VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2017

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

CHEMISTRY
Written examination

Wednesday 7 June 2017

Reading time: 10.00 am to 10.15 am (15 minutes)
Writing time: 10.15 am to 12.45 pm (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	11	11	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 correction fluid/tape.

Materials supplied
- Question and answer book of 37 pages.
- 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.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- 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.

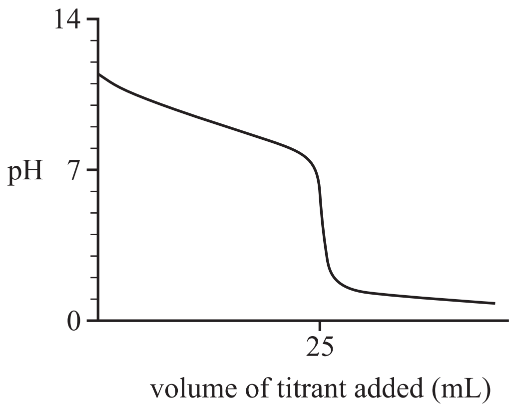
SECTION A – Multiple-choice questions

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.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

The diagram below represents a particular acid-base titration.



Which one of the following statements about this titration is correct?

A. At the equivalence point, the pH of the solution is close to 4.5
B. A solution of a strong base has been delivered by the burette
C. Phenolphthalein is a suitable indicator for this reaction
D. The titrant is a solution of a weak acid

Question 2

Manganese can exist in several oxidation states.
In which compound is manganese in its highest oxidation state?

A. Mn_2O_3
B. $KMnO_4$
C. $MnCO_3$
D. $MnO(OH)$

Question 3

The systematic name of $CH_3C(CH_3)ClCH_2CH_3$ is

A. 1-chloro-1,1-dimethylpropane.
B. 3-chloro-3-methylbutane.
C. 2-chloro-2-methylbutane.
D. 3-chloropentane.

Question 4

Sodium hydroxide, NaOH, solutions carefully prepared from analytical-grade NaOH pellets cannot be used as primary standards in acid-base titrations.

This is because

A. the NaOH solutions prepared are colourless.

B. strong bases are caustic and can cause chemical burns.

C. the NaOH pellets are too difficult to put into volumetric flasks.

D. the exact concentration of the NaOH solutions made from the pellets is unknown.

Question 5

A pure protein sample is mixed with dilute acid at 25 °C.

Which structure(s) of the protein is likely to be disrupted?

A. primary and secondary

B. secondary and tertiary

C. primary and tertiary

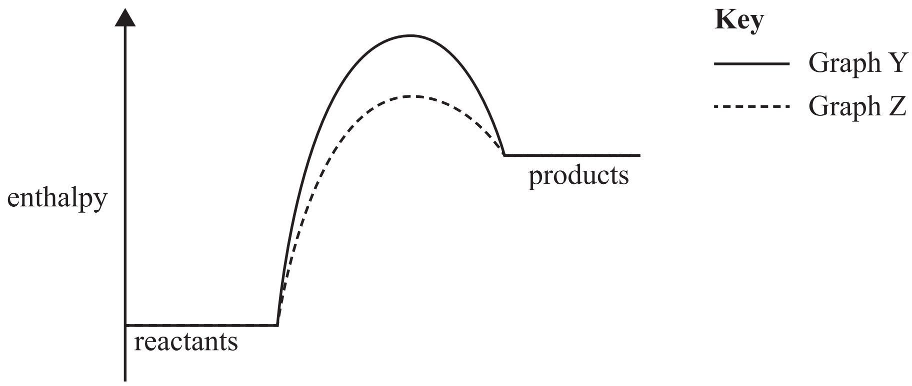
D. tertiary only

Question 6

In the diagram below, Graph Y represents the energy profile for the reaction between two gases in a sealed container.

The experiment was repeated and one change was made to the reaction conditions.

Graph Z represents the energy profile under the new conditions.



Which one of the following possible changes to the reaction conditions would result in the change in the energy profile from Graph Y to Graph Z?

A. The initial temperature of the gases was higher.

B. An inert gas was added to the reaction container.

C. The volume of the reaction container was decreased.

D. A catalyst was added to the reaction container with the gases.

Question 7

Which one of the following statements is correct for an exothermic reaction?

A. The enthalpy change is positive.

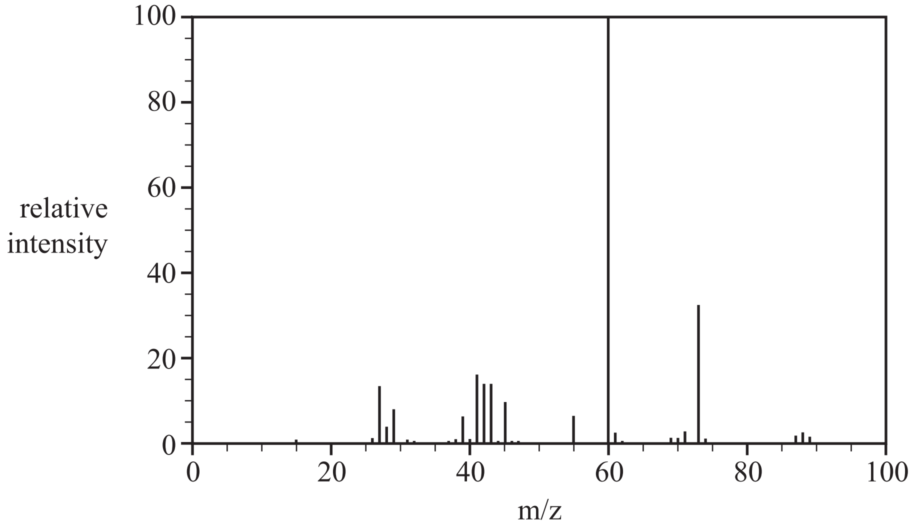
B. The activation energy is negative.

C. Heat energy is absorbed from the environment.

D. The enthalpy of the reactants is higher than that of the products.

Question 8

An unidentified organic substance with the molecular formula $C_4H_8O_2$ is found to react with a base. Mass spectrometry shows the parent molecular ion has a mass-to-charge ratio, m/z, of 88.



Source: NIST Chemistry WebBook; NIST Mass Spectrometry Data Center Collection;
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Which one of the following species is consistent with a peak on the mass spectrum at m/z = 45?

A. $[COOH]^+$

B. $[CH_3CH_2O]^+$

C. $[CH_3CH_2OH]^+$

D. $[CH_3CH_2CH_2COOH]^+$

Question 9

To determine the concentration of a peptide in a mixture of peptides, which one of the following analytical techniques would be used?

A. high-performance liquid chromatography

B. thin layer chromatography

C. paper chromatography

D. gas chromatography

Use the following information to answer Questions 10–12.

Ammonia can be synthesised by reacting nitrogen, N_2, gas with hydrogen, H_2, gas according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Question 10

The expression for the equilibrium constant for this reaction is

A. $\dfrac{[NH_3]}{3[H_2][N_2]}$

B. $\dfrac{2[NH_3]}{3[H_2][N_2]}$

C. $\dfrac{[NH_3]^2}{[H_2]^3[N_2]^3}$

D. $\dfrac{[NH_3]^2}{[H_2]^3[N_2]}$

Question 11

If an inert gas is added to the equilibrium system at a constant temperature and a constant volume, the concentration of H_2 in the mixture will

A. increase.

B. decrease.

C. not change.

D. decrease then increase.

Question 12

The rate at which equilibrium is established can be lowered by increasing the

A. temperature of the reaction mixture at a constant volume.

B. total volume of the reaction vessel at a constant temperature.

C. concentration of the reactants at a constant temperature.

D. pressure in the reaction vessel at a constant temperature.

Question 13

Magnesium, Mg, metal reacts with oxygen, O_2, according to the following equation.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s) \qquad \Delta H = -1200 \text{ kJ mol}^{-1} \qquad M(Mg) = 24.3 \text{ g mol}^{-1}$$

For this equation, 1200 kJ represents the

A. activation energy for the reaction.

B. heat energy released when 2 g of Mg reacts.

C. heat energy released when 48.6 g of Mg reacts.

D. heat energy released when 1 mol of Mg reacts.

Question 14

100 mL of 0.4 M nitric acid, HNO_3, is added to 100 mL of 0.1 M barium hydroxide, $Ba(OH)_2$.
The pH of the resulting solution is

A. 0.3
B. 0.7
C. 0.8
D. 1.0

Question 15

Which one of the following factors is **least** likely to affect the rate at which the components of a gas mixture flow through a gas chromatography column?

A. the length of the column
B. the temperature of the column
C. the rate of flow of the carrier gas
D. the molecular masses of the gases in the gas mixture

Question 16

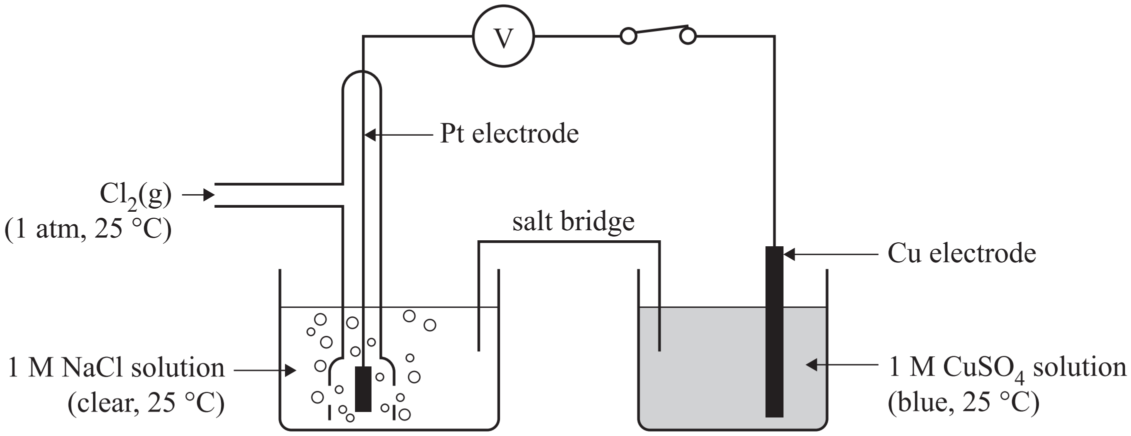
$$\boxed{CH_3CH_2Cl} \xrightarrow{\text{NaOH}} \boxed{CH_3CH_2OH} \xrightarrow{\text{Reagent X}} \boxed{CH_3COOH} \xrightarrow{CH_3CH_2CH_2OH} \boxed{\text{Product Z}}$$

For the reaction pathway shown above, which of the following correctly identifies Reagent X and Product Z?

	Reagent X	Product Z
A.	O_2	ethyl ethanoate
B.	$H^+/Cr_2O_7^{2-}$	ethyl propanoate
C.	NaOH	propyl propanoate
D.	H^+/MnO_4^-	propyl ethanoate

Use the following information to answer Questions 17 and 18.

The galvanic cell shown below is set up under a fume hood by a Chemistry student at a university. Chlorine gas, Cl_2, is continually bubbled through the left half-cell.



Question 17

When the cell begins to operate

A. the cell voltage will start at 1.02 V, then slowly drop.

B. the Cu electrode will have positive polarity and act as the cathode.

C. electrons will move out of the Pt electrode and along the wiring to the Cu electrode.

D. electrons will move through the salt bridge towards the Cu half-cell and complete the circuit.

Question 18

What is the student most likely to observe in the Cu half-cell sometime after the switch is turned on?

A. bubbles forming over the electrode

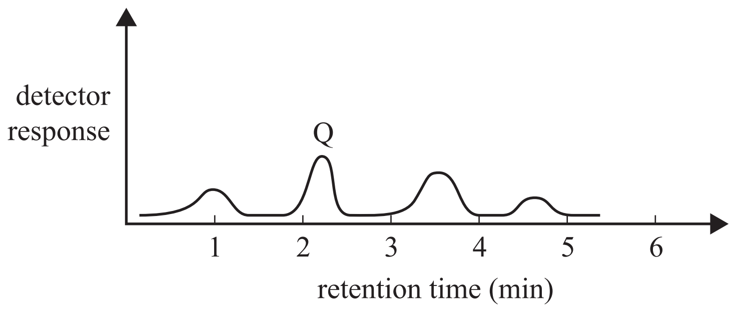
B. the Cu electrode looking corroded

C. the solution becoming a lighter blue in colour

D. crystals of Cu growing over the electrode

Question 19

A sample containing a mixture of four straight-chain alcohols – butanol, ethanol, hexanol and pentanol – is analysed by gas chromatography.



On the chromatogram, the peak at Q was most likely produced by

A. butanol.

B. ethanol.

C. hexanol.

D. pentanol.

Question 20

Some information given on the labels of a bottle of disinfectant is shown below.

500 mL

Smiley Clean

Powerful disinfectant

Active ingredient

BENZALKONIUM CHLORIDE 1.5% w/w

DIRECTIONS

FOR HOSPITAL STANDARD DISINFECTION

Use undiluted

FOR GENERAL HOUSEHOLD USE

Dilute 1 part disinfectant with 20 parts water

Data

- benzalkonium chloride: $C_{17}H_{30}ClN$
- density (Smiley Clean): 1.0 g mL^{-1}
- molar mass of $C_{17}H_{30}ClN$: 283.5 g mol^{-1}

The concentration, in mol L^{-1}, of benzalkonium chloride in a diluted solution of Smiley Clean disinfectant, ready for general household use, is

A. 1.5×10^{-2}

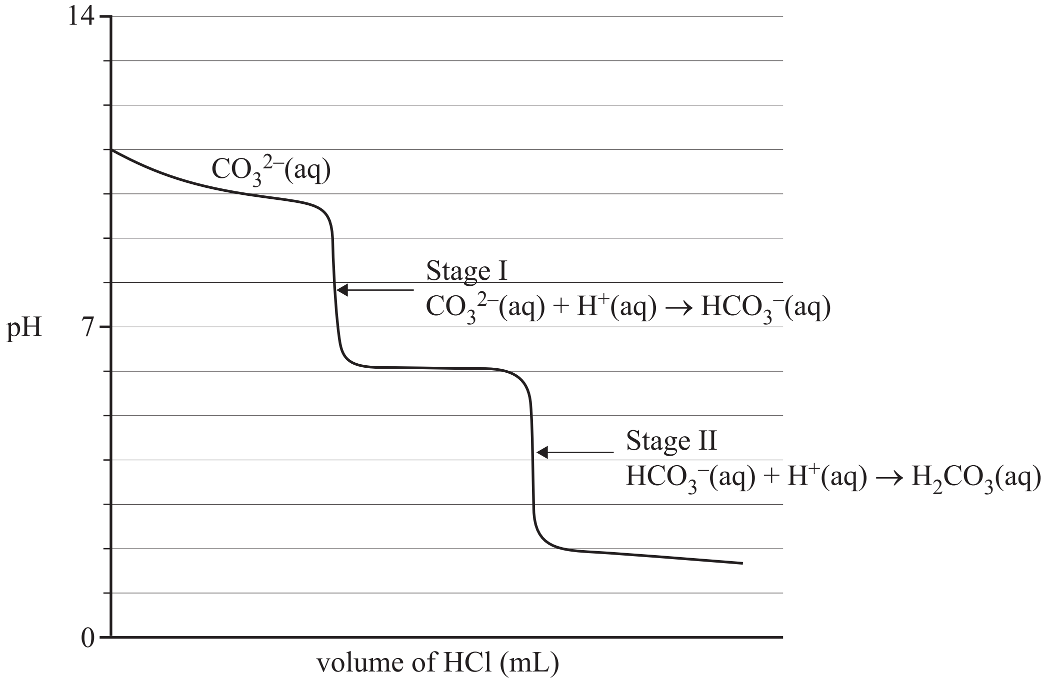
B. 5.3×10^{-2}

C. 2.5×10^{-3}

D. 2.6×10^{-3}

Question 21

The graph below represents the titration of 1.0 M sodium carbonate solution, Na_2CO_3, against 1.0 M hydrochloric acid, HCl. The titration has two equivalence points, Stage I and Stage II, corresponding to the addition of successive protons to the base.



Which one of the following indicators is the most appropriate to use to detect the end point for Stage II?

A. phenolphthalein

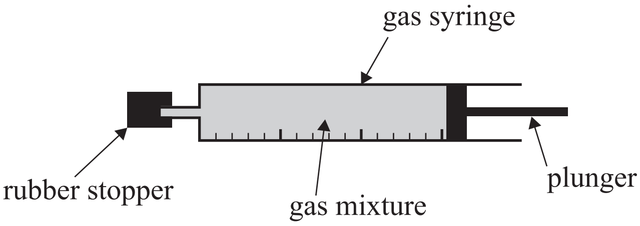
B. methyl orange

C. thymol blue

D. phenol red

Question 22

A sealed gas syringe contains an equilibrium mixture of brown nitrogen dioxide gas, NO_2, and colourless dinitrogen tetroxide gas, N_2O_4. This is shown in the diagram below.



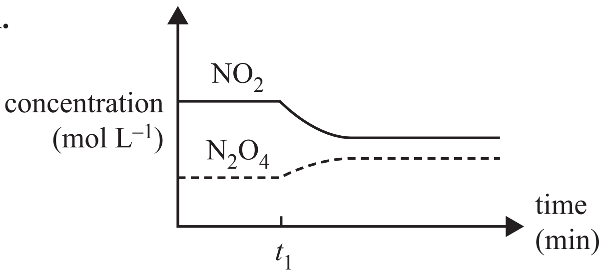
The equation for this equilibrium reaction is

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +57.20 \text{ kJ mol}^{-1}$$

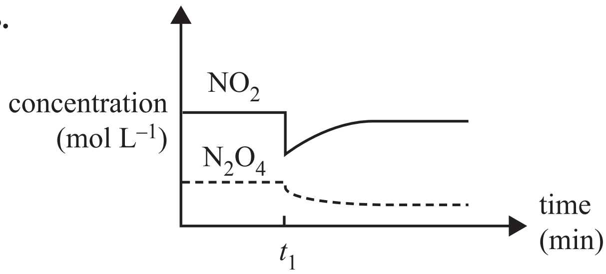
The plunger is suddenly pushed in at time t_1, thus decreasing the total volume of the gas mixture. The temperature of the gas mixture is kept constant.

Which one of the following concentration–time graphs represents the change that occurs?

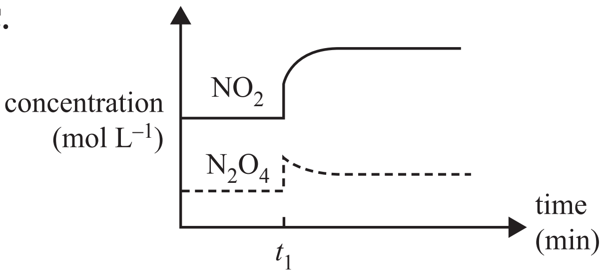
A.



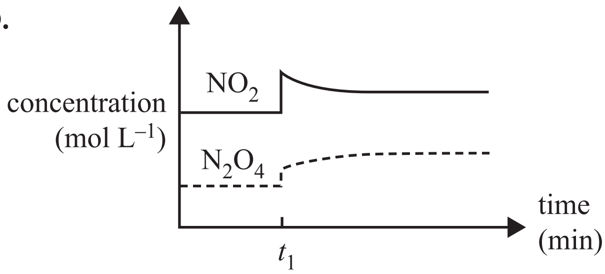
B.



C.



D.



Question 23

The equation below represents the complete combustion of methanol.

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

The heat of combustion of methanol, in kJ g^{-1}, is closest to

A. 1450

B. 725

C. 45.31

D. 22.66

Question 24

Narrow strips of Metal X were placed in solutions of four different salts in separate test tubes. The table below shows the observations made after 10 minutes.

Solution	Observations
copper(II) sulfate	small reddish crystals formed on Metal X; blue colour of solution lightened slightly
iron(III) chloride	solution turned from a yellowish colour to a greenish colour
nickel(II) sulfate	small greyish crystals formed on Metal X; green colour of solution lightened slightly
aluminium sulfate	no apparent change

Metal X is most likely

A. silver.

B. copper.

C. iron.

D. nickel.

Question 25

An analyst is given a flask containing a 20.0 mL solution of 0.52 M barium chloride, $BaCl_2$. She adds 25.0 mL of 0.75 M sulfuric acid, H_2SO_4. She collects and dries the resulting barium sulfate precipitate, $BaSO_4$. The mass of the dried precipitate is 2.43 g.

What is the concentration of SO_4^{2-} ions, in mol L^{-1}, in the filtrate?

A. 0.19

B. 0.23

C. 0.33

D. 0.42

Question 26

When ethanol, C_2H_5OH, reacts with a limited amount of dichromic acid, $H_2Cr_2O_7$, the reaction produces chromium(III) ions, Cr^{3+}, and ethanal, C_2H_4O.

What is the balanced half-equation for the oxidation reaction?

A. $2Cr_2O_7^{2-}(aq) \rightarrow 4Cr^{3+}(aq) + 7O_2(g) + 16e^-$

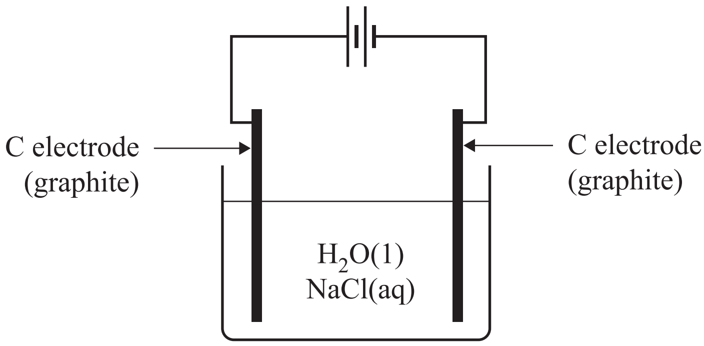
B. $C_2H_5OH(aq) \rightarrow C_2H_4O(aq) + 2H^+(aq) + 2e^-$

C. $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

D. $3C_2H_5OH(aq) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3C_2H_4O(aq) + 7H_2O(l)$

Question 27

An electric current is passed through water to which a very small amount of sodium chloride, NaCl, has been added. The electrolytic cell is shown in the diagram below.



The net cell reaction is

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

Which one of the following statements applies to this electrolytic cell as it operates?

A. H_2O will be the reactant at each electrode.

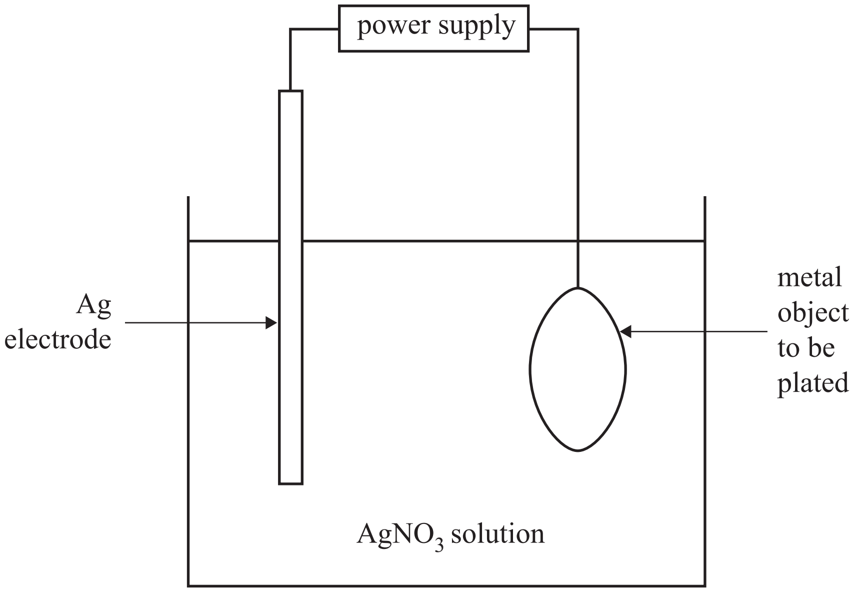
B. The rate of bubbling will be the same at each electrode.

C. H_2 gas will be produced at the anode and O_2 gas will be produced at the cathode.

D. For each mole of electrons passed through the cell, 1 mol of H_2 gas will be collected.

Use the following information to answer Questions 28 and 29.

As part of an investigation into silver plating, a group of students wants to coat a metal object with silver, Ag, by electrolysis. They set up a simple electrolytic cell using silver nitrate, $AgNO_3$, solution, as shown in the diagram below.



Question 28

Which one of the following statements is correct?

A. During the electrolysis, the concentration of the $AgNO_3$ solution will not change.

B. During the electrolysis, each gram of Ag deposited will require 1 mol of electrons.

C. During the electrolysis, water will be the reactant at the Ag electrode.

D. During the electrolysis, the Ag electrode will have negative polarity.

Question 29

A total of 0.75 g of Ag is required to plate the metal object.

The electrolytic cell is first operated at 0.75 A for 10 minutes. The current is then changed to 1.00 A.

For how much longer would the cell need to operate to complete the plating?

A. 71 s

B. 220 s

C. 450 s

D. 670 s

Question 30

Primary cells, secondary cells and fuel cells can all be used as sources of energy.

The features that can be associated with one or more of the three types of cells include the following:

1. The cell is rechargeable.
2. The cell requires a continuous supply of reactants.
3. Reduction takes place at the cathode when discharging.
4. Oxidation takes place at the positive electrode when recharging.

Which of the above features are displayed by secondary cells?

A. 1, 2 and 3

B. 2, 3 and 4

C. 1, 3 and 4

D. 1, 2, 3 and 4

END OF SECTION A

SECTION B

Instructions for Section B

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

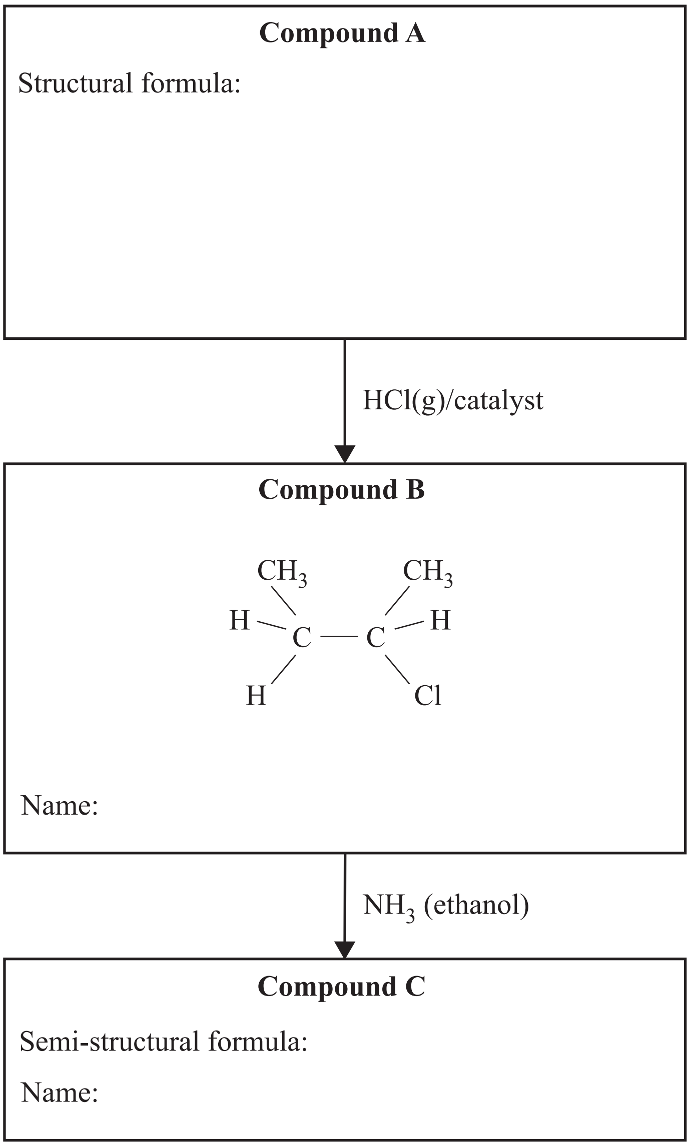
To obtain full marks for your responses, you should:

- 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).

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (7 marks)

a. Compound C may be synthesised according to the following pathway.



i. Draw the structural formula of Compound A in the box provided. 1 mark

ii. Write the systematic name of Compound B in the box provided. 1 mark

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

b. Butan-1-ol, C_4H_9OH, can react with acidified permanganate ions, MnO_4^-, to produce butanoic acid, C_3H_7COOH.

i. Write a balanced redox half-equation for the production of C_3H_7COOH from C_4H_9OH. 1 mark

ii. C_3H_7COOH reacts with ethanol, C_2H_5OH, in the presence of sulfuric acid, H_2SO_4.

Name the product formed. 1 mark

iii. Draw the structural formula of the product named in **part b.ii.** 1 mark

Question 2 (7 marks)

Glutathione is a tripeptide that is found in the human body. It acts as an antioxidant, helping to prevent damage to cells. The sequence for this tripeptide is glu-cys-gly.

a. Draw a structure that represents this sequence of amino acids, clearly showing the linkages between the amino acids. 3 marks

b. Glutamic acid can be isolated from a sample of glutathione.

Draw a structure of glutamic acid in a 1.0 M sodium hydroxide solution. 2 marks

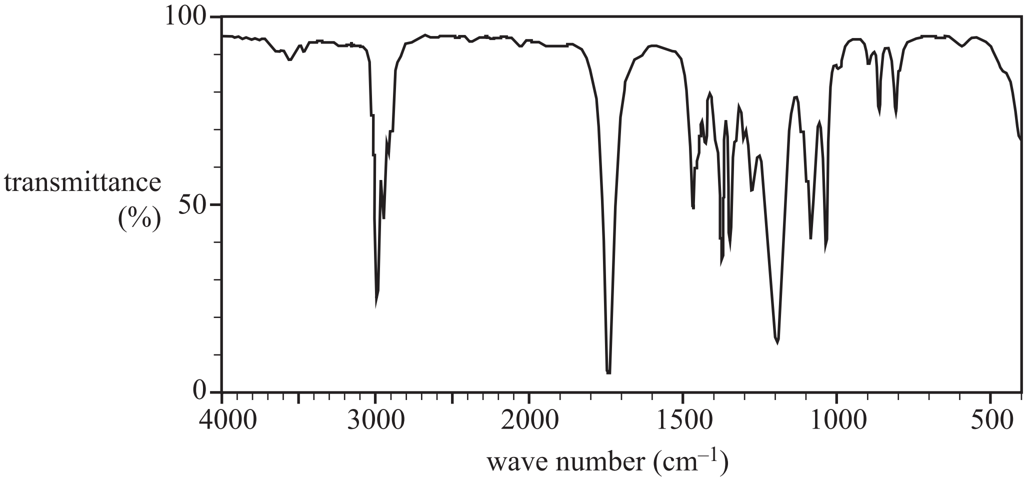
c. In human body cells, glutathione is oxidised to glutathione disulfide. This reaction is reversed in the presence of the enzyme glutathione reductase. This enzyme works optimally at body temperature.

Explain why glutathione reductase would not be effective at higher temperatures. 2 marks

Question 3 (6 marks)

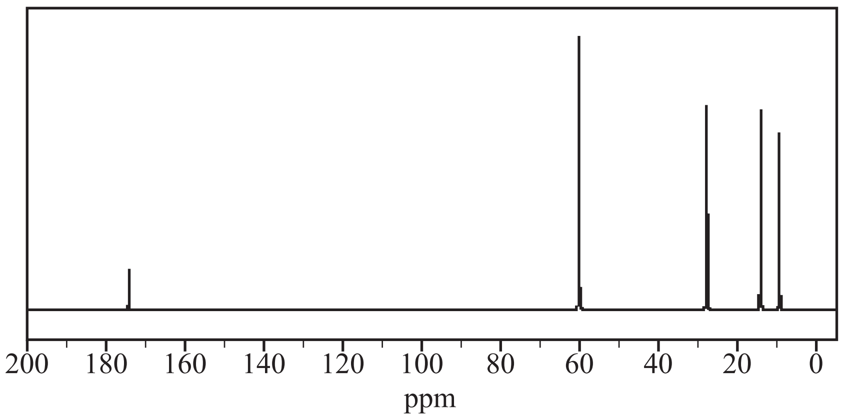
A compound has the molecular formula $C_5H_{10}O_2$. It is analysed by infrared (IR), ^{13}C NMR and ^{1}H NMR spectroscopy. The resulting spectra are shown below.

IR spectrum



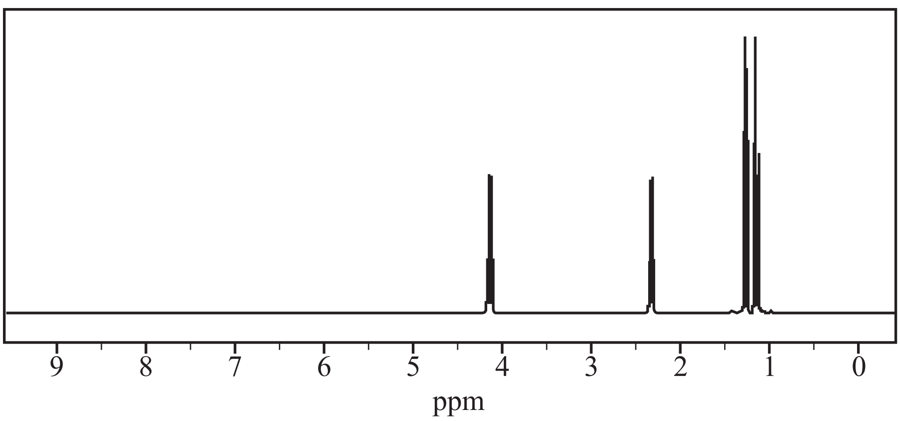
Data: SDBS Web, http://sdbs.db.aist.go.jp, National Institute of Advanced Industrial Science and Technology

^{13}C NMR spectrum



Data: SDBS Web, http://sdbs.db.aist.go.jp, National Institute of Advanced Industrial Science and Technology

^{1}H NMR spectrum



Data: SDBS Web, http://sdbs.db.aist.go.jp, National Institute of Advanced Industrial Science and Technology

Information for the splitting pattern of the ^{1}H NMR spectrum is shown below.

Chemical shift	Relative peak area	Splitting pattern
4.1	2	4 peaks
2.3	2	4 peaks
1.3	3	3 peaks
1.1	3	3 peaks

a. Using the IR spectrum provided, identify a bond in a molecule of $C_5H_{10}O_2$ and give its wave number. 1 mark

___

b. Using the ^{1}H NMR spectrum provided, state the number of hydrogen environments in a molecule of $C_5H_{10}O_2$. 1 mark

___

c. What specific information about the structure of a molecule of $C_5H_{10}O_2$ is provided by the splitting pattern in the ^{1}H NMR spectrum? 1 mark

___

___

___

d. Draw a structure consistent with the data provided for a molecule of $C_5H_{10}O_2$. Explain how the structure you have drawn is supported by evidence from the ^{13}C NMR spectrum, which contains five peaks. 3 marks

___

___

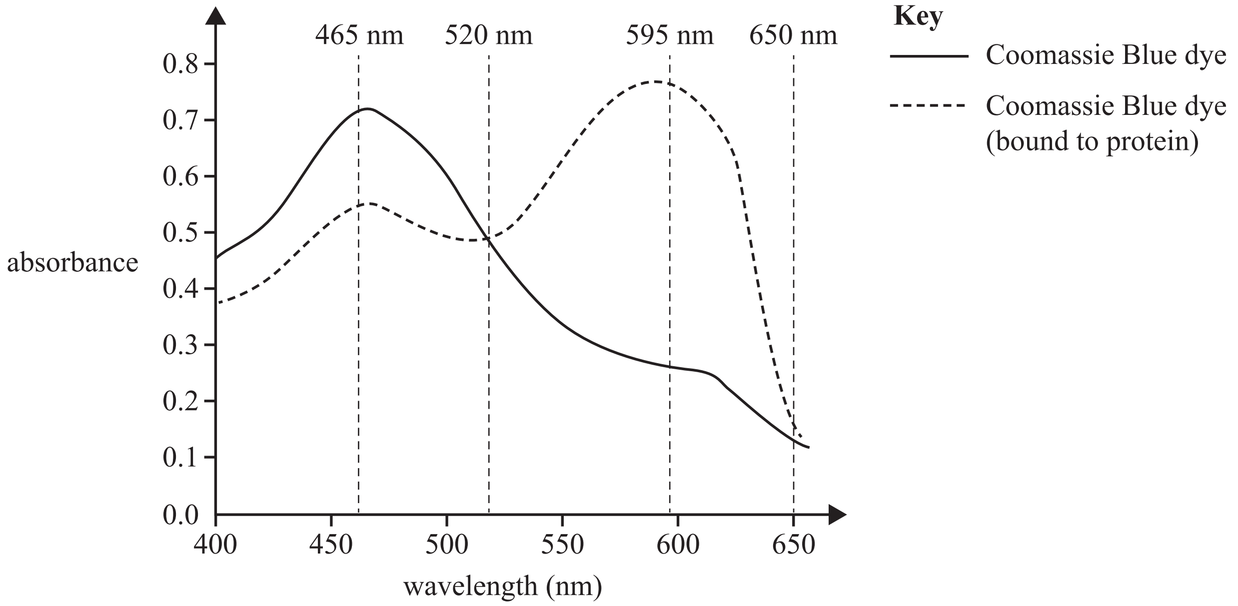
___

Question 4 (6 marks)

The Bradford protein assay is a spectroscopic method of determining the concentration of proteins in a solution.

The Bradford protein assay uses acidified Coomassie Blue dye (G-250), which changes from brown to brilliant blue when it binds to proteins in a solution. The intensity of the blue colour of the dye increases as the concentration of proteins in the solution increases.

The absorption spectra used for the Bradford protein assay are shown in the graph below.



a. Name the type of spectroscopy used in the Bradford protein assay. 1 mark

____

b. What wavelength would be most appropriate to determine the concentration of proteins in a solution? Justify your answer. 2 marks

____

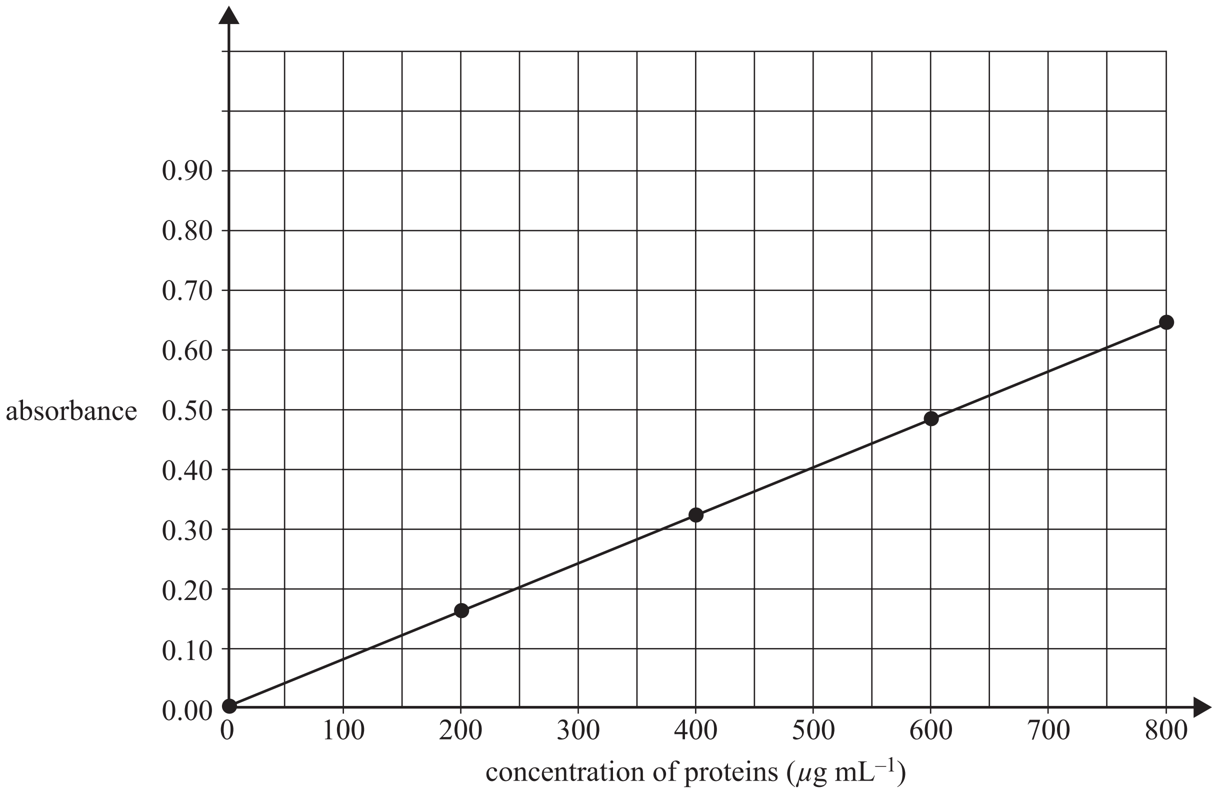
____

____

c. The Bradford protein assay was used to determine the concentration of proteins in a liver cell extract.

- Equal volumes of standard solutions of proteins were prepared. The same volume of dye was added to each one.
- The spectrometer was adjusted to read zero absorbance for the 0 $\mu g\ mL^{-1}$ standard.
- The absorbance of each of the standard solutions was measured and the data was plotted on a graph.

The graph below shows the calibration curve for absorbance as a function of the concentration of proteins.



Prior to its absorbance being measured, 1.50 mL of the liver cell extract was made up to 10.00 mL with a buffer solution. Using the same equipment with the same settings, the absorbance of the diluted sample of the liver cell extract was measured as 0.28

i. What is the concentration of proteins in the diluted sample of the liver cell extract? 1 mark

___

ii. Calculate the concentration, in mg mL^{-1}, of proteins in the undiluted sample of the liver cell extract. 2 marks

___

___

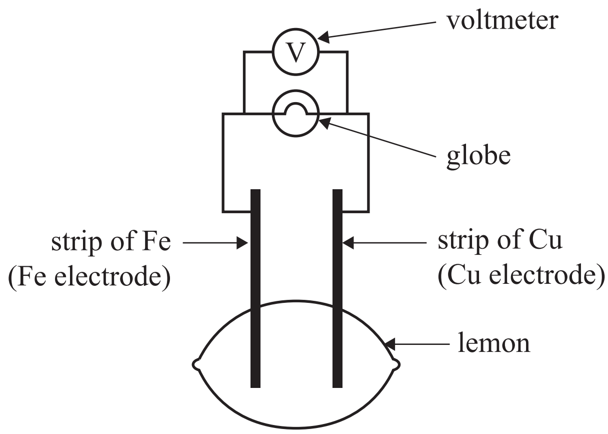
___

___

Question 5 (8 marks)

Some students set up a 'lemon battery' experiment using freshly sanded strips of copper, Cu, and iron, Fe, as the electrodes.

The students closed the switch, measured the voltage and determined the direction of the flow of electrons in the external circuit. A diagram depicting their experiment and a table of their results are shown below.



Results

voltage	0.35 V
movement of electrons	from Fe to Cu

a. Lemon juice can be considered as an aqueous solution of H^+ ions.

Write balanced half-equations for the reactions at the electrodes in the copper-iron lemon battery. 2 marks

- Cu electrode ______________________________
- Fe electrode ______________________________

b. Identify the electrode that acts as the cathode. 1 mark

____

c. **i.** Using the electrochemical series, state the theoretical voltage for this lemon battery. 1 mark

____

ii. Explain why the experimental value of the voltage is different from the theoretical voltage. 2 marks

____

____

____

d. The Cu electrode in the lemon battery is replaced with a freshly sanded strip of aluminium, Al.

For this aluminium-iron lemon battery, state the expected direction of electron flow. Justify your answer. 2 marks

Question 6 (13 marks)

Ethanoic acid, CH_3COOH, is the active ingredient in white vinegar. A sample of white vinegar is analysed to accurately determine the concentration of CH_3COOH using the following steps:

Step 1 – Dilute a 10.00 mL sample of the white vinegar to 100.00 mL in a volumetric flask.

Step 2 – Rinse the burette with the standardised sodium hydroxide solution, NaOH, that is provided.

Step 3 – Fill the burette with the standardised NaOH solution.

Step 4 – Pipette 20.00 mL of the diluted white vinegar solution into a 250 mL conical flask.

Step 5 – Add several drops of phenolphthalein indicator to the conical flask. Titrate the diluted white vinegar solution against the standardised NaOH solution.

Step 6 – Repeat Steps 3–5 until concordant results are obtained.

The equation for this analysis is

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

Data

aliquot of diluted white vinegar solution	20.00 mL
mean titre of NaOH solution	25.60 mL
concentration of standardised NaOH solution	0.1123 M

a. **i.** Calculate the concentration of CH_3COOH in the undiluted white vinegar sample. 3 marks

ii. If the burette is rinsed with water instead of the standardised NaOH solution, what would be the effect, if any, on the experimental value obtained for the concentration of CH_3COOH in white vinegar? Justify your answer. 2 marks

b. CH_3COOH is a weak acid.

i. Write the equation for the ionisation of CH_3COOH in water. 1 mark

ii. Write the expression for the acidity constant for CH_3COOH. 1 mark

c. An alternative method of determining the concentration of CH_3COOH in white vinegar is to measure the pH of the vinegar.

In another experiment, the pH of the undiluted white vinegar sample is found to be 2.29 using a calibrated digital pH probe.

Calculate the concentration of CH_3COOH in the undiluted white vinegar sample using the pH value provided. 2 marks

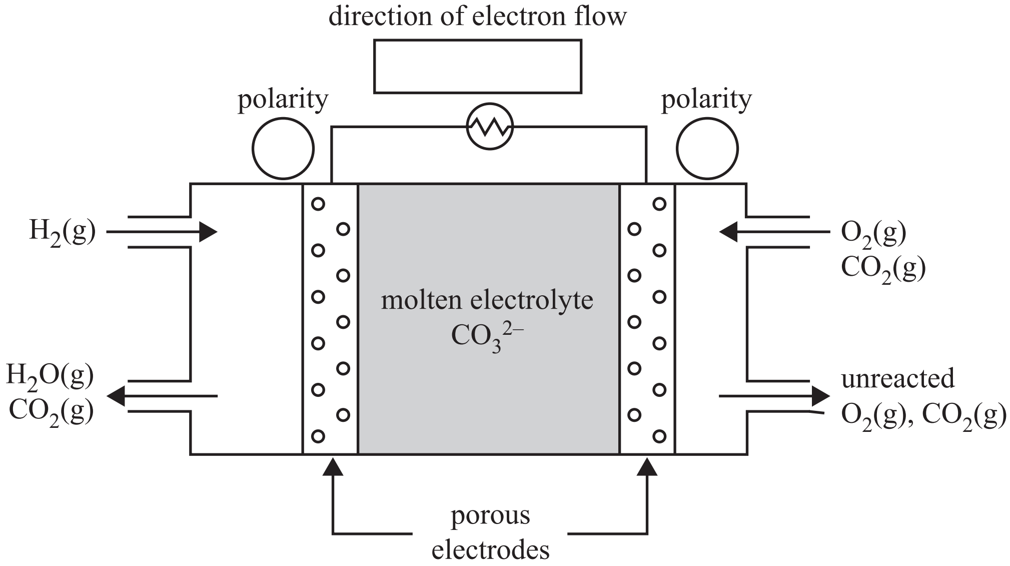
d. Suggest an explanation for any difference in the results obtained for the concentration of CH_3COOH from the two different experiments. 2 marks

e. A solution of CH_3COOH is diluted.

What effect, if any, would this have on the percentage ionisation of CH_3COOH? Justify your answer. 2 marks

Question 7 (7 marks)

Molten carbonate fuel cells (MCFCs) can be used as a stationary energy source. They operate at temperatures between 600 °C and 700 °C. The electrolyte in an MCFC is typically a molten mixture of lithium, sodium or potassium carbonates. A simplified diagram of an MCFC is shown below.



At one electrode of the MCFC, carbon dioxide, CO_2, gas reacts with oxygen, O_2, gas to form carbonate ions. At the other electrode, hydrogen, H_2, gas reacts with molten carbonate ions to form steam and CO_2 gas.

a. On the diagram above

i. label the polarity of the electrodes in the circles provided — 1 mark

ii. show the direction of electron flow in the external circuit by drawing an arrow in the box above the cell. — 1 mark

b. On a small scale, electricity can be generated in a variety of ways.

What is **one** advantage of producing electricity from an MCFC rather than from a petrol generator? — 1 mark

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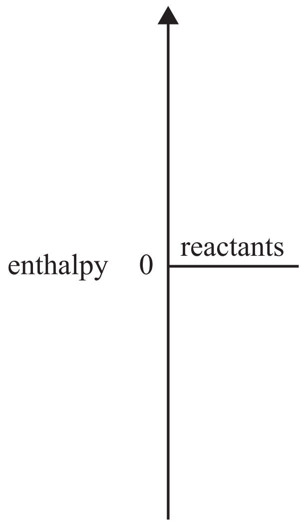
c. **i.** Write a balanced half-equation for the production of carbonate ions from CO_2 and O_2. 1 mark

ii. Calculate the volume of O_2 gas, at 665 °C and 2.50 atm, needed to produce 11.50 mol of carbonate ions. 3 marks

Question 8 (10 marks)

a. Write the balanced thermochemical equation for the complete combustion of methane. 2 marks

b. Complete and label the incomplete diagram provided below to show the energy profile for the combustion of methane. Label the ΔH, activation energy E_a and the products. 3 marks



c. A sample of biogas contains 78.0%, by mass, of methane. This biogas is burnt as a source of energy.

Calculate the maximum amount of energy, in kilojoules, that could be produced from the combustion of the methane present in 100 kg of this biogas. 3 marks

d. Identify one advantage and one disadvantage of using biogas as an energy source. 2 marks

Advantage ____

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Disadvantage ____

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Question 9 (13 marks)

When colourless hydrogen, H_2, gas and purple iodine, I_2, gas are mixed at high temperatures, they react to produce colourless hydrogen iodide, HI. This reaction does not go to completion but instead forms an equilibrium mixture. The equation for the reaction is shown below.

$$\underset{\text{colourless}}{H_2(g)} + \underset{\text{purple}}{I_2(g)} \rightleftharpoons \underset{\text{colourless}}{2HI(g)} \qquad \Delta H = \text{positive}$$

a. A chemist injects equal amounts of H_2 gas and I_2 gas into an insulated, evacuated and sealed 1.0 L container to which a temperature probe is attached. Both gases and the container had an initial temperature of 250 °C. The chemist's observations over the next hour are shown in the table below.

Observations

Time from moment of mixing (min)	Temperature (°C)	Colour of gas mixture
0	250	dark purple
15	239	purple
30	232	pale purple
45	232	pale purple (no further change)
60	232	pale purple (no further change)

Explain why the initial dark-purple colour of the gas mixture lightens to pale purple and then remains unchanged. 2 marks

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b. Identify **one** change that could be made to the original reaction's conditions so that equilibrium is reached at a faster rate. Justify your answer. 2 marks

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c. The chemist performs three tests to observe how the equilibrium mixture responds to change.

Predict the effect of each of the following changes on the colour of the gas mixture as it was after 60 minutes. Justify your answers. 9 marks

- Heat the gas mixture to a constant 280 °C. Assume the volume remains constant.

  Circle the predicted effect on the colour of the gas mixture.

  darker lighter unchanged

Justification ______________________________

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- Restore the temperature of the gas mixture to 232 °C. Increase the volume of the container to 1.5 L at a constant temperature of 232 °C.

  Circle the predicted effect on the colour of the gas mixture.

  darker lighter unchanged

Justification ______________________________

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- Restore the volume of the container to 1.0 L. Inject some HI into the container at a constant temperature of 232 °C.

  Circle the predicted effect on the colour of the gas mixture.

  darker lighter unchanged

Justification ______________________________

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Question 10 (7 marks)

A bomb calorimeter is calibrated using an electrical heater. The data for the calibration is given in Table 1.

Table 1

initial temperature of the water	22.53 °C
final temperature of the water	25.23 °C
current supplied	4.50 A
voltage supplied	5.80 V
time	300 s

a. Use the data in Table 1 to calculate the calibration factor for the bomb calorimeter. State your answer in kJ $°C^{-1}$. 2 marks

b. Methyl laurate (methyl dodecanoate), $C_{13}H_{26}O_2$, is a component of some biodiesels and is a liquid at room temperature. The previously calibrated bomb calorimeter is used to determine the molar enthalpy of $C_{13}H_{26}O_2$.

A sample of $C_{13}H_{26}O_2$ is injected into the bomb calorimeter and then burnt in excess oxygen. The data for this experiment is given in Table 2.

Table 2

initial temperature of the water	23.83 °C
final temperature of the water	35.15 °C
mass of $C_{13}H_{26}O_2$	0.905 g
molar mass of $C_{13}H_{26}O_2$	214.0 g mol^{-1}

Calculate the amount of energy released, in kilojoules, when the sample of $C_{13}H_{26}O_2$ was burnt. 1 mark

c. Calculate the molar enthalpy of combustion of $C_{13}H_{26}O_2$ using the data from this experiment. 3 marks

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d. Hence, complete the following balanced equation for the combustion of $C_{13}H_{26}O_2$ in excess oxygen. 1 mark

$2C_{13}H_{26}O_2(l) + 37O_2(g) \rightarrow 26CO_2(g) + 26H_2O(g)$ $\Delta H =$ ______________________

Question 11 (6 marks)

A Chemistry class was asked to determine the sodium content of a particular brand of potato chips by gravimetric analysis. The class' results would then be compared with the sodium content stated on the label on the packet of potato chips, which was 'sodium 644 mg/100 g'.

The following is an extract from the logbook of a particular pair of students identified as Pair A.

Procedure

1. Approximately 10 g of potato chips were weighed and then crushed with a mortar and pestle.
2. The oily mixture was transferred to a beaker and approximately 30 mL of water was added.
3. After stirring, the mixture was transferred to a separating funnel. The mixture was shaken for two minutes and allowed to settle.
4. The water layer was drained, then filtered. The residue was washed.
5. $AgNO_3$ solution was added to the filtrate until no more AgCl precipitate was observed to form.
6. The AgCl precipitate was filtered, rinsed and dried.
7. The AgCl precipitate was scraped off the filter paper and into a bottle, then weighed.

Equation

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Results

mass of potato chips	9.832 g
mass of dried AgCl	0.417 g

Calculations

n(AgCl) = 0.417/143.4 mol = 0.00291 mol

Thus n(Na^+) = 0.00291 mol

Hence m(Na^+) in 9.832 g of potato chips = 0.00291 × 23.0 = 0.0669 g

So m(NaCl) in 100 g of potato chips = 0.0669 × 100/9.832 g = 1.73 g

And m(Na) = 1.73/58.5 × 23.0 g/100 g = 0.680 g/100 g

The results for the entire class were recorded as follows.

Pair	A	B	C	D	E	F	G
Mass Na(g/100 g)	0.680	0.704	0.221	0.731	0.979	0.649	0.712

SECTION B – Question 11 – continued

Analyse and evaluate the experimental design and the class' results.

In your response, you should:

- comment on **one** assumption that has been made in conducting this experiment
- suggest a modification that could be made to the experimental design and justify your answer
- comment on the conclusions that might be drawn from the class' results
- compare the results obtained with the manufacturer's claim and suggest a reason for any difference.

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2017

CHEMISTRY

Written examination

Wednesday 7 June 2017

Reading time: 10.00 am to 10.15 am (15 minutes)
Writing time: 10.15 am to 12.45 pm (2 hours 30 minutes)

DATA BOOK

Instructions

- 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

Key: atomic number / symbol of element / relative atomic mass / name of element — 79
Au
197.0
gold

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	**57–71** lanthanoids	**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	**89–103** actinoids	**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		**114** **Fl** (289) flerovium		**116** **Lv** (292) livermorium		

57 **La** 138.9 lanthanum	**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

89 **Ac** (227) actinium	**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

Reaction	Standard electrode potential (E^0) in volts at 25 °C
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+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 (self-ionisation constant) for water (K_w) at 298 K	1.00×10^{-14} mol^2 L^{-2}
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

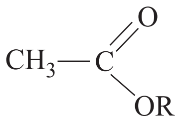
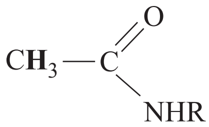
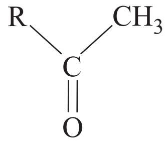
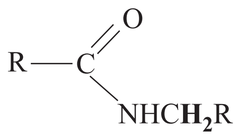
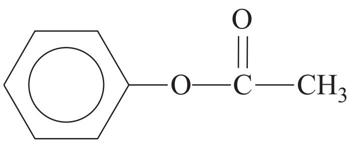
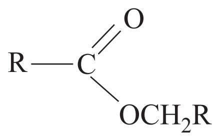
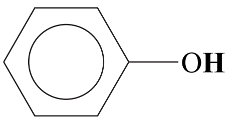
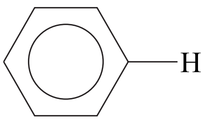
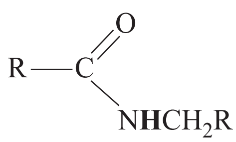
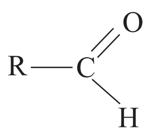
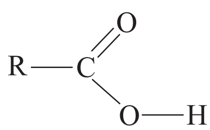
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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

Type of proton	Chemical shift (ppm)
 or 	2.0
	2.1–2.7
R–CH_2–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H₂**–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**H₂**	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	9–13

6. ^{13}C NMR data

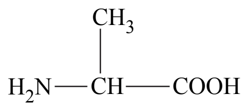
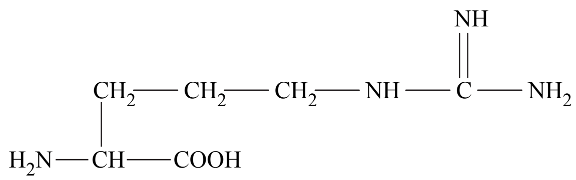
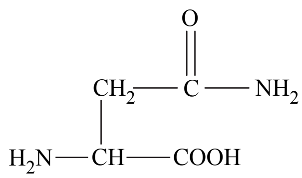
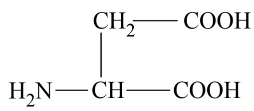
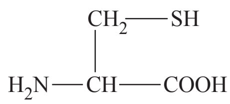
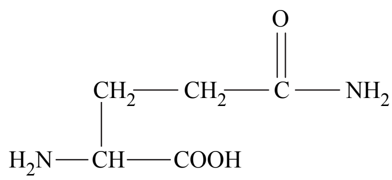
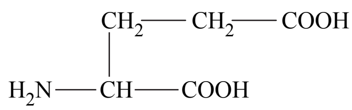
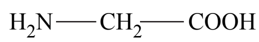
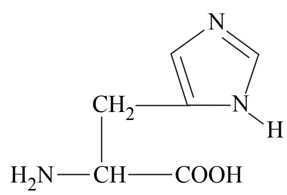
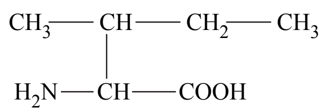
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

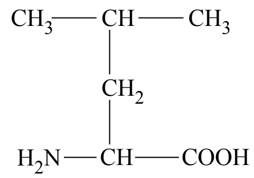
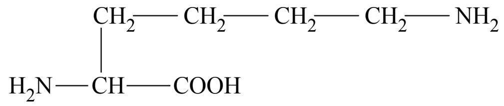
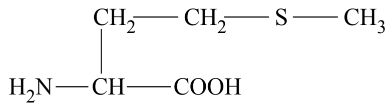
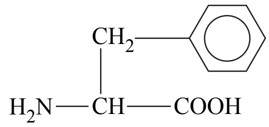
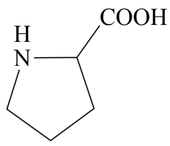
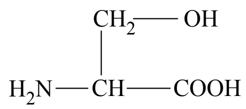
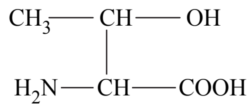
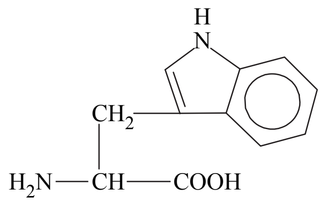
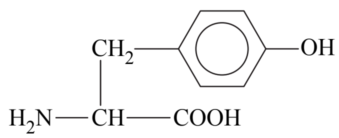
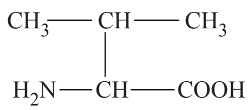
7. Infrared absorption data

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)

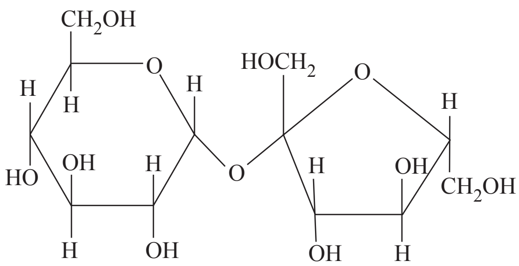
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

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

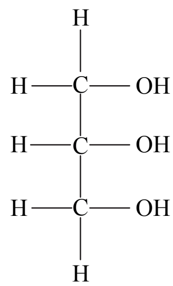
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

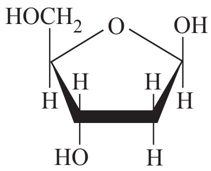
10. Structural formulas of some important biomolecules



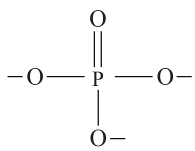
sucrose



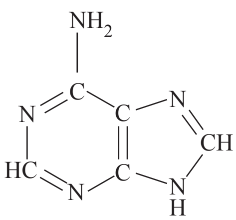
glycerol



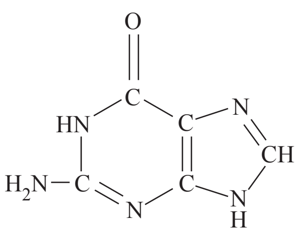
deoxyribose



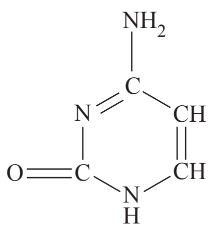
phosphate



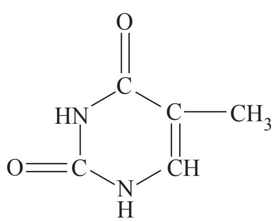
adenine



guanine



cytosine



thymine

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}	1	–3509
hexane	C_6H_{14}	1	–4158
octane	C_8H_{18}	1	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	1	–725
ethanol	C_2H_5OH	1	–1364
1-propanol	$CH_3CH_2CH_2OH$	1	–2017
2-propanol	$CH_3CHOHCH_3$	1	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK