VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2015

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

CHEMISTRY

Written examination

Tuesday 10 November 2015

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	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 41 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.

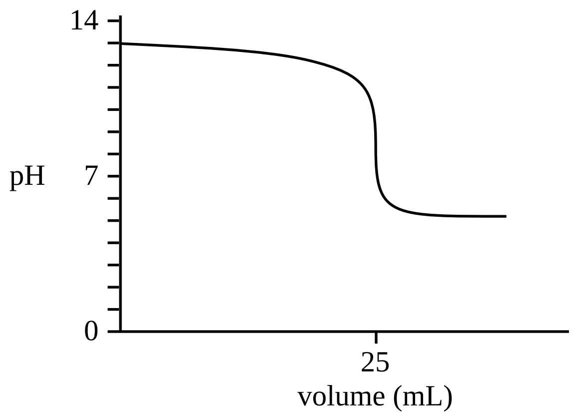
Marks will **not** be deducted for incorrect answers.

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

Question 1

Which one of the following graphs represents the pH change when a weak acid is added to a strong base?

A.



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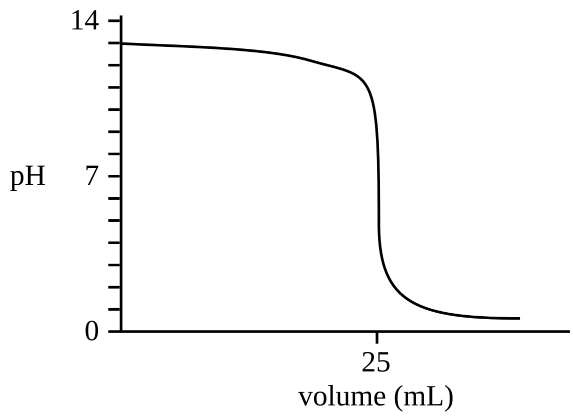

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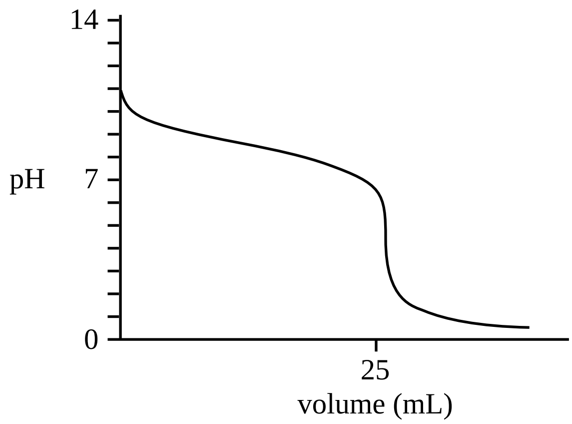

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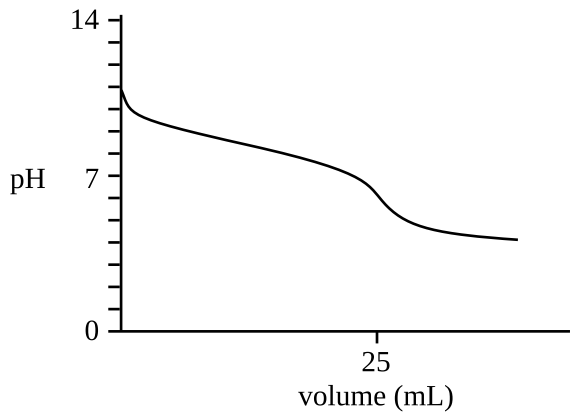

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Question 2

When concentrated sulfuric acid is added to dry sucrose, $C_{12}H_{22}O_{11}$, a black residue of pure carbon is produced.

An equation for the reaction is

$$2C_{12}H_{22}O_{11}(s) + 2H_2SO_4(aq) + O_2(g) \rightarrow 22C(s) + 2CO_2(g) + 24H_2O(g) + 2SO_2(g)$$

$$M(C_{12}H_{22}O_{11}) = 342.0 \text{ g mol}^{-1}$$

The mass of carbon residue that could be produced by the reaction of 50.0 g of sucrose with excess concentrated sulfuric acid is

A. 0.159 g

B. 0.877 g

C. 19.3 g

D. 38.6 g

Question 3

In an experiment, 0.051 mol of sodium hydroxide, NaOH, reacted completely with 0.017 mol of citric acid, $C_6H_8O_7$.

Which one of the following equations correctly represents the reaction between citric acid and the sodium hydroxide solution?

A. $NaOH(aq) + C_6H_8O_7(aq) \rightarrow NaC_6H_7O_7(aq) + H_2O(l)$

B. $2NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_2C_6H_6O_7(aq) + 2H_2O(l)$

C. $3NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

D. $4NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_4C_6H_4O_7(aq) + 4H_2O(l)$

Question 4

The emergency oxygen system in a passenger aircraft uses the decomposition of sodium chlorate to produce oxygen.

At 76.0 kPa and 292 K, each adult passenger needs about 1.60 L of oxygen per minute. The equation for the reaction is

$$2NaClO_3(s) \rightarrow 2NaCl(s) + 3O_2(g)$$

$$M(NaClO_3) = 106.5 \text{ g mol}^{-1}$$

The mass of sodium chlorate required to provide the required volume of oxygen for each adult passenger per minute is

A. 3.56 g

B. 5.34 g

C. 7.85 g

D. 53.7 g

Question 5

Which one of the following statements best defines a renewable energy resource?

A. an energy resource that will not be consumed within our lifetime

B. an energy resource that does not produce greenhouse gases when consumed

C. an energy resource derived from plants that are grown for the production of liquid biofuels

D. an energy resource that can be replaced by natural processes within a relatively short time

Question 6

In which one of the following compounds is sulfur in its lowest oxidation state?

A. SO_3

B. HSO_4^-

C. SO_2

D. Al_2S_3

Question 7

Retention time can be used to identify a compound in a mixture using gas chromatography.

Which one of the following will **not** affect the retention time of a compound in a gas chromatography column?

A. concentration of the compound

B. nature of the stationary phase

C. rate of flow of the carrier gas

D. temperature of the column

Question 8

Consider the following statements about a high-performance liquid chromatography (HPLC) column that uses a polar solvent and a non-polar stationary phase to analyse a solution:

Statement I – Polar molecules in the solution will be attracted to the solvent particles by dipole-dipole attraction.

Statement II – Non-polar molecules in the solution will be attracted to the stationary phase by dispersion forces.

Statement III – Polar molecules in the solution will travel through the HPLC column more rapidly than non-polar molecules.

Which of these statements are true?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Question 9

Which two isomers of $C_3H_6Br_2$ have two peaks (other than the TMS peak) in their ^{13}C NMR spectrum?

A. $CH_3CBr_2CH_3$ and $CHBr_2CH_2CH_3$

B. $CHBr_2CH_2CH_3$ and $CH_2BrCHBrCH_3$

C. $CH_2BrCHBrCH_3$ and $CH_2BrCH_2CH_2Br$

D. $CH_2BrCH_2CH_2Br$ and $CH_3CBr_2CH_3$

Question 10

The high-resolution proton NMR spectrum of chloroethane has two sets of peaks. Both peaks are split.

Which of the following correctly describes the splitting pattern?

A. a singlet and a doublet

B. a doublet and a doublet

C. a doublet and a triplet

D. a triplet and a quartet

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SECTION A – continued

Question 11

Electromagnetic radiation of a specific wavelength can interact with some molecules and atoms by promoting electrons at a low energy level to higher energy levels.

Which pair of analytical techniques relies on the measurement of these electronic transitions?

A. atomic absorption spectroscopy and UV-visible spectroscopy

B. infrared spectroscopy and atomic absorption spectroscopy

C. proton NMR spectroscopy and UV-visible spectroscopy

D. mass spectrometry and infrared spectroscopy

Question 12

Which one of the following techniques is used to distinguish between 1,1,1-trichloropropane and 1,2,3-trichloropropane?

A. atomic absorption spectroscopy

B. UV-visible spectroscopy

C. proton NMR spectroscopy

D. gravimetric analysis

Question 13

What is the name of the product formed when chlorine, Cl_2, reacts with but-1-ene?

A. 1,2-dichlorobutane

B. 1,4-dichlorobutane

C. 2,2-dichlorobutane

D. 2,3-dichlorobutane

Question 14

Which one of the following is **not** true of protein denaturation?

A. It could result from a temperature change.

B. It may be caused by a pH change.

C. It alters the primary structure.

D. It results in a change in the shape of the protein.

Question 15

Which compound of 24 carbon atoms has the **least** number of carbon–hydrogen, C–H, bonds?

A. a polypeptide that consists of four isoleucine residues

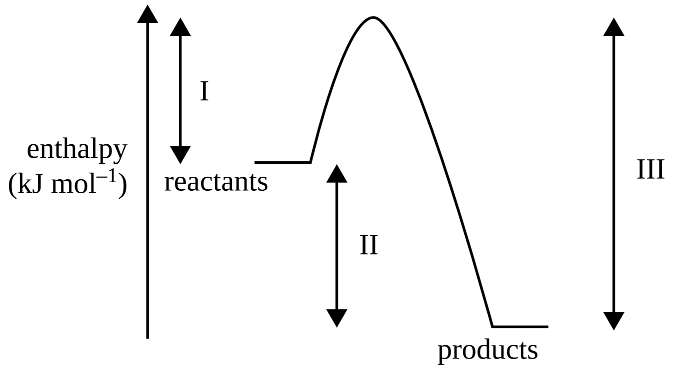
B. a molecule of lignoceric acid, which is a saturated fatty acid

C. a segment of polyethene that consists of 12 ethene residues

D. a molecule of maltotetraose, which is a polysaccharide that has four glucose residues

Question 16

Consider the following energy profile for a particular chemical reaction, where I, II and III represent enthalpy changes during the reaction.



Which one of the following statements is correct?

A. The activation energy for the reverse reaction is (III–II).

B. The net energy released for the forward reaction is represented by II.

C. The energy required to break the reactant bonds is represented by II.

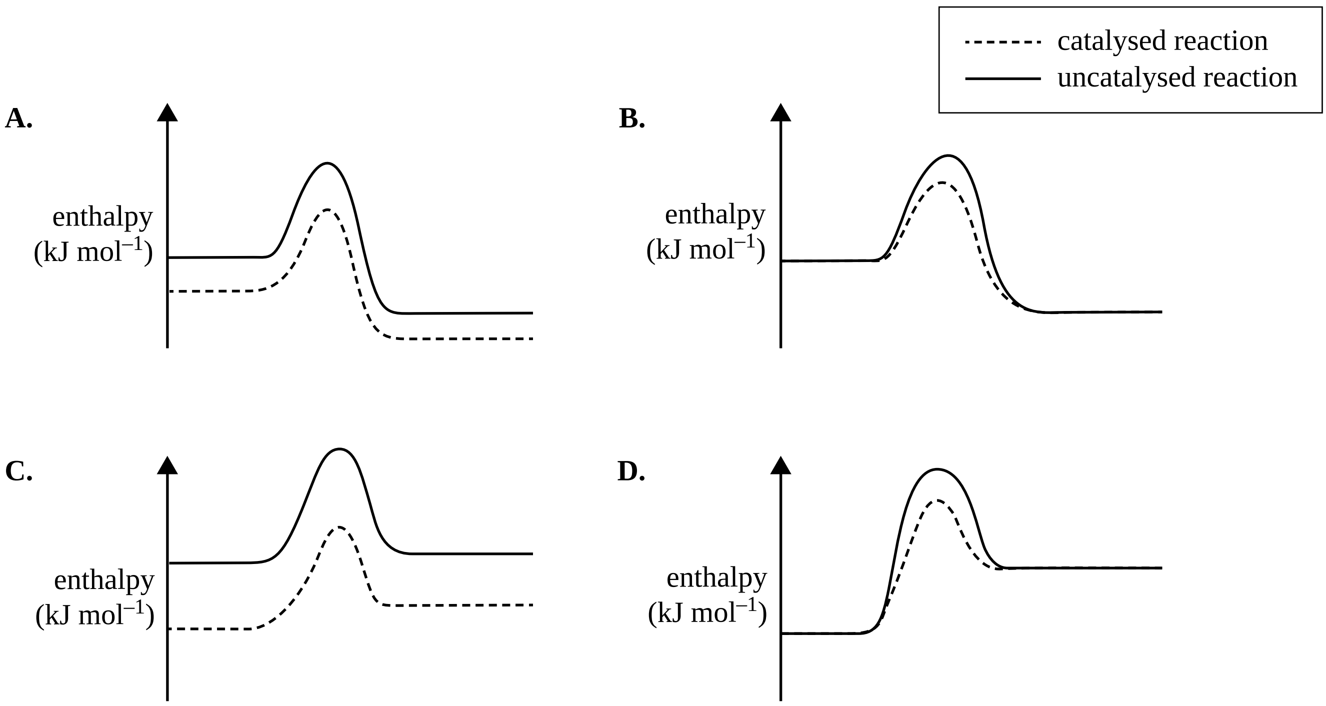
D. The energy released by the formation of new bonds is represented by I.

Question 17

The oxidation of sulfur dioxide is an exothermic reaction. The reaction is catalysed by vanadium(V) oxide.

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

Which one of the following energy profile diagrams correctly represents both the catalysed and the uncatalysed reaction?



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Question 18

Consider the following equations.

$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H = +30$ kJ mol^{-1}

$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ $\Delta H = +10$ kJ mol^{-1}

The enthalpy change for the reaction $N_2O_4(g) \rightarrow 2NO_2(g)$ is

A. –50 kJ mol^{-1}

B. +20 kJ mol^{-1}

C. +50 kJ mol^{-1}

D. +70 kJ mol^{-1}

Use the following information to answer Questions 19–21.

A solution contains an equilibrium mixture of two different cobalt(II) ions.

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq)} + 6H_2O(l)$$

The solution contains pink $Co(H_2O)_6^{2+}$ ions and blue $CoCl_4^{2-}$ ions, and the solution has a purple colour.

10 mL of the purple solution was poured into each of three test tubes labelled X, Y and Z.

Question 19

The test tubes were placed in separate water baths, each having a different temperature. The resulting colour changes in the equilibrium mixtures were observed.

The results are shown in the following table.

Test tube	Water bath temperature	Observation
X	20 °C	solution remained purple
Y	80 °C	solution turned blue
Z	0 °C	solution turned pink

Which one of the following conclusions can be drawn from these observations?

A. Cooling significantly reduced the volume of the solution and this favoured the forward reaction.

B. Heating caused some water to evaporate and this favoured the reverse reaction.

C. Heating increased the value of the equilibrium constant for the reaction.

D. The forward reaction must be exothermic.

Question 20

Which one of the following changes would cause 10 mL of the purple cobalt(II) ion solution to turn blue?

A. the addition of a few drops of 10 M hydrochloric acid at a constant temperature

B. the addition of a few drops of 0.1 M silver nitrate at a constant temperature

C. the addition of a few drops of a catalyst at a constant temperature

D. the addition of a few drops of water at a constant temperature

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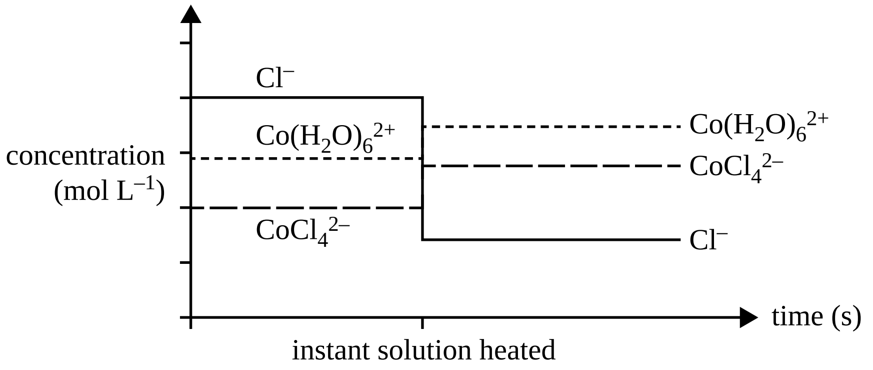
Question 21

When the equilibrium system was heated, the colour changed from purple to blue.

Which one of the following concentration–time graphs best represents this change?

A.



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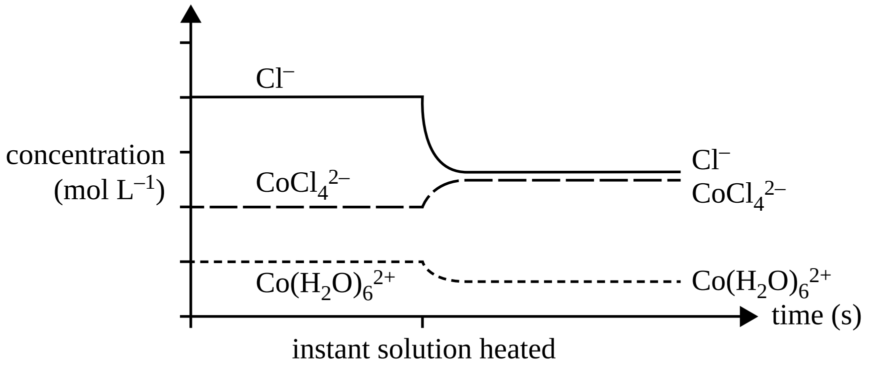
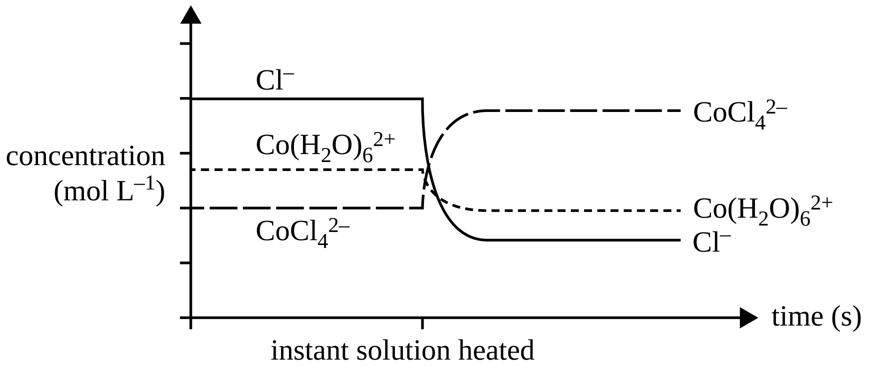
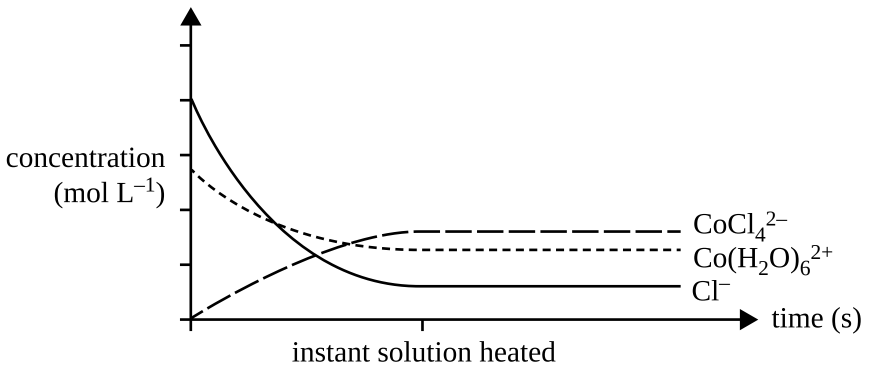


C.



D.



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Question 22

What is the pH of a 0.0500 M solution of barium hydroxide, $Ba(OH)_2$?

A. 1.00

B. 1.30

C. 12.7

D. 13.0

Question 23

The following table shows the value of the ionisation constant of pure water at various temperatures and at a constant pressure.

Temperature (°C)	0	25	50	75	100
K_w	1.1×10^{-15}	1.0×10^{-14}	5.5×10^{-14}	2.0×10^{-13}	5.6×10^{-13}

Given this data, which one of the following statements about pure water is correct?

A. The $[OH^-]$ will decrease with increasing temperature.

B. The $[H_3O^+]$ will increase with increasing temperature.

C. Its pH will increase with increasing temperature.

D. Its pH will always be exactly 7 at any temperature.

Question 24

The reaction between hydrogen peroxide and ammonium ions is represented by the following equation.

$$3H_2O_2(aq) + 2NH_4^+(aq) \rightarrow N_2(g) + 2H^+(aq) + 6H_2O(l)$$

Which one of the following is the correct half-equation for the reduction reaction?

A. $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$

B. $2NH_4^+(aq) \rightarrow N_2(g) + 8H^+(aq) + 6e^-$

C. $2NH_4^+(aq) + 2e^- \rightarrow N_2(g) + 4H_2(g)$

D. $H_2O_2(aq) + 2H_2O(l) \rightarrow 2O_2(g) + 6H^+(aq) + 6e^-$

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Question 25

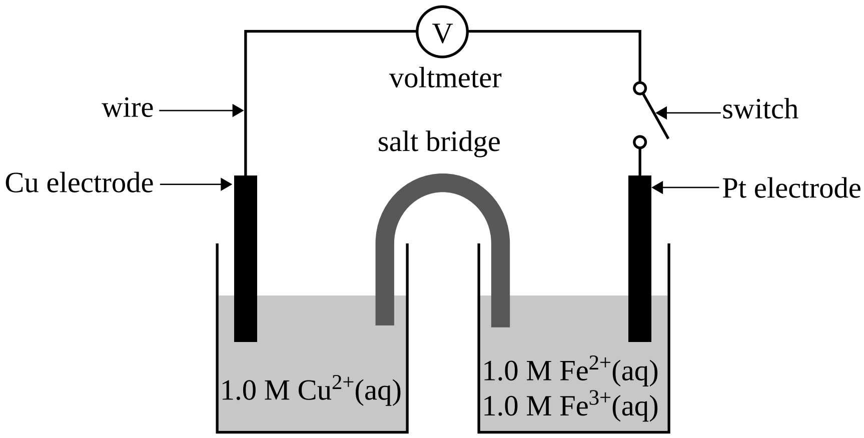
Solution I – 1.0 M NaCl
Solution II – 1.0 M $CuCl_2$
Solution III – 1.0 M $MgCl_2$

Which solution or solutions above will react with Zn powder?

A. Solution I only
B. Solution II only
C. Solutions I and III only
D. Solutions I, II and III

Question 26

The switch in the galvanic cell below may be closed to allow a current to flow through the circuit.



Which of the following best describes the direction of electron flow in the external circuit or wire, and the maximum predicted cell voltage measured at the voltmeter when the switch is closed?

	Direction of electron flow is towards the	Maximum predicted cell voltage is
A.	Cu electrode	0.43 V
B.	Cu electrode	1.11 V
C.	Pt electrode	0.43 V
D.	Pt electrode	1.11 V

Question 27

Which one of the following classes of electrochemical cells involves **only** a non-spontaneous redox reaction?

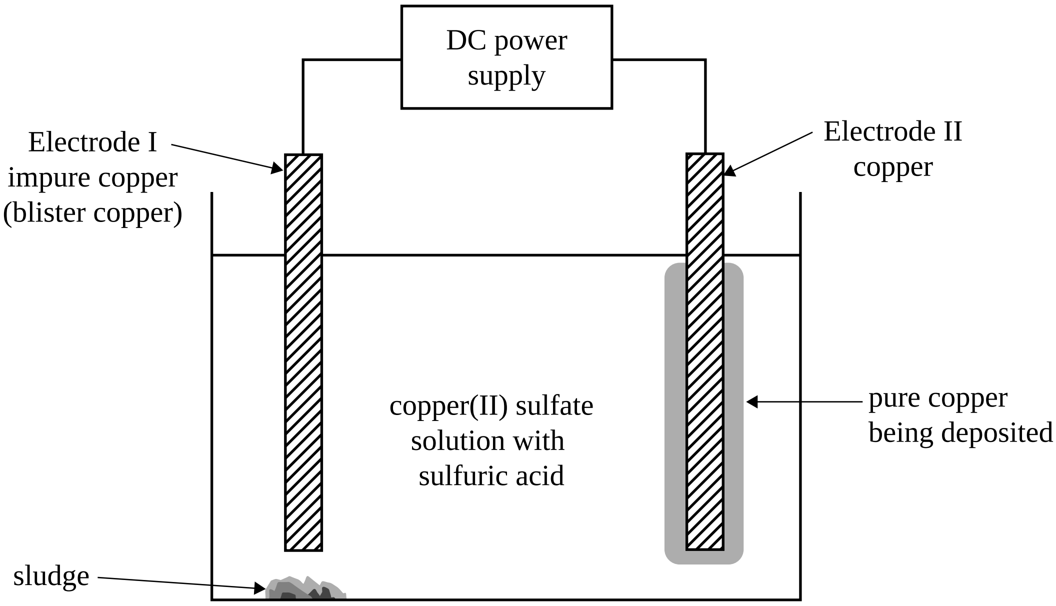
A. fuel cells
B. electroplating cells
C. primary galvanic cells
D. secondary galvanic cells

Use the following information to answer Questions 28–30.

An electrolytic cell is set up to obtain pure copper from an impure piece of copper called 'blister copper'.

The electrolyte solution contains both copper(II) sulfate and sulfuric acid. The blister copper, Electrode I, contains impurities such as zinc, cobalt, silver, gold, nickel and iron. The cell voltage is adjusted so that only copper is deposited on Electrode II. Sludge, which contains some of the solid metal impurities present in the blister copper, forms beneath Electrode I. The other impurities remain in solution as ions.

The diagram below represents the cell.



Question 28

The solid metal impurities that are found in the sludge are

A. gold, nickel and cobalt.

B. cobalt, nickel and iron.

C. nickel and iron.

D. silver and gold.

Question 29

Which of the following correctly shows both the equation for the reaction occurring at the cathode and the polarity of Electrode I?

	Cathode reaction	Polarity of Electrode I
A.	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	positive
B.	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	negative
C.	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	negative
D.	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	positive

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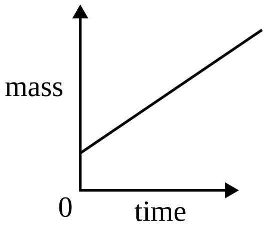
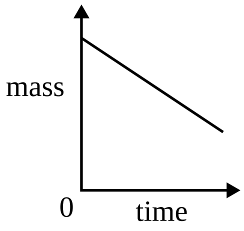
Question 30

Which one of the following graphs best shows the change in mass of Electrode I over a period of time, starting from the moment the power supply is connected?

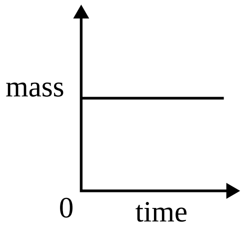
A.



B.



C.



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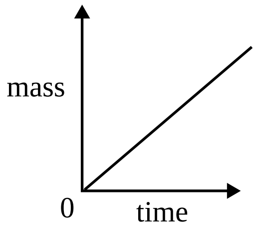

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END OF SECTION A

SECTION B

Instructions for Section B

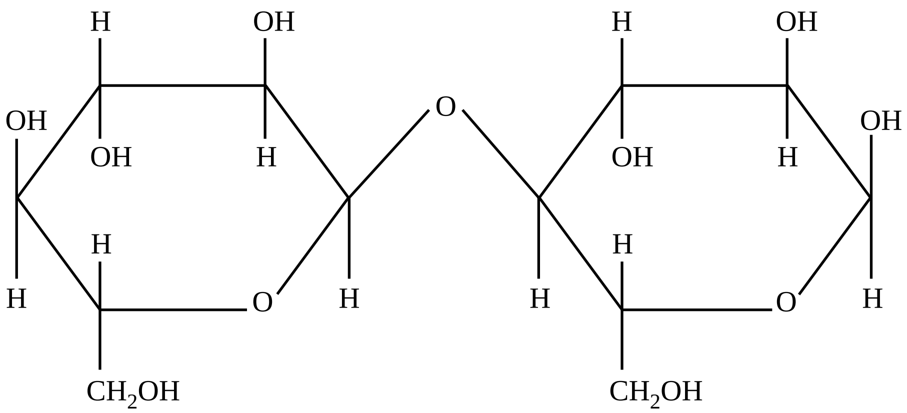
Answer **all** questions in the spaces provided. Write using black or blue pen.

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 (4 marks)

Maltose is a sugar often used in the production of beer. The structure of maltose is shown below.



a. In the space provided below, draw a structure of the monomer from which maltose is derived. 1 mark

b. What is the name of the monomer drawn in **part a.** on page 14? 1 mark

____

c. Identify the type of reaction that occurs when these monomers combine to form maltose. 1 mark

____

d. Name the linkage joining the monomers in maltose. 1 mark

____

Question 2 (8 marks)

A small group of Chemistry students analysed household cloudy ammonia (a detergent used in domestic cleaning). A back titration was used because the detergent contained ammonia, which is very volatile.

The teacher's instructions for the analysis were as follows:

Step 1 – Pipette 20.00 mL of the cloudy ammonia into a 250.00 mL volumetric flask.

Step 2 – Add 100.00 mL of hydrochloric acid, which is in excess.

Step 3 – Make the volume up to the 250 mL mark with deionised water. Label this 'Solution A'.

Step 4 – Fill a burette with sodium hydroxide solution.

Step 5 – Transfer a 20.00 mL aliquot of Solution A (from Step 3) to a titration flask. Add indicator and titrate with the sodium hydroxide solution.

Step 6 – Repeat Step 5 until three concordant results are obtained.

The relevant equations for this analysis are as follows.

the equilibrium mixture in cloudy ammonia	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
the initial reaction with supplied HCl	$NH_4OH(aq) + HCl(aq) \rightarrow NH_4Cl(aq) + H_2O(l)$
the titration reaction between excess HCl and NaOH	$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

The students' results for the analysis are shown in the table below.

Measurement	Result
volume of cloudy ammonia sample	20.00 mL
volume of HCl added to cloudy ammonia sample	100.00 mL
concentration of HCl added to cloudy ammonia sample	0.5866 M
total volume of Solution A	250.00 mL
volume of aliquot of Solution A used in each titration	20.00 mL
concentration of NaOH solution	0.1194 M
mean titre	22.75 mL

SECTION B – Question 2 – continued

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a. Calculate the amount, in moles, of hydrochloric acid initially added to the undiluted ammonia sample. 1 mark

b. Calculate the amount, in moles, of excess hydrochloric acid in a 20.00 mL aliquot of the diluted solution from Step 5. 2 marks

The manufacturer claims that the detergent contains 45.2 g L^{-1} ammonia as ammonium hydroxide, NH_4OH.

c. **i.** Use the students' experimental results to calculate 4 marks

- the amount, in moles, of HCl that reacted with the ammonia in the titration flask

- the amount, in moles, of ammonia initially pipetted into the 250 mL volumetric flask

- the concentration, in g L^{-1}, of NH_4OH in the cloudy ammonia sample.

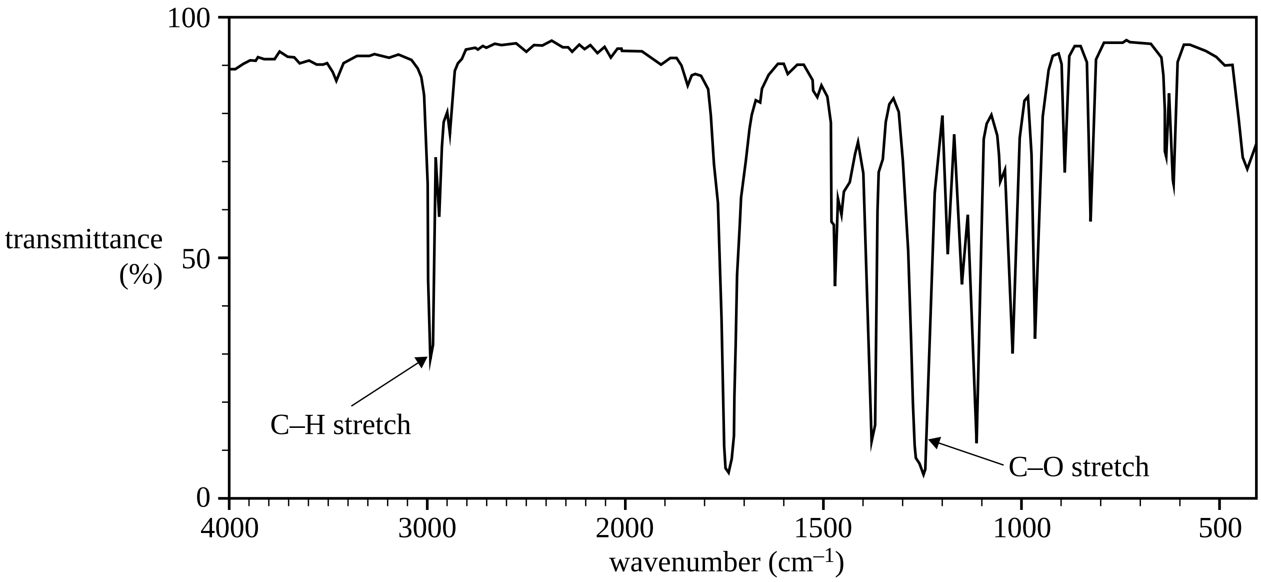
ii. Provide **one** explanation for any difference between the students' results and the manufacturer's claim. 1 mark

Question 3 (6 marks)

While cleaning out a laboratory shelf labelled 'Carboxylic acids and esters', a chemist discovers a bottle simply labelled '$C_5H_{10}O_2$'. To identify the molecular structure of the contents of the bottle, a sample is submitted for analysis using infrared spectroscopy, and ^1H and ^{13}C NMR spectroscopy.

The spectra are shown on pages 18–20. Use the information provided to answer the questions on pages 20 and 21.

Infrared (IR) spectrum



Data: SDBSWeb; http://sdbs.db.aist.go.jp
(National Institute of Advanced Industrial Science and Technology)

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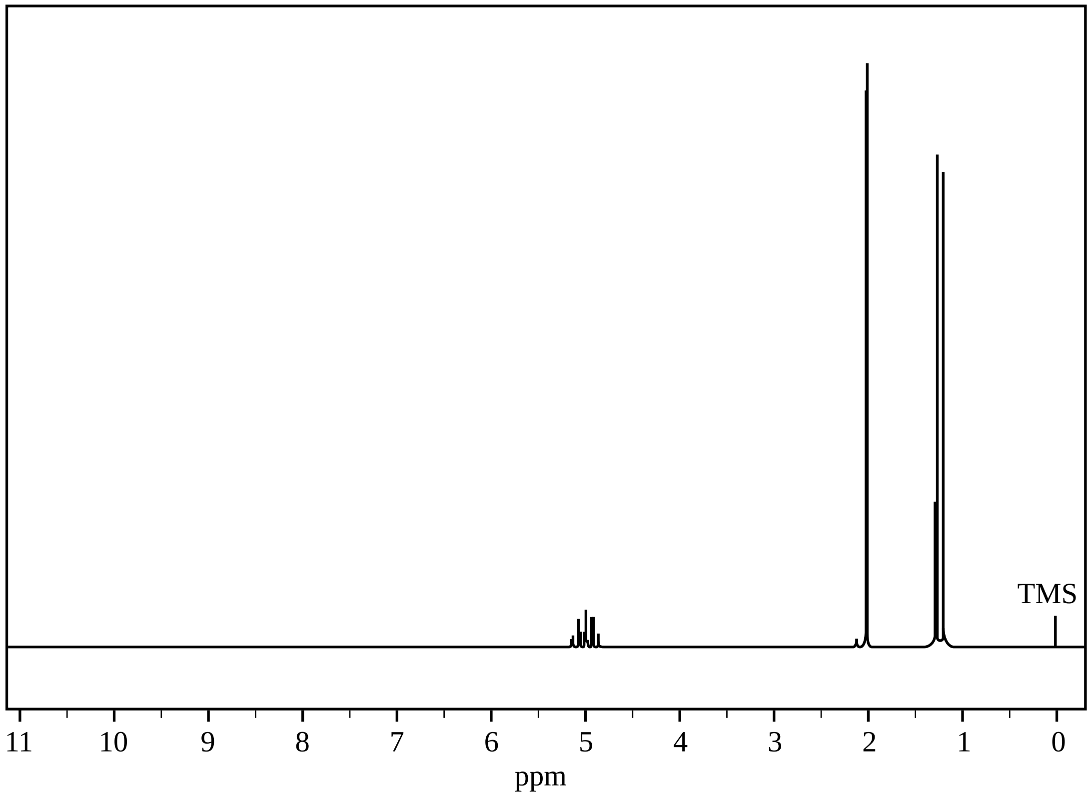
^{1}H NMR spectrum



Data: SDBSWeb; http://sdbs.db.aist.go.jp
(National Institute of Advanced Industrial Science and Technology)

^{1}H NMR data

Chemical shift (ppm)	Relative peak area	Peak splitting
1.2	6	doublet (2)
2.0	3	singlet (1)
5.0	1	septet (7)

SECTION B – Question 3 – continued
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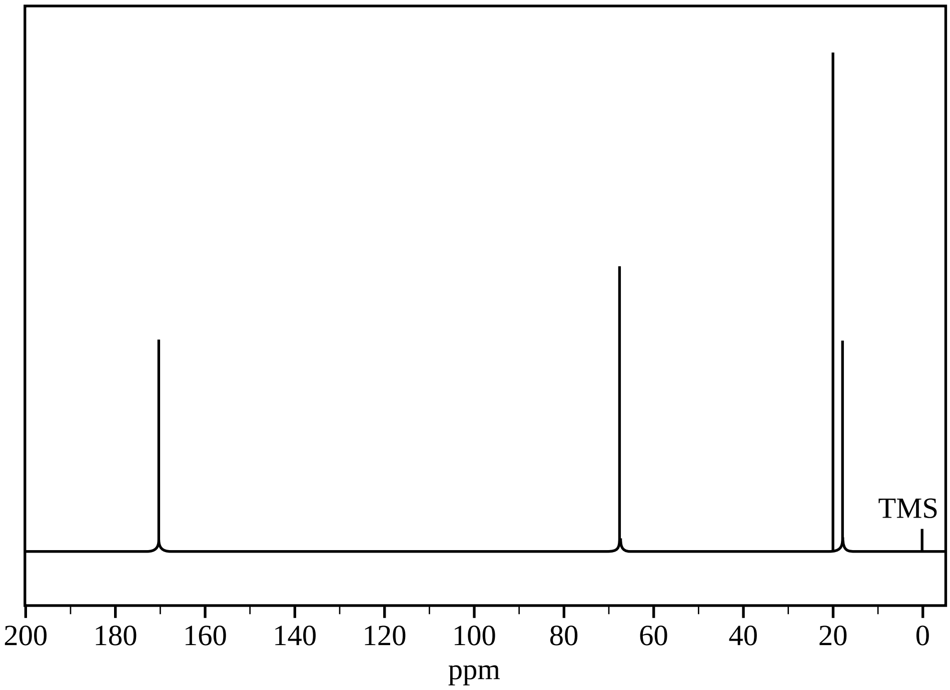
^{13}C NMR spectrum



Data: SDBSWeb; http://sdbs.db.aist.go.jp
(National Institute of Advanced Industrial Science and Technology)

a. Based on the IR spectrum, determine whether the molecule is a carboxylic acid or an ester. Provide a reason for your answer. 2 marks

b. Use the information provided in the ^{1}H and ^{13}C NMR spectra to identify the number of different chemical environments for hydrogen and carbon in this molecule. 2 marks

Number of different chemical environments for hydrogen	
Number of different chemical environments for carbon	

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c. Draw a structure for this molecule. 2 marks

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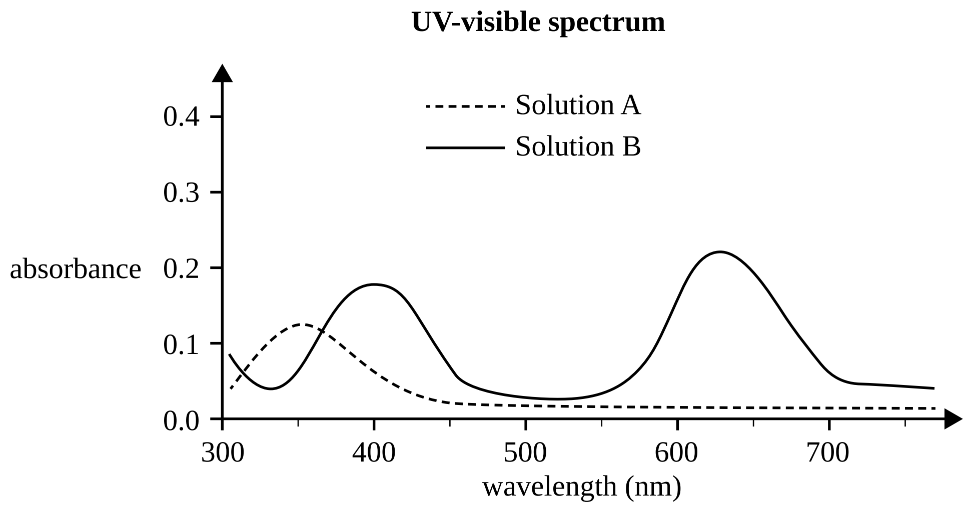
Question 4 (6 marks)

UV-visible spectroscopy was used to measure the spectra of two solutions, A and B. Solution A was a pink colour, while Solution B was a green colour.

The analyst recorded the absorbance of each solution over a range of wavelengths on the same axes. The resultant absorbance spectrum is shown below.



a. If 10.00 mL of Solution A was mixed with 10.00 mL of Solution B, which wavelength should be used to measure the absorbance of Solution B in this mixture? Justify your answer. 2 marks

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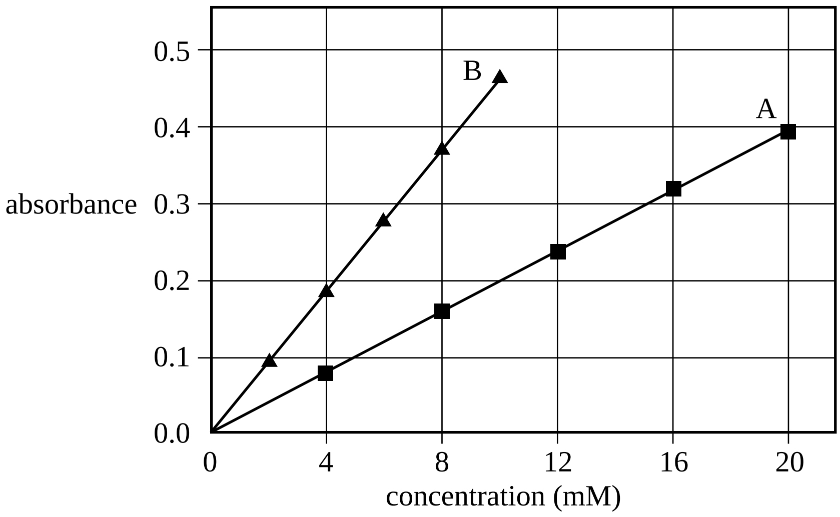
The analyst used two sets of standard solutions and blanks to determine the calibration curves for the two solutions. The absorbances were plotted on the same axes. The graph is shown below.



b. The analyst found that, when it was measured at the appropriate wavelength, Solution A had an absorbance of 0.2

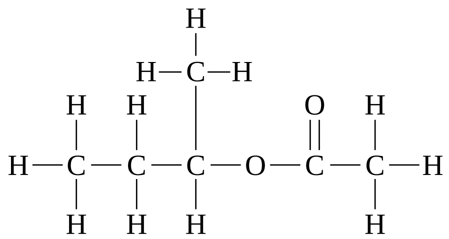
If Solution A was cobalt(II) nitrate, $Co(NO_3)_2$, determine its concentration in mg L^{-1}.
$M(Co(NO_3)_2)$ = 182.9 g mol^{-1} 1 mM = 10^{-3} M 2 marks

c. In **another** mixture, the pink compound in Solution A and the green compound in Solution B each have a concentration of approximately 1.5×10^{-2} M.

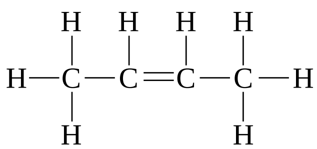
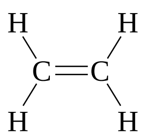
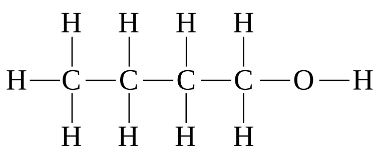
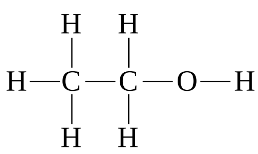
Could the analyst reliably use both of the calibration curves to determine the concentrations for Solution A and Solution B by UV-visible spectroscopy? Justify your answer. 2 marks

Question 5 (10 marks)

a. A reaction pathway is designed for the synthesis of the compound that has the structural formula shown below.

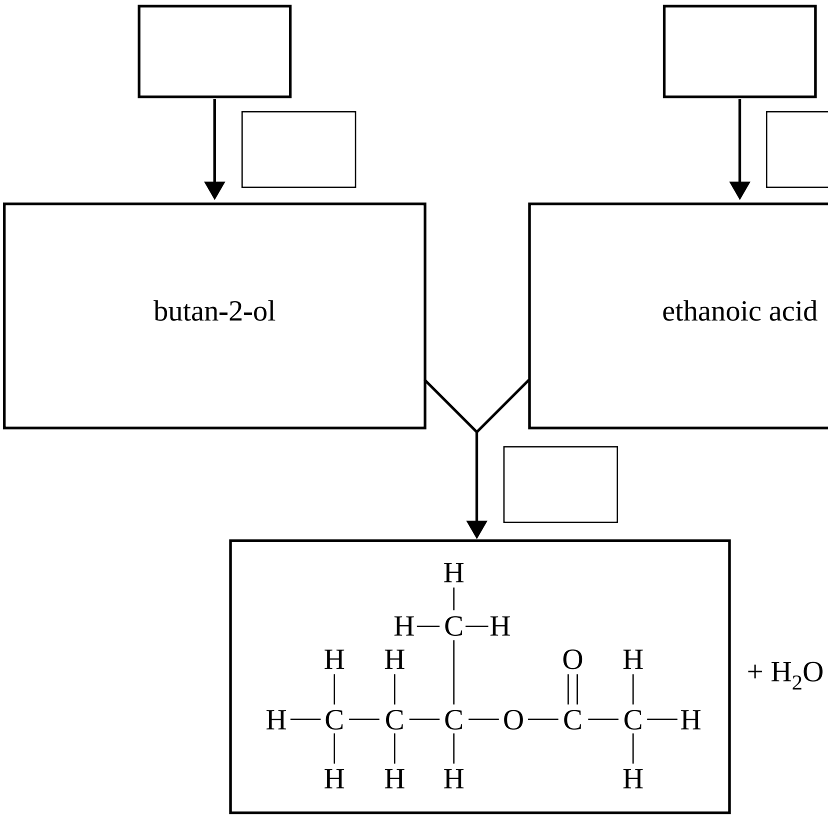


The table below gives a list of available organic reactants and reagents.

Letter	Available organic reactants and reagents
A	acidified $KMnO_4$
B	concentrated H_2SO_4
C	H_2O and H_3PO_4
D	
E	
F	
G	

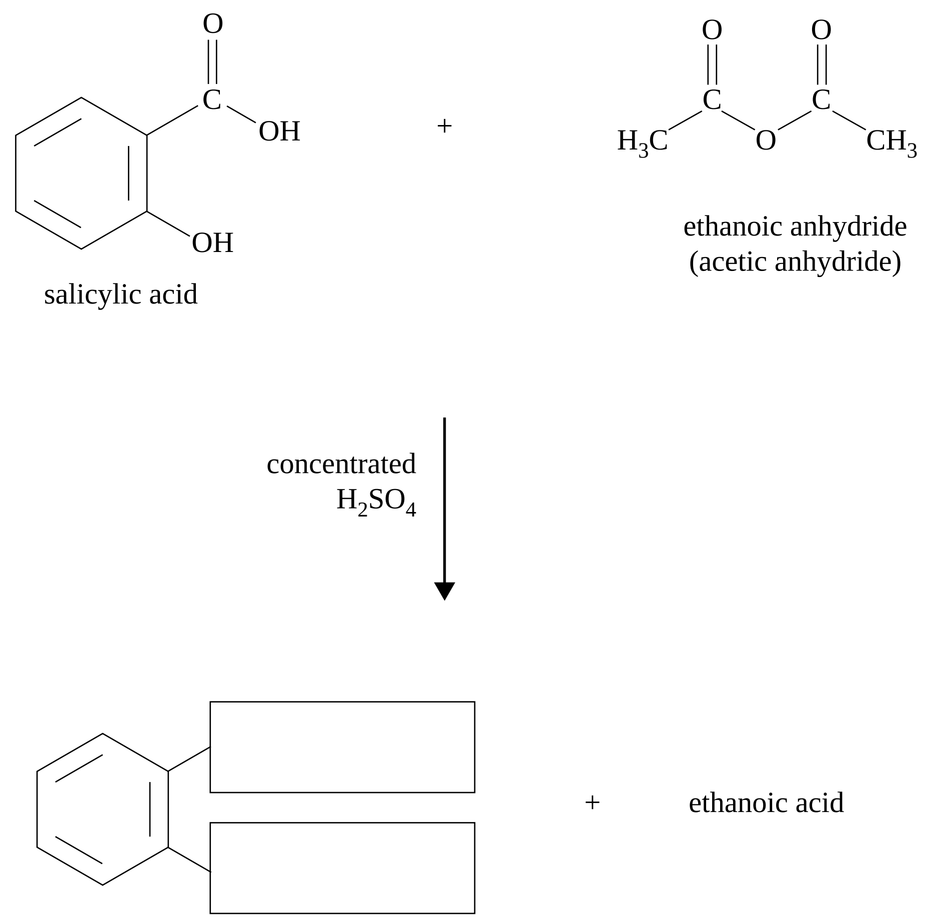
Complete the reaction pathway design flow chart on page 25. Write the corresponding letter for the structural formula of all organic reactants in each of the boxes provided. The corresponding letter for the formula of other necessary reagents should be shown in the boxes next to the arrows. 5 marks

Reaction pathway design flow chart



b. In the space below, draw the full structural formula of an isomer of butan-2-ol. 1 mark

c. A student mixed salicylic acid with ethanoic anhydride (acetic anhydride) in the presence of concentrated sulfuric acid. The products of this reaction were the painkilling drug aspirin (acetyl salicylic acid) and ethanoic acid.



aspirin
(incomplete structure)

i. An incomplete structure of the aspirin molecule is shown above.

Complete the structure by filling in the two boxes provided in the diagram. 2 marks

ii. Sulfuric acid is used as a catalyst in this reaction.

Explain how a catalyst increases the rate of this reaction. 2 marks

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Question 6 (9 marks)

After a murder had been committed, a forensic chemist obtained crime scene blood samples and immediately placed them in two sterile containers labelled Sample I and Sample II.

a. The chemist discovered that Sample I contained a particular protein, which was analysed to reveal the following sequence of amino acid residues.

-ser-gly-tyr-

i. Referring to the data book, draw the structure of this sequence of amino acid residues and circle one amide link/peptide bond in your drawing. 3 marks

ii. The protein was hydrolysed in the presence of a suitable enzyme and the amino acid glycine was isolated. The glycine sample was then dissolved in a 0.1 M solution of sodium hydroxide.

Draw the structure of glycine in this solution. 1 mark

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b. Sample II was carefully treated to replicate and extract sections of the DNA. It was found that the DNA matched that of one of the murder suspects.

i. A section of the suspect's DNA contained a unique fault within the base sequence, -CAGCAG-, repeated many times.

What would be the base sequence matching this in the complementary strand? 1 mark

____

ii. What kind of bonding operates between base pairs? Is this bonding stronger or weaker than the bonding between the components in a single strand of DNA? 2 marks

____

____

iii. To what component of a DNA strand are the bases attached? What kind of bonding operates between this component and the base? 2 marks

____

____

Question 7 (7 marks)

Consider the reaction shown in the following equation.

$$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g) \qquad \Delta H = -16.1 \text{ kJ mol}^{-1},\ K_c = 1.3 \times 10^{-2} \text{ M}^{-1} \text{ at 1000 K}$$

a. Write an expression for the equilibrium constant for this reaction. 1 mark

b. 10.0 mol of NOBr, 10.0 mol of NO and 5.0 mol of Br_2 are placed in a 1.0 L container at 1000 K.

Predict in which direction the reaction will proceed. Justify your answer. 3 marks

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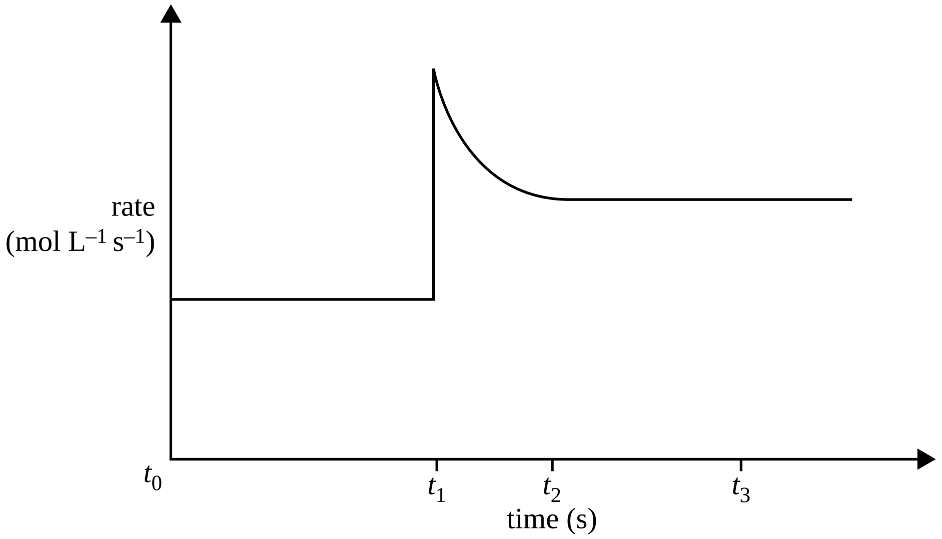
c. A mixture of NO, NOBr and Br_2 is initially at equilibrium.

The following graph shows how the **rate** of formation of NOBr in the mixture changes when the volume of the reaction vessel is decreased at time t_1.



Use collision theory and factors that affect the rate of a reaction to explain the shape of the graph at the time intervals indicated in the following table. 3 marks

Time	Explanation
between t_0 and t_1	
at t_1	
between t_1 and t_2	

Question 8 (7 marks)

Hydrogen sulfide, in solution, is a diprotic acid and ionises in two stages.

$$H_2S(aq) + H_2O(l) \rightleftharpoons HS^-(aq) + H_3O^+(aq) \quad K_{a1} = 9.6 \times 10^{-8}\ M$$

$$HS^-(aq) + H_2O(l) \rightleftharpoons S^{2-}(aq) + H_3O^+(aq) \quad K_{a2} = 1.3 \times 10^{-14}\ M$$

A student made two assumptions when estimating the pH of a 0.01 M solution of H_2S:

1. The pH can be estimated by considering only the first ionisation reaction.
2. The concentration of H_2S at equilibrium is approximately equal to 0.01 M.

a. Explain why these two assumptions are justified. 2 marks

Assumption 1 ______________________________

____

____

Assumption 2 ______________________________

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b. Use the two assumptions given above to calculate the pH of a 0.01 M solution of H_2S. 3 marks

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c. Some solid sodium hydrogen sulfide, NaHS, is added to a 0.01 M solution of H_2S.

Predict the effect of this addition on the pH of the hydrogen sulfide solution. Justify your prediction. 2 marks

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Question 9 (13 marks)

Biodiesel is a mixture of fatty acid methyl esters. A particular triglyceride used in the manufacture of biodiesel was analysed by reacting it with excess methanol and a potassium hydroxide catalyst. This reaction produced fatty acid methyl esters and glycerol.

At the conclusion of the reaction, two liquid layers were observed in the reaction vessel. The bottom layer was an aqueous solution.

a. Other than water, name **one** substance that would be found in the aqueous layer. Justify your answer. 2 marks

The top layer is a non-aqueous mixture. It was separated from the aqueous layer and then purified. The non-aqueous layer was found to contain the fatty acid methyl esters.

A small sample of the purified ester mixture was passed through a gas chromatograph (GC) attached to a mass spectrometer.

The chromatogram showed two peaks, indicating that the ester mixture contained two different fatty acid methyl esters, A and B. The peak area of each compound and the mass-to-charge ratio of the molecular ion of each compound are shown in the following table. Assume that the charge on each molecular ion is +1.

Methyl ester	Peak area	Mass-to-charge ratio of the molecular ion
A	1000	270
B	2000	298

b. What information about the relative amounts of the two methyl esters is provided by the chromatogram? 1 mark

The mass spectrum of methyl ester A corresponds to that of methyl palmitate, $CH_3(CH_2)_{14}COOCH_3$.

c. What are the name and semi-structural formula of methyl ester B? (Refer to 'Formulas of some fatty acids' in the data book.) 2 marks

Name

Semi-structural formula

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d. Use the information provided on page 34 to draw a structure of the triglyceride. Use semi-structural formulas to represent the fatty acid residues. 3 marks

A weighed sample of methyl palmitate, $C_{17}H_{34}O_2$, was burnt in excess oxygen in a bomb calorimeter. The experimental results are shown in the following table.

mass of methyl palmitate	2.28 g
temperature rise	1.18 °C
calorimeter constant (calibration factor)	42.4 kJ $°C^{-1}$
$M(C_{17}H_{34}O_2)$	270.0 g mol^{-1}

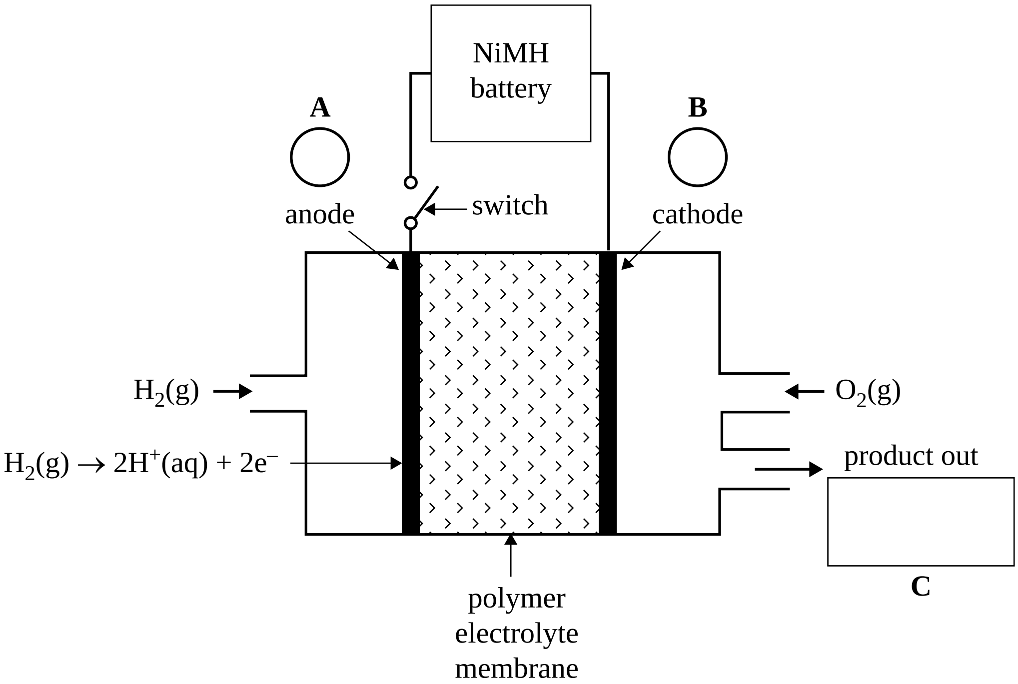
e. **i.** Use the data provided to calculate the molar enthalpy of combustion of the methyl palmitate. 3 marks

ii. Write a balanced **thermochemical** equation for the combustion reaction. 2 marks

Question 10 (14 marks)

A car manufacturer is planning to sell hybrid cars powered by a type of hydrogen fuel cell connected to a nickel metal hydride, NiMH, battery.

A representation of the hydrogen fuel cell is given below.



The overall cell reaction is

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

a. **i.** On the diagram above, indicate the polarity of the anode and the cathode in circles A and B, and identify the product of the reaction in box C. 2 marks

ii. Write an equation for the reaction that occurs at the cathode when the switch is closed. 1 mark

Cathode reaction ______________________________

iii. Identify one advantage and one disadvantage of using this fuel cell instead of a petrol engine to power the car. 2 marks

Advantage ______________________________

____

Disadvantage ______________________________

____

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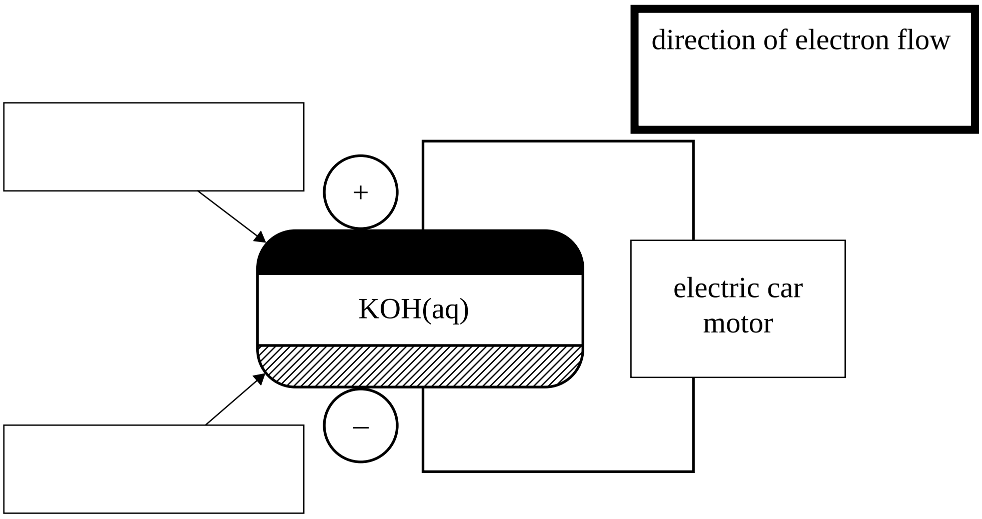
b. The storage battery to be used in the hybrid cars is comprised of a series of nickel metal hydride, NiMH, cells. MH represents a metal hydride alloy that is used as one electrode. The other electrode contains nickel oxide hydroxide, NiOOH. The electrolyte is aqueous KOH.



The simplified equation for the reaction at the anode while **recharging** is

$$Ni(OH)_2(s) + OH^-(aq) \rightarrow NiOOH(s) + H_2O(l) + e^-$$

The simplified equation for the reaction at the cathode while **recharging** is

$$M(s) + H_2O(l) + e^- \rightarrow MH(s) + OH^-(aq)$$

i. What is the overall equation for the **discharging** reaction? 1 mark

____

ii. In the boxes on the diagram above, indicate which is the MH electrode and which is the NiOOH electrode. 1 mark

iii. In the bold box provided above the cell diagram, use an arrow, → or ←, to indicate the direction of the electron flow as the cell is discharging. 1 mark

iv. The battery discharged for 60 minutes, producing a current of 1.15 A.

What mass, in grams, of NiOOH would be used during this period? 3 marks

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c. The new hybrid car has two hydrogen gas storage tanks. The total volume of the tanks is 122.4 L and the hydrogen is at a pressure of 70.0 MPa (1 MPa = 1000 kPa).

What is the mass, in kilograms, of the hydrogen at a temperature of 25.0 °C? 3 marks

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Question 11 (6 marks)

Two Chemistry students were set the task of using gravimetric analysis to determine the percentage by mass of iron in an iron ore sample. They were informed that the small rock of iron ore they had been given as a sample only contained iron in the form of iron(III) oxide.

Below is part of their report.

Procedure

As the iron ore sample contains iron in the form of iron(III) oxide, we conducted some internet research into the properties of iron(III) oxide. We found that:

- iron(III) oxide is an insoluble basic oxide
- iron(III) oxide should dissolve in hot concentrated hydrochloric acid

$$Fe_2O_3(s) + 6H^+(aq) \rightarrow 2Fe^{3+}(aq) + 3H_2O(l)$$

- Fe^{3+} ions form an insoluble precipitate with hydroxide ions

$$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$$

- $Fe(OH)_3$ decomposes to Fe_2O_3 when heated.

$$2Fe(OH)_3(s) \rightarrow Fe_2O_3(s) + 3H_2O(g)$$

Experimental procedure

1. The rock was weighed into a 500 mL beaker, which was then placed in a fume cupboard. We then added 20 mL of concentrated hydrochloric acid and warmed the solution over a hotplate to dissolve the rock.
2. The solution was then slowly diluted to 200 mL with distilled water. Some 5 M sodium hydroxide solution was then added until no more precipitate formed.
3. The mixture was filtered. The precipitate and filter paper were then transferred to a crucible, which was heated until the precipitate was judged to be dry.
4. The crucible was cooled, and the paper and solid were removed from it and weighed.

Results

Observations

The precipitate was a red-brown gel. The final solid was also red-brown.

Substance	Mass (g)
ore sample	31.54
dried iron(III) oxide + filter paper	1.282

Calculations

$$\% \text{ iron} = \frac{\text{mass of dried iron oxide + filter paper}}{\text{mass of ore sample}} \times \frac{100}{1}$$

$$= \frac{1.282}{31.54} \times \frac{100}{1}$$

$$= 4.1\%$$

Conclusion

We found that the iron content in the ore was 4.1%.

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The students' description of their experimental procedure and calculations contains some errors, which may include omissions.

In the table provided below, briefly describe two errors in their experimental procedure and one error in their calculations. In each case, predict how the error would have affected their calculated value for the percentage of iron in the rock. Justify your answers. (Assume that the students recorded each step in their procedure and calculations.)

Brief description of error	**Prediction and justification**
Experimental procedure error 1	Prediction
	Justification
Experimental procedure error 2	Prediction
	Justification
Calculation error	Prediction
	Justification

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2015

CHEMISTRY

Written examination

Tuesday 10 November 2015

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

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 — 79; symbol of element — Au; relative atomic mass — 197.0; name of element — 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

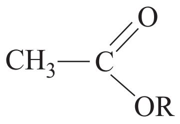
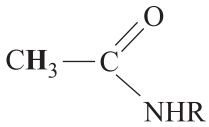
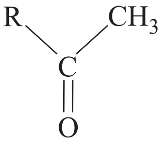
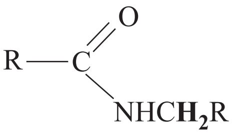
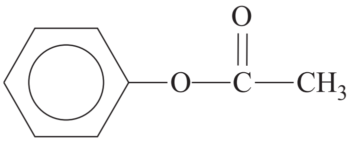
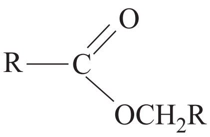
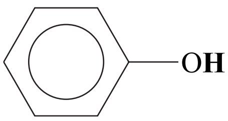
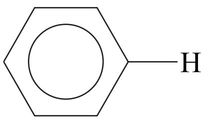
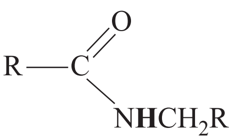
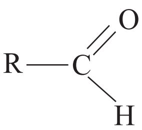
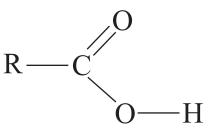
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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
$R–C\mathbf{H_2}–OH$, $R_2–C\mathbf{H}–OH$	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
$RHC{=}C\mathbf{H_2}$	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	9–13

6. ^{13}C NMR data

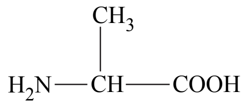
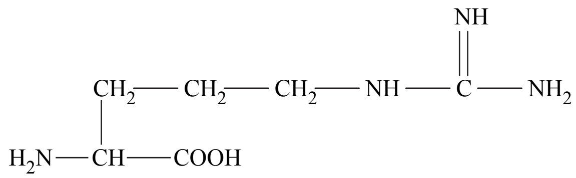
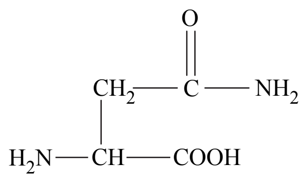
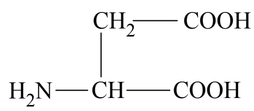
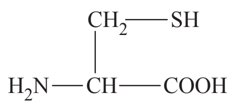
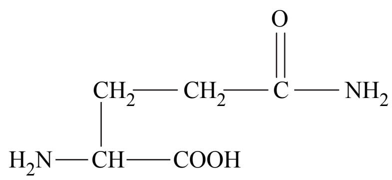
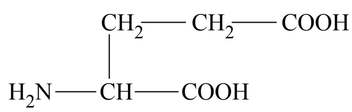
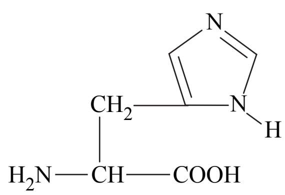
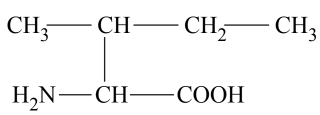
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

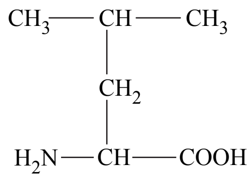
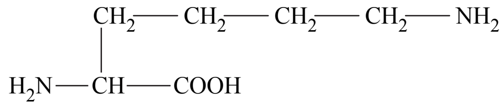
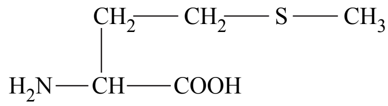
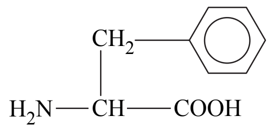
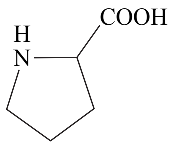
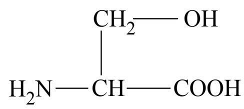
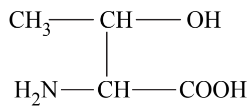
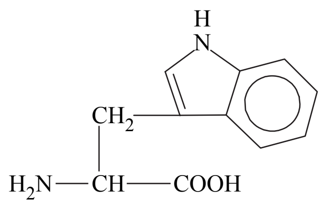
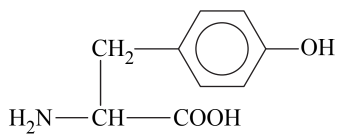
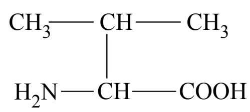
7. Infrared absorption data

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)

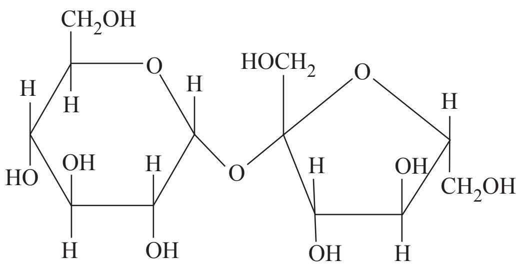
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	

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

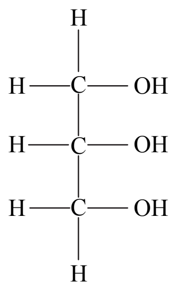
9. Formulas of some fatty acids

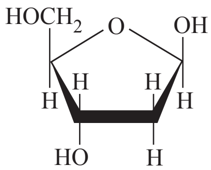
Name	Formula
lauric	$C_{11}H_{23}COOH$
myristic	$C_{13}H_{27}COOH$
palmitic	$C_{15}H_{31}COOH$
palmitoleic	$C_{15}H_{29}COOH$
stearic	$C_{17}H_{35}COOH$
oleic	$C_{17}H_{33}COOH$
linoleic	$C_{17}H_{31}COOH$
linolenic	$C_{17}H_{29}COOH$
arachidic	$C_{19}H_{39}COOH$
arachidonic	$C_{19}H_{31}COOH$

10. Structural formulas of some important biomolecules

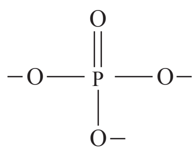


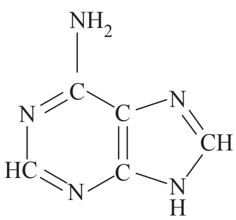
sucrose


glycerol

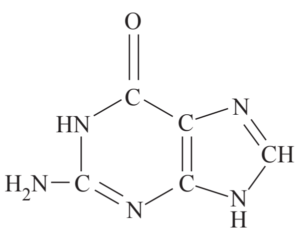


deoxyribose

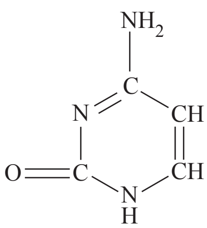

phosphate



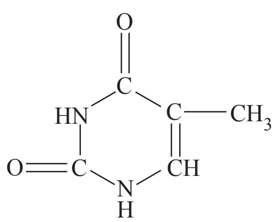
adenine



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}	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