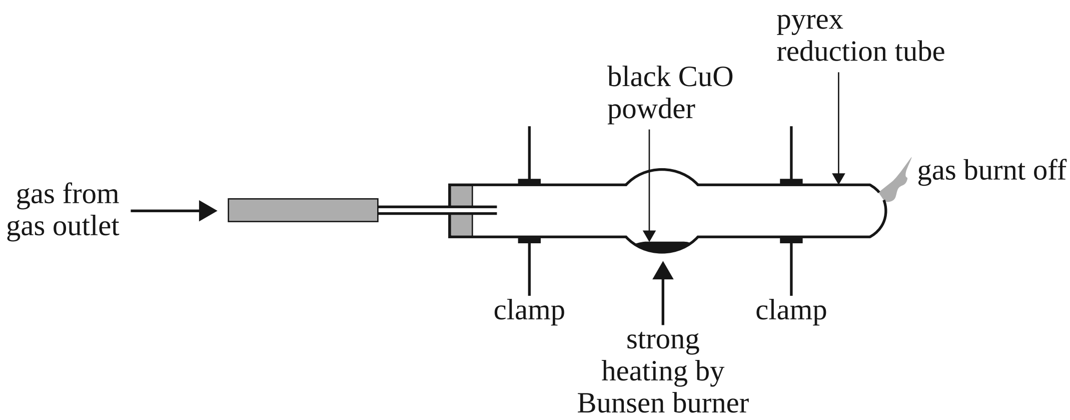
B. 0.965 A

C. 1.93 A

D. 3.86 A

Question 30

Some students conducted an experiment to determine the percentage by mass of copper in copper(II) oxide. The apparatus they used is shown in the diagram below.



The equation for the redox reaction is

$$2CuO(s) \rightarrow 2Cu(s) + O_2(g)$$

The gas passing through the tube prevented the copper from re-oxidising to CuO.

The students weighed:

- the empty tube
- the tube and CuO before heating
- the tube and Cu after heating and cooling.

They found that the percentage by mass of copper in the copper oxide was 76.42%. The theoretical value is 79.86%.

Which one of the following could **not** be a possible explanation for the lower experimental result?

A. The copper(II) oxide, which is black, was contaminated with some carbon.

B. Some copper(II) oxide remained unreacted when heating was stopped.

C. Contamination on the outside of the tube was burnt off during the heating.

D. Some of the copper(II) oxide powder was blown out of the tube by the gas.

END OF SECTION A

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SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using black or blue pen.

To obtain full marks for your responses, you should:

- give simplified answers, with an appropriate number of significant figures, to all numerical questions; unsimplified answers will not be given full marks
- show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$, NaCl(s).

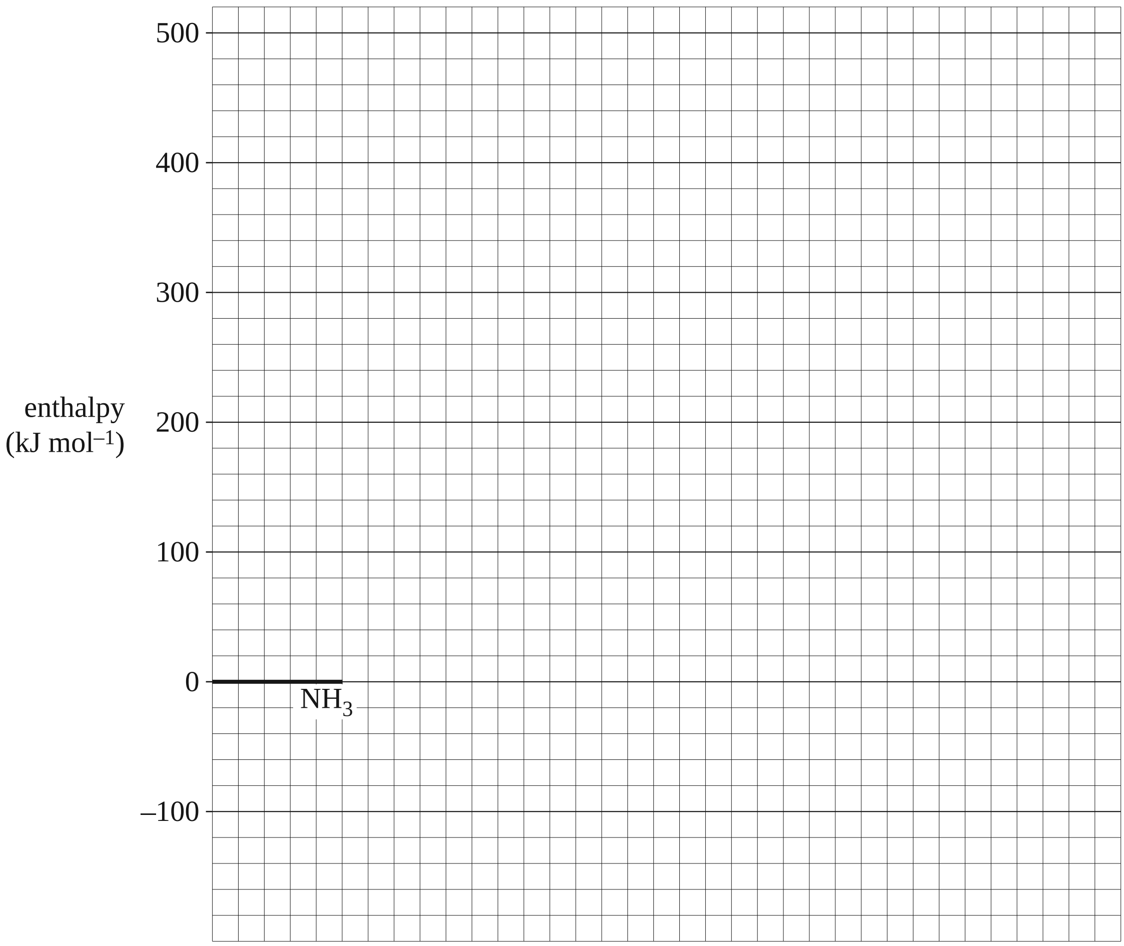
Question 1 (5 marks)

The decomposition of ammonia is represented by the following equation.

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

a. The activation energy for the uncatalysed reaction is 335 kJ mol^{-1}.
The activation energy for the reaction when tungsten is used as a catalyst is 163 kJ mol^{-1}.

On the grid provided below, draw a labelled energy profile diagram for the uncatalysed and catalysed reactions. 3 marks



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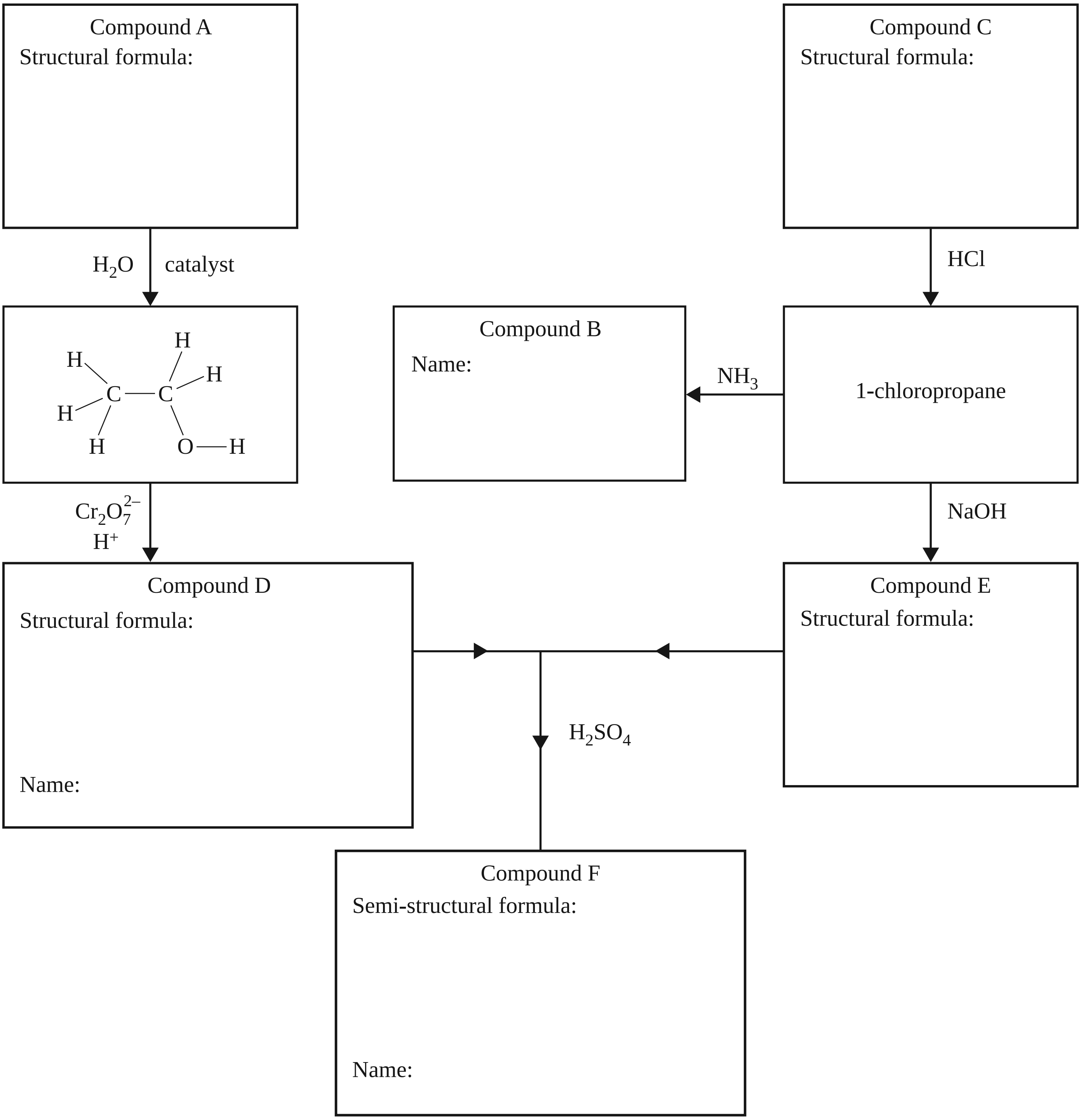
b. When osmium is used as a catalyst, the activation energy is 197 kJ mol^{-1}.

Which catalyst – osmium or tungsten – will cause ammonia to decompose at a faster rate? Justify your answer in terms of the chemical principles you have studied this year. 2 marks

Question 2 (8 marks)

Compounds B and F may be synthesised as follows.



a. Draw the structural formulas of Compounds A, C, D and E in the boxes provided. 4 marks

b. Write the systematic **names** of Compounds B and D in the appropriate boxes. 2 marks

c. Insert the semi-structural formula and systematic name of Compound F in the box provided. 2 marks

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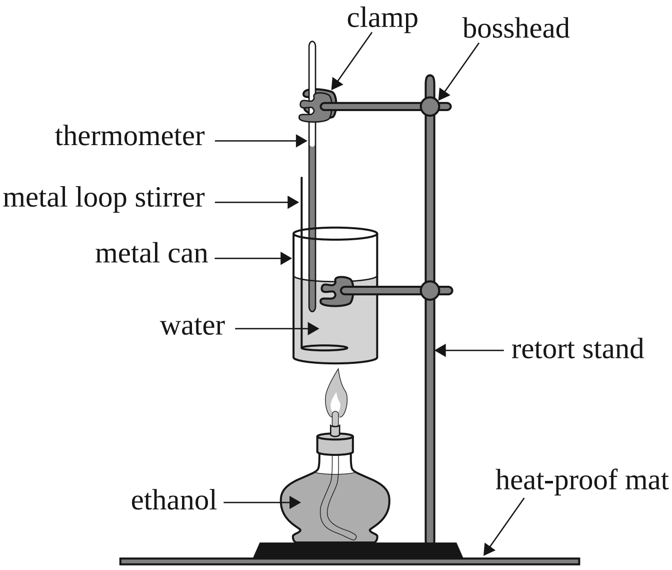
Question 3 (9 marks)

The enthalpy for the combustion of ethanol is provided in the data book. This combustion of ethanol is represented by the following equation.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

A spirit burner used 1.80 g of ethanol to raise the temperature of 100.0 g of water in a metal can from 25.0 °C to 40.0 °C.



a. Calculate the percentage of heat lost to the environment and to the apparatus. 5 marks

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b. Identify **one** way to limit heat loss to the environment. 1 mark

c. Biodiesel may be produced by reacting canola oil with methanol in the presence of a strong base. Since canola oil contains a mixture of triglycerides, the reaction produces glycerol and a mixture of biodiesel molecules. A typical biodiesel molecule derived from canola oil has the chemical formula $C_{15}H_{30}O_2$.

i. Write the semi-structural formula of this molecule, then circle and name the functional group present. 2 marks

ii. The heat content of canola oil can be determined by placing it in the spirit burner in place of ethanol. A typical result is 17 kJ g^{-1}.

Suggest why the heat content of fuels such as canola oil and biodiesel are measured in kJ g^{-1} and not kJ mol^{-1}. 1 mark

Question 4 (7 marks)

A small organic molecule has the molecular formula of the form $C_xH_yO_2Cl$.

A pH probe was inserted into a dilute aqueous solution of this compound and the pH was 4.5.

The mass spectrum, infrared spectrum, ^1H NMR spectrum and ^{13}C NMR spectrum of this compound are provided on pages 23 and 24.

a. On the infrared spectrum, label the peaks that correspond to the presence of two functional groups in this compound. Note: The peak due to the C-Cl stretch has been labelled. 2 marks

b. Use the data provided to determine the values of x and y in $C_xH_yO_2Cl$. 2 marks

x = y =

c. **i.** What specific information about the structure of the compound is provided by the splitting pattern in the ^1H NMR spectrum? 1 mark

ii. Draw the complete molecular structure for this molecule. 1 mark

d. Give a reason why the mass spectrum shows two molecular ion peaks at m/z = 108 and 110, rather than just one. 1 mark

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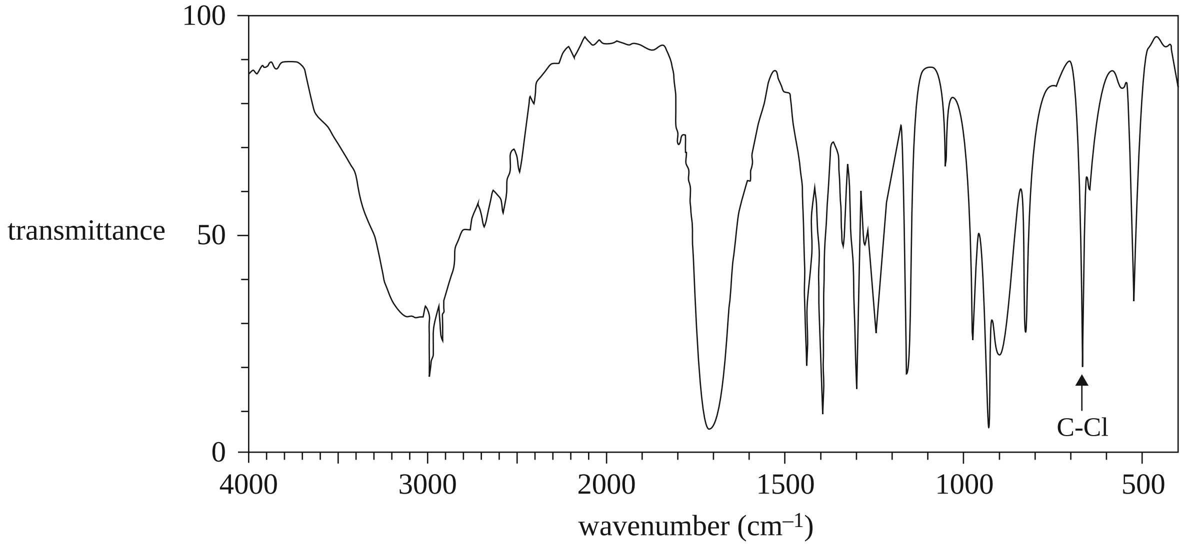
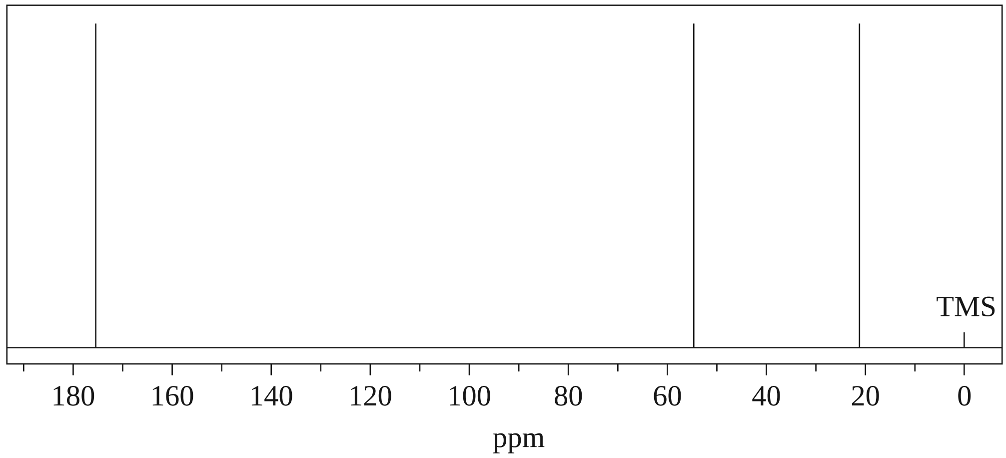
IR spectrum



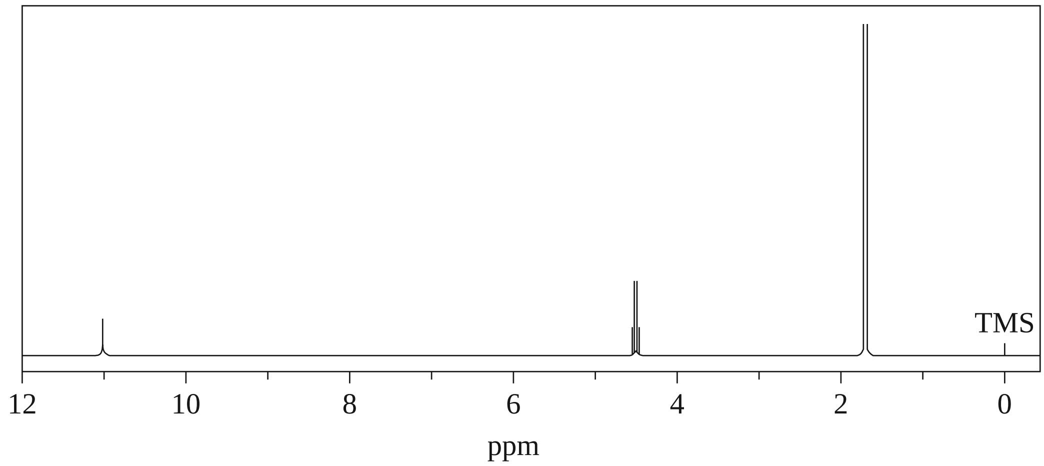
Data: National Institute of Advanced Industrial Science and Technology

^{13}C NMR spectrum



Data: National Institute of Advanced Industrial Science and Technology

^{1}H NMR spectrum

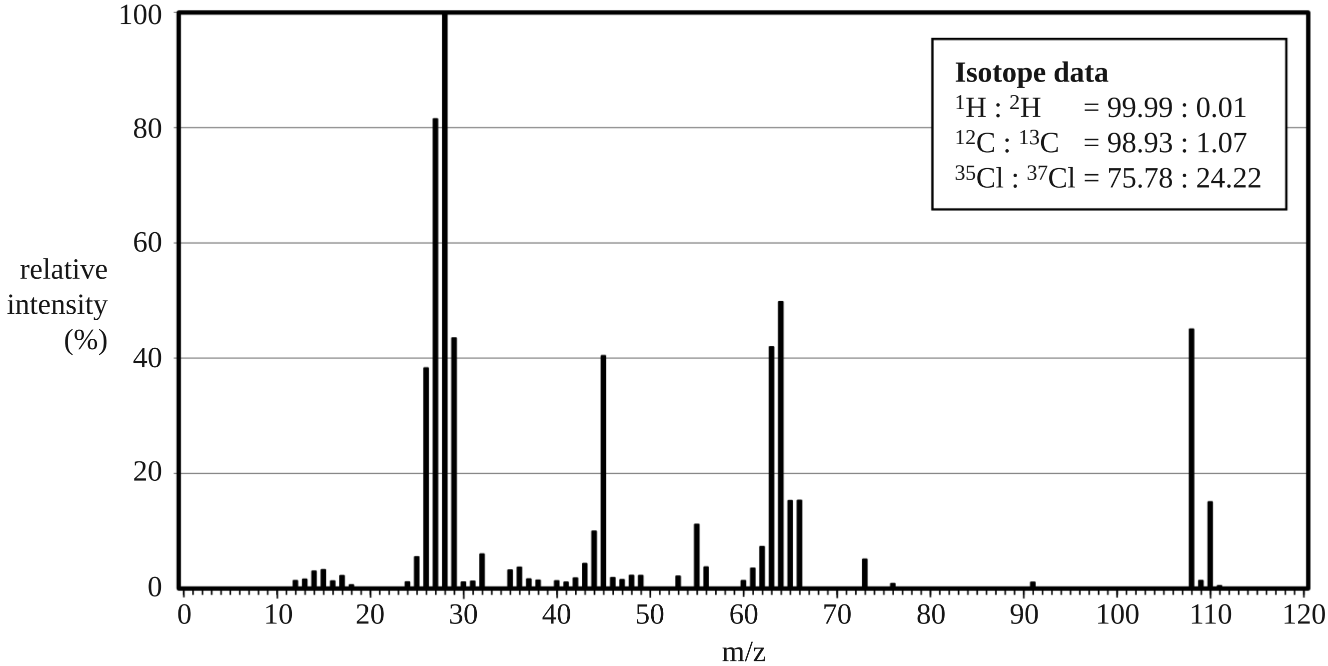


Data: National Institute of Advanced Industrial Science and Technology

^{1}H NMR data

Chemical shift (ppm)	Peak splitting	Relative peak area
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

$C_xH_yO_2Cl$ mass spectrum



Data: National Institute of Advanced Industrial Science and Technology

SECTION B – continued

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Question 5 (7 marks)

A 2% solution of glycolic acid (2-hydroxyethanoic acid), $CH_2(OH)COOH$, is used in some skincare products.

a. Draw the structural formula of glycolic acid. 1 mark

b. The equation for the ionisation of glycolic acid is

$$CH_2(OH)COOH(aq) + H_2O(l) \rightleftharpoons CH_2(OH)COO^-(aq) + H_3O^+(aq) \qquad K_a = 1.48 \times 10^{-4}$$

Sodium glycolate, $CH_2(OH)COONa$, is a soluble salt of glycolic acid.

How does the pH of a solution of glycolic acid change when some solid sodium glycolate is dissolved in the solution? Justify your answer. 2 marks

c. The solubility of glycolic acid is 1.0×10^6 mg per litre at 25 °C.

Calculate the concentration, in mol L^{-1}, of a saturated solution of glycolic acid. The molar mass of glycolic acid is 76 g mol^{-1}. 1 mark

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d. 100 mL of the saturated solution of glycolic acid is spilt onto the floor.

What is the minimum mass of sodium carbonate that should be used to neutralise the spill?
The equation for this reaction is shown below. 2 marks

$$Na_2CO_3(s) + 2CH_2(OH)COOH(aq) \rightarrow 2CH_2(OH)COONa(aq) + H_2O(l) + CO_2(g)$$

$(M(Na_2CO_3) = 106 \text{ g mol}^{-1})$

e. The Material Safety Data Sheet (MSDS) for a concentrated solution of glycolic acid states that it is corrosive to the eyes, skin and respiratory system, and that it is harmful if a concentrated solution of it is ingested or inhaled.

Outline **one** safety precaution that should be taken when handling this compound. 1 mark

Question 6 (7 marks)

A mixture of hydrogen gas and iodine gas is injected into a vessel that is then sealed. The mixture will establish an equilibrium system as described by the following equation.

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

a. In an experiment, 3.00 mol of iodine and 2.00 mol of hydrogen were added to a 1.00 L reaction vessel. The amount of iodine present at equilibrium was 1.07 mol. A constant temperature was maintained in the reaction vessel throughout the experiment.

i. Write the expression for the equilibrium constant for this reaction. 1 mark

ii. Determine the equilibrium concentrations of hydrogen and hydrogen iodide, and calculate the value of the equilibrium constant. 3 marks

DO NOT WRITE IN THIS AREA

b. A graph of the decrease in the concentration of I_2 until equilibrium is effectively reached is shown in Figure 1 below.

i. On Figure 1, draw clearly labelled graphs to show how the concentrations of H_2 and HI changed over the same period of time. 2 marks

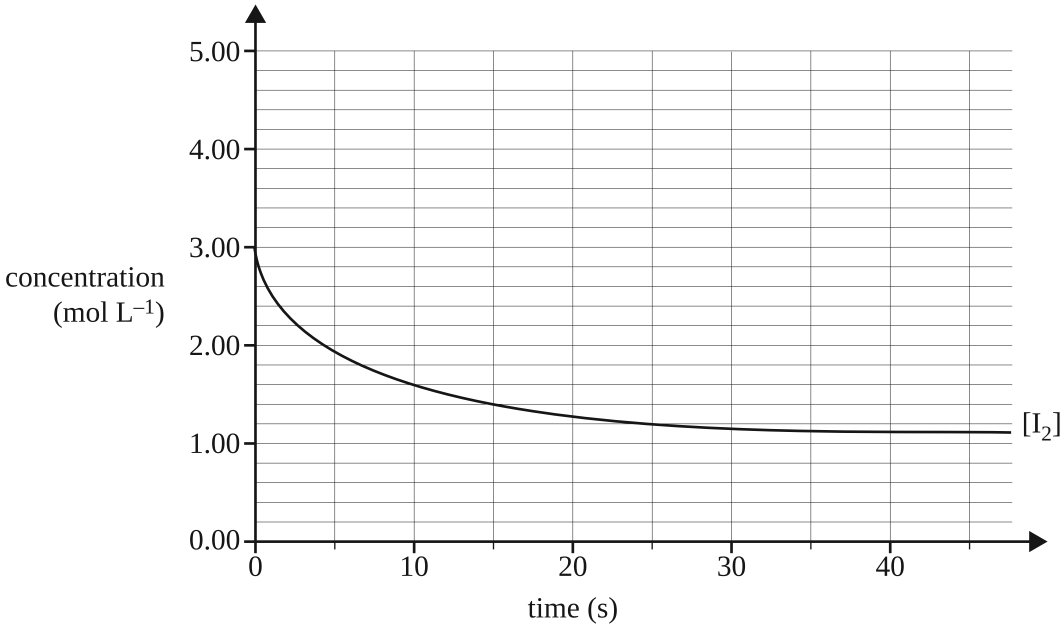

Figure 1

ii. Indicate on Figure 2 how the I_2 concentration would have changed if a catalyst had been added to the vessel as well. Assume all other conditions remain the same. 1 mark

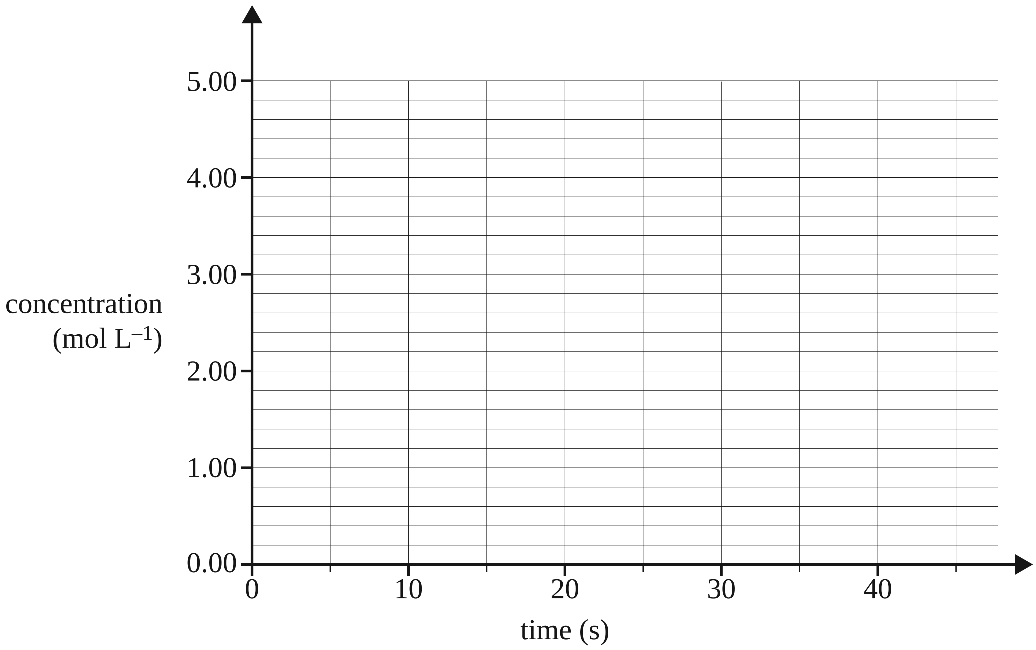

Figure 2

Question 7 (7 marks)

Amino acids can be classified according to the nature of their side chains (Z groups). These may be polar, non-polar, acidic or basic.

a. Referring to the data book, name one amino acid that has a non-polar side chain and one amino acid that has an acidic side chain. 2 marks

- amino acid with a non-polar side chain

- amino acid with an acidic side chain

The table below provides examples of different categories of side chains at a pH of 7.

Name of amino acid	Structure of side chain of pH 7
alanine (Ala)	$-CH_3$
asparagine (Asn)	$-CH_2-CO-NH_2$
aspartic acid (Asp)	$-CH_2COO^-$
cysteine (Cys)	-CH-SH
lysine (Lys)	$-CH_2-CH_2-CH_2-CH_2-NH_3^+$
serine (Ser)	$-CH_2OH$

b. The tertiary structure of proteins is a result of the bonding interactions between side chains of amino acid residues.

Use the information provided in the table above to

i. identify the amino acid that is involved in the formation of disulfide bonds (sulfur bridges) 1 mark

ii. give an example of **two** amino acid side chains that may form hydrogen bonds between each other 1 mark

iii. give an example of amino acid side chains that may form ionic bonds (salt bridges) between each other 1 mark

iv. identify the type of bonding that exists between the side chains of two alanine residues. 1 mark

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c. The enzyme trypsin catalyses the breaking of peptide bonds in proteins. Trypsin is active in the upper part of the small intestine, where the pH is between 7.5 and 8.5.

Trypsin is not effective in the stomach, where the pH is 4.

Suggest a reason why. 1 mark

Question 8 (12 marks)

The conversion of sulfur dioxide to sulfuric acid is used in a number of analytical techniques to determine the amount of analyte present in a substance. The half-equation for this reaction is

$$SO_2(aq) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$$

a. What type of reaction is this? 1 mark

b. Sulfur dioxide is often used as a preservative in food and drink. The sulfur dioxide content in dried apricots was determined by gravimetric analysis as follows:

- The dried apricots were powderised in a blender.
- A sample of the apricot powder weighing 50.00 g was put into a conical flask containing 100 mL of de-ionised water.
- A 3% solution of hydrogen peroxide was added to convert the dissolved sulfur dioxide to sulfate ions.
- An excess of barium chloride solution was then added. The barium sulfate precipitate was filtered off, dried and weighed to constant mass.

The equation for the precipitation of barium sulfate is

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

The following results were recorded.

mass of dry filter paper	0.864 g
mass of dry filter paper and $BaSO_4$ sample	1.338 g

$M(BaSO_4) = 233.4 \text{ g mol}^{-1}$ $\quad$ $M(SO_2) = 64.1 \text{ g mol}^{-1}$

i. Determine the percentage, by mass, of SO_2 in the apricot sample. 4 marks

SECTION B – Question 8 – continued

ii. Express the concentration of sulfur dioxide in the apricot sample in ppm. 1 mark

iii. Why were the apricots ground to a fine powder prior to the reaction? 1 mark

c. Oil absorbs a small amount of water from its surroundings. In 1935, Karl Fischer, a German chemist, published a technique for the determination of the water content in oil samples. This technique also involves the conversion of sulfur dioxide to sulfate.

In this analytical technique, the reactants – iodine, sulfur dioxide and a base – are all dissolved in methanol. The base is an organic compound and is represented by B in the balanced equation for this reaction. States are not included in this equation.

$$H_2O + I_2 + SO_2 + CH_3OH + 3B \rightarrow [BH]SO_4CH_3 + 2[BH]I$$

i. What is the mole ratio between iodine and water in this reaction? 1 mark

The iodine titrating agent was prepared by dissolving 15.0 g of iodine, I_2, in methanol using a volumetric flask and making up the volume to 500.0 mL. A 10.0 mL sample of oil was analysed using the iodine solution. The mean titre was found to be 4.95 mL.

$M(I_2) = 253.8 \text{ g mol}^{-1}$ $M(H_2O) = 18.0 \text{ g mol}^{-1}$

ii. Determine the mass of water present in a 10.0 mL sample of oil. 2 marks

iii. Determine the percentage by mass of water present if the density of the oil sample is 0.918 g mL^{-1}. 2 marks

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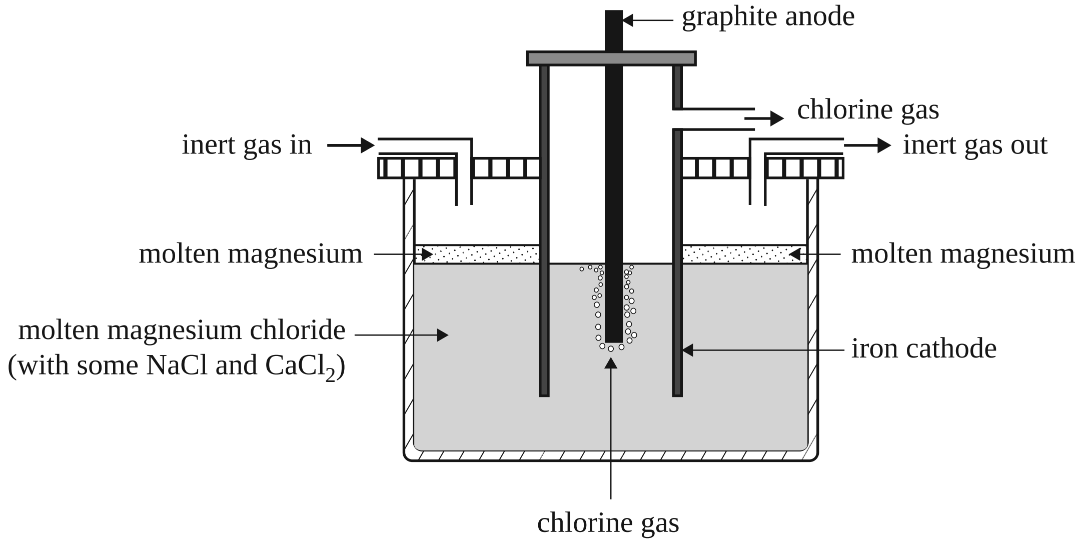
Question 9 (8 marks)

Magnesium is one of the most abundant elements on Earth. It is used extensively in the production of magnesium-aluminium alloys. It is produced by the electrolysis of molten magnesium chloride.

A schematic diagram of the electrolytic cell is shown below.



The design of this cell takes into account the following properties of both magnesium metal and magnesium chloride:

- Molten magnesium reacts vigorously with oxygen.
- At the temperature of molten magnesium chloride, magnesium is a liquid.
- Molten magnesium has a lower density than molten magnesium chloride and forms a separate layer on the surface.

a. Write a balanced half-equation for the reaction occurring at each of — 2 marks

- the cathode

- the anode.

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b. Explain why an inert gas is constantly blown through the cathode compartment. 1 mark

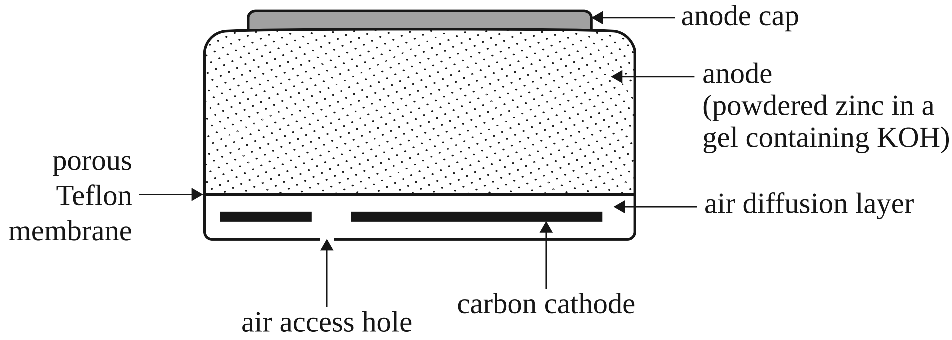
c. The melting point of a compound can often be lowered by the addition of small amounts of other compounds. In an industrial process, this will save energy. In this cell, NaCl and $CaCl_2$ are used to lower the melting point of $MgCl_2$.

Why can NaCl and $CaCl_2$ be used to lower the melting point of $MgCl_2$ but $ZnCl_2$ cannot be used? 2 marks

d. What difference would it make to the half-cell reactions if the graphite anode were replaced with an iron anode? Write the half-equation for any different half-cell reaction. Justify your answer. 3 marks

Question 10 (6 marks)

The following diagram shows a cross-section of a small zinc-air button cell, a button cell that is used in hearing aids.



The zinc acts as the anode. It is in the form of a powder dispersed in a gel (a jelly-like substance) that also contains potassium hydroxide. The cathode consists of a carbon disc. Oxygen enters the cell via a porous Teflon membrane. This membrane also prevents any chemicals from leaking out.

The following reaction takes place as the cell discharges.

$$2Zn(s) + O_2(g) + 2H_2O(l) \rightarrow 2Zn(OH)_2(s)$$

a. Write a balanced half-equation for the reaction occurring at the anode. 1 mark

____

b. Suggest **one** role of potassium hydroxide in this cell. 1 mark

____

____

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c. A zinc-air button cell is run for 10 hours at a steady current of 2.36 mA.

What mass of zinc metal reacts to form zinc hydroxide? 3 marks

d. A hydrogen-oxygen fuel cell can operate with an alkaline electrolyte such as potassium hydroxide. In this cell, the reaction at the cathode is the same as that in the zinc-air cell. A porous carbon cathode is used.

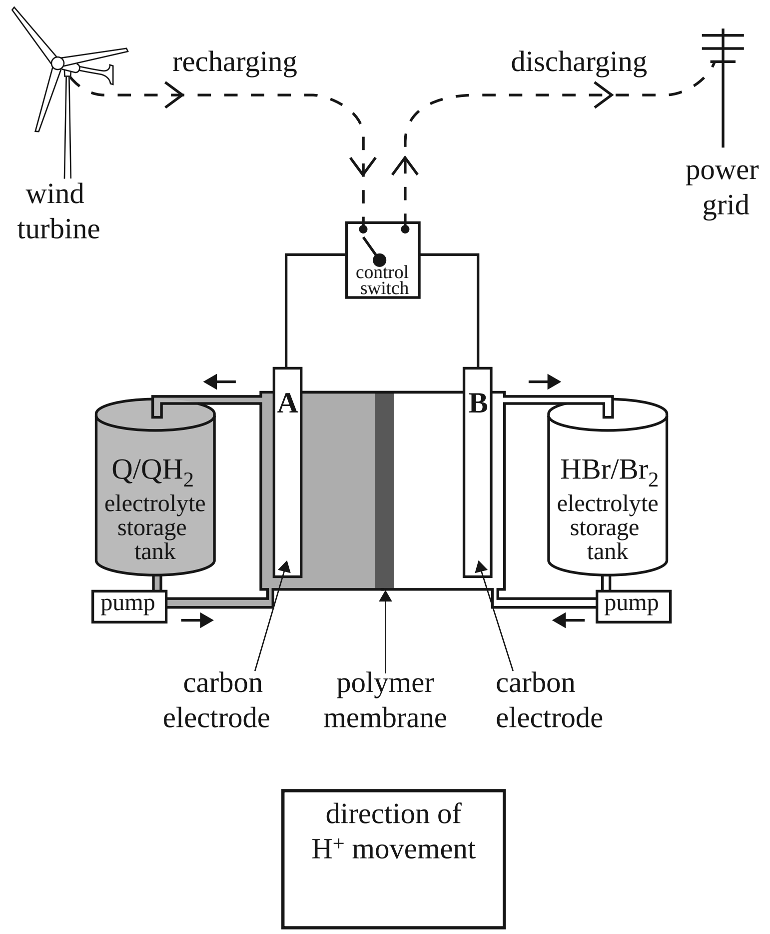
Write the half-equation for the reaction that occurs at the anode in a hydrogen-oxygen cell with an alkaline electrolyte. 1 mark

Question 11 (9 marks)

Redox flow batteries are used to store the excess electrical energy generated by commercial wind and solar farms. The batteries are recharged using electricity generated by the wind turbines or solar cells. A scientific report, published in January 2014, described a redox flow battery that used a family of chemicals commonly occurring in plants such as rhubarb. These are organic and are known as quinones and hydroquinones. A diagram showing how such a redox flow battery might operate is provided below.

In the diagram, Q represents the quinone and QH_2 represents the corresponding hydroquinone.

The researchers made a model of the redox flow battery using aqueous solutions of the redox pairs, Q/QH_2 and Br_2/Br^-. Refer to the diagram below.



During discharge, QH_2 is converted to Q and Br_2 is converted to HBr.

a. Write balanced half-equations for the reactions occurring at the positive and negative electrodes as the cell is **discharged**. Assume the electrolytes are acidic. 2 marks

Positive electrode ______________________________

Negative electrode ______________________________

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b. Write an overall equation for the reaction that occurs when the cell is **recharged**. 1 mark

c. The researchers reported that their tests indicated that only hydrogen ions were able to move through the polymer membrane separating the cells.

i. In the box provided on the diagram on page 40, use an arrow (→ or ←) to indicate the direction of movement of hydrogen ions as the cell is **recharged**. 1 mark

ii. Why is it important that the other reactants in the half-cells are not able to pass through the polymer? 1 mark

d. The researchers also reported that the voltage applied to the cell during recharging was kept below 1.5 V to avoid the electrolysis of water.

Write an equation for the overall reaction that occurs when water is electrolysed. 1 mark

e. Two K_a values, 10^{-7} and 10^{-11}, are reported for QH_2.

Write an equation and an expression for the acidity constant of the first ionisation reaction of QH_2. 2 marks

f. Quinones have a number of industrial applications and are cheaply synthesised on a large scale from anthracene, which is found in crude oil. The report's researchers suggest that because these compounds also exist in plants such as rhubarb, the electrolyte material is itself a renewable resource.

What is meant by the term 'renewable' in this context? 1 mark

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Question 12 (5 marks)

A student investigated the effect of different catalysts on the molar enthalpy of the decomposition reaction of hydrogen peroxide. The student's report is provided below.

Report – Effect of different catalysts on the enthalpy of a reaction

Background

Different catalysts, such as manganese dioxide, MnO_2, and iron(III) nitrate solution, $Fe(NO_3)_3$, will increase the rate of decomposition of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Purpose

This experiment investigated the effect of using different catalysts on the molar enthalpy of the decomposition of hydrogen peroxide.

Procedure

The temperature change was measured when MnO_2 catalyst was added to a volume of hydrogen peroxide in a beaker. The procedure was repeated using $Fe(NO_3)_3$ solution as a catalyst.

Results

	Trial 1	**Trial 2**
Volume H_2O_2	100 mL	200 mL
Concentration H_2O_2	2.0 M	4.0 M
Catalyst	0.5 g MnO_2	50 mL 0.1 M $Fe(NO_3)_3$
Temperature change °C	3.0	10.1

Conclusion

The change in temperature using the $Fe(NO_3)_3$ catalyst was greater than the change in temperature using the MnO_2 catalyst. This demonstrates that the molar enthalpy for the decomposition reaction depends on the catalyst used.

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The student's conclusion is not valid because the experimental design is flawed.

Critically review the student's experimental design. In your response, you should:

- identify and explain **three** improvements or modifications that you would make to the experimental design
- discuss the experimental outcomes you would expect regarding the effect of different catalysts on molar heats of reaction. Justify your expectations in terms of chemical ideas you have studied this year.

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2014

CHEMISTRY

Written examination

Tuesday 11 November 2014

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

DATA BOOK

Directions to students

- A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

Table of contents

1. Periodic table of the elements

atomic number relative atomic mass	79 **Au** 197.0 Gold	symbol of element name of element

1 **H** 1.0 Hydrogen																	**2** **He** 4.0 Helium
3 **Li** 6.9 Lithium	**4** **Be** 9.0 Beryllium											**5** **B** 10.8 Boron	**6** **C** 12.0 Carbon	**7** **N** 14.0 Nitrogen	**8** **O** 16.0 Oxygen	**9** **F** 19.0 Fluorine	**10** **Ne** 20.2 Neon
11 **Na** 23.0 Sodium	**12** **Mg** 24.3 Magnesium											**13** **Al** 27.0 Aluminium	**14** **Si** 28.1 Silicon	**15** **P** 31.0 Phosphorus	**16** **S** 32.1 Sulfur	**17** **Cl** 35.5 Chlorine	**18** **Ar** 39.9 Argon
19 **K** 39.1 Potassium	**20** **Ca** 40.1 Calcium	**21** **Sc** 45.0 Scandium	**22** **Ti** 47.9 Titanium	**23** **V** 50.9 Vanadium	**24** **Cr** 52.0 Chromium	**25** **Mn** 54.9 Manganese	**26** **Fe** 55.8 Iron	**27** **Co** 58.9 Cobalt	**28** **Ni** 58.7 Nickel	**29** **Cu** 63.5 Copper	**30** **Zn** 65.4 Zinc	**31** **Ga** 69.7 Gallium	**32** **Ge** 72.6 Germanium	**33** **As** 74.9 Arsenic	**34** **Se** 79.0 Selenium	**35** **Br** 79.9 Bromine	**36** **Kr** 83.8 Krypton
37 **Rb** 85.5 Rubidium	**38** **Sr** 87.6 Strontium	**39** **Y** 88.9 Yttrium	**40** **Zr** 91.2 Zirconium	**41** **Nb** 92.9 Niobium	**42** **Mo** 96.0 Molybdenum	**43** **Tc** (98) Technetium	**44** **Ru** 101.1 Ruthenium	**45** **Rh** 102.9 Rhodium	**46** **Pd** 106.4 Palladium	**47** **Ag** 107.9 Silver	**48** **Cd** 112.4 Cadmium	**49** **In** 114.8 Indium	**50** **Sn** 118.7 Tin	**51** **Sb** 121.8 Antimony	**52** **Te** 127.6 Tellurium	**53** **I** 126.9 Iodine	**54** **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	**56** **Ba** 137.3 Barium	**57** **La** 138.9 Lanthanum	**72** **Hf** 178.5 Hafnium	**73** **Ta** 180.9 Tantalum	**74** **W** 183.8 Tungsten	**75** **Re** 186.2 Rhenium	**76** **Os** 190.2 Osmium	**77** **Ir** 192.2 Iridium	**78** **Pt** 195.1 Platinum	**79** **Au** 197.0 Gold	**80** **Hg** 200.6 Mercury	**81** **Tl** 204.4 Thallium	**82** **Pb** 207.2 Lead	**83** **Bi** 209.0 Bismuth	**84** **Po** (210) Polonium	**85** **At** (210) Astatine	**86** **Rn** (222) Radon
87 **Fr** (223) Francium	**88** **Ra** (226) Radium	**89** **Ac** (227) Actinium	**104** **Rf** (261) Rutherfordium	**105** **Db** (262) Dubnium	**106** **Sg** (266) Seaborgium	**107** **Bh** (264) Bohrium	**108** **Hs** (267) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Cn** (285) Copernicium	**113** **Uut** (284)	**114** **Uuq** (289)	**115** **Uup** (288)	**116** **Uuh** (293)	**117** **Uus** (294)	**118** **Uuo** (294)

58 **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.4 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.3 Gadolinium	**65** **Tb** 158.9 Terbium	**66** **Dy** 162.5 Dysprosium	**67** **Ho** 164.9 Holmium	**68** **Er** 167.3 Erbium	**69** **Tm** 168.9 Thulium	**70** **Yb** 173.1 Ytterbium	**71** **Lu** 175.0 Lutetium
90 **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237) Neptunium	**94** **Pu** (244) Plutonium	**95** **Am** (243) Americium	**96** **Cm** (247) Curium	**97** **Bk** (247) Berkelium	**98** **Cf** (251) Californium	**99** **Es** (252) Einsteinium	**100** **Fm** (257) Fermium	**101** **Md** (258) Mendelevium	**102** **No** (259) Nobelium	**103** **Lr** (262) Lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

2. The electrochemical series

	E° in volt
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(1)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.23
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.03
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.67
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.34
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.02

3. Physical constants

Avogadro's constant (N_A) = 6.02×10^{23} mol^{-1}

charge on one electron = -1.60×10^{-19} C

Faraday constant (F) = 96 500 C mol^{-1}

gas constant (R) = 8.31 J K^{-1}mol^{-1}

ionic product for water (K_w) = 1.00×10^{-14} mol^2 L^{-2} at 298 K
(self-ionisation constant)

molar volume (V_m) of an ideal gas at 273 K, 101.3 kPa (STP) = 22.4 L mol^{-1}
molar volume (V_m) of an ideal gas at 298 K, 101.3 kPa (SLC) = 24.5 L mol^{-1}

specific heat capacity (c) of water = 4.18 J g^{-1} K^{-1}
density (d) of water at 25 °C = 1.00 g mL^{-1}

1 atm = 101.3 kPa = 760 mm Hg
0 °C = 273 K

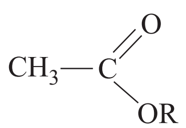
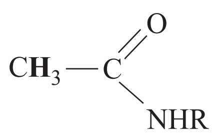
4. SI prefixes, their symbols and values

SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

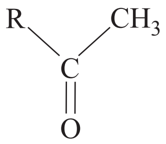
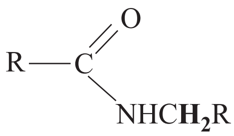
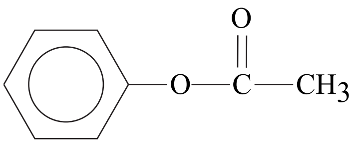
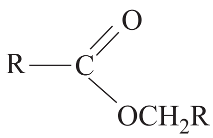
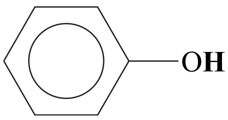
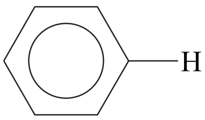
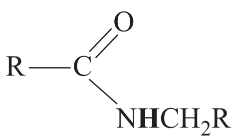
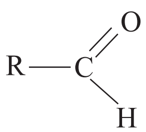
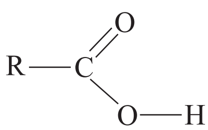
5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

Type of proton	Chemical shift (ppm)
$R–CH_3$	0.8–1.0
$R–CH_2–R$	1.2–1.4
$RCH = CH–C\mathbf{H_3}$	1.6–1.9
$R_3–CH$	1.4–1.7
 or 	2.0

TURN OVER

Type of proton	Chemical shift (ppm)
	2.1–2.7
R–CH_2–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H_2**–OH, R_2–C**H**–OH	3.3–4.5
	3.2
R—O—CH_3 or R—O—CH_2R	3.3
	2.3
	4.1
R–O–H	1–6 (varies considerably under different conditions)
R–NH_2	1–5
RHC═C**H_2**	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	9–13

6. ^{13}C NMR data

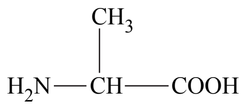
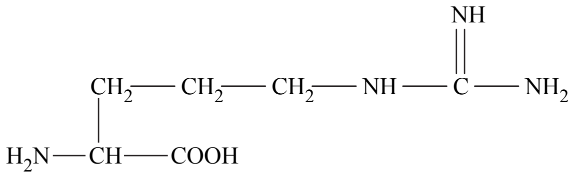
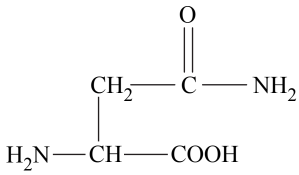
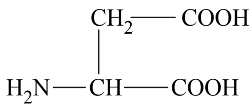
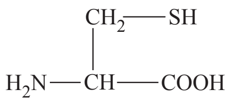
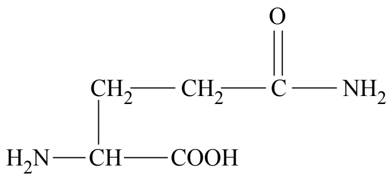
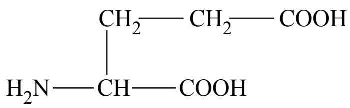
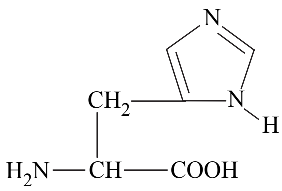
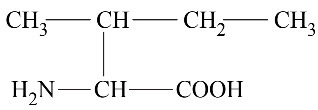
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

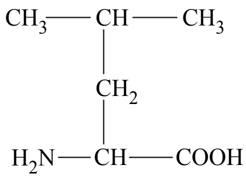
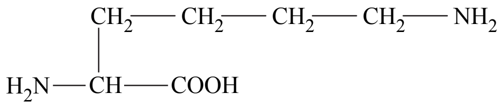
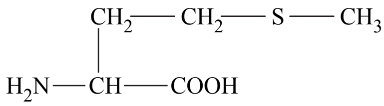
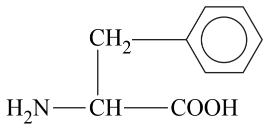
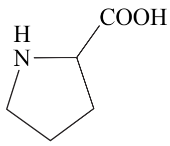
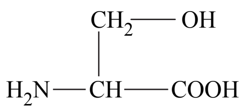
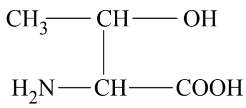
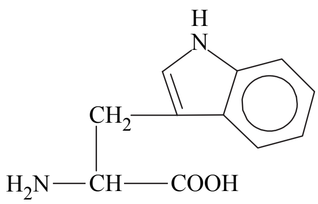
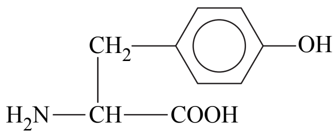
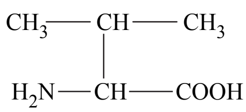
7. Infrared absorption data

Characteristic range for infrared absorption

Bond	Wave number (cm^{-1})
C–Cl	700–800
C–C	750–1100
C–O	1000–1300
C=C	1610–1680
C=O	1670–1750
O–H (acids)	2500–3300
C–H	2850–3300
O–H (alcohols)	3200–3550
N–H (primary amines)	3350–3500

8. 2-amino acids (*α*-amino acids)

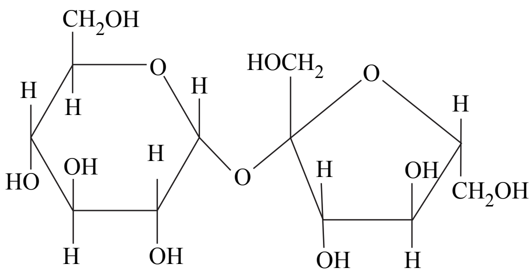
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

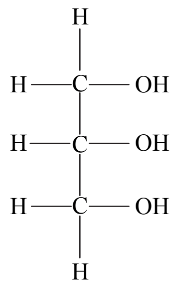
9. Formulas of some fatty acids

Name	Formula
lauric	$C_{11}H_{23}COOH$
myristic	$C_{13}H_{27}COOH$
palmitic	$C_{15}H_{31}COOH$
palmitoleic	$C_{15}H_{29}COOH$
stearic	$C_{17}H_{35}COOH$
oleic	$C_{17}H_{33}COOH$
linoleic	$C_{17}H_{31}COOH$
linolenic	$C_{17}H_{29}COOH$
arachidic	$C_{19}H_{39}COOH$
arachidonic	$C_{19}H_{31}COOH$

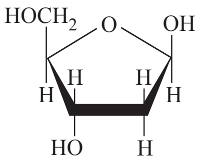
10. Structural formulas of some important biomolecules



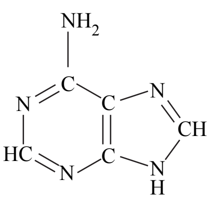
sucrose



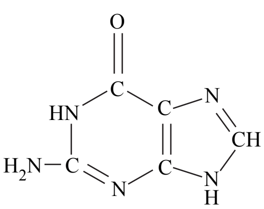
glycerol



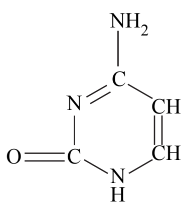
deoxyribose



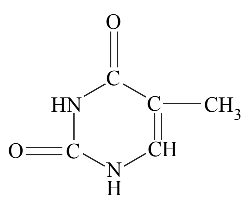
adenine



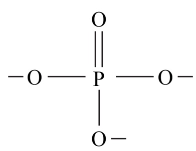
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
thymol blue	1.2–2.8	red	yellow	2×10^{-2}
methyl orange	3.1–4.4	red	yellow	2×10^{-4}
bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
methyl red	4.2–6.3	red	yellow	8×10^{-6}
bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
phenol red	6.8–8.4	yellow	red	1×10^{-8}
phenolphthalein	8.3–10.0	colourless	red	5×10^{-10}

12. Acidity constants, K_a, of some weak acids at 25 °C

Name	Formula	K_a
ammonium ion	NH_4^+	5.6×10^{-10}
benzoic	C_6H_5COOH	6.4×10^{-5}
boric	H_3BO_3	5.8×10^{-10}
ethanoic	CH_3COOH	1.7×10^{-5}
hydrocyanic	HCN	6.3×10^{-10}
hydrofluoric	HF	7.6×10^{-4}
hypobromous	$HOBr$	2.4×10^{-9}
hypochlorous	$HOCl$	2.9×10^{-8}
lactic	$HC_3H_5O_3$	1.4×10^{-4}
methanoic	$HCOOH$	1.8×10^{-4}
nitrous	HNO_2	7.2×10^{-4}
propanoic	C_2H_5COOH	1.3×10^{-5}

13. Values of molar enthalpy of combustion of some common fuels at 298 K and 101.3 kPa

Substance	Formula	State	ΔH_c (kJ mol^{-1})
hydrogen	H_2	g	–286
carbon (graphite)	C	s	–394
methane	CH_4	g	–889
ethane	C_2H_6	g	–1557
propane	C_3H_8	g	–2217
butane	C_4H_{10}	g	–2874
pentane	C_5H_{12}	l	–3509
hexane	C_6H_{14}	l	–4158
octane	C_8H_{18}	l	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	l	–725
ethanol	C_2H_5OH	l	–1364
1-propanol	$CH_3CH_2CH_2OH$	l	–2016
2-propanol	$CH_3CHOHCH_3$	l	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK