

Trial Examination 2021

VCE Chemistry Unit 3

Written Examination

Question and Answer Booklet

Reading time: 15 minutes

Writing time: 1 hour 30 minutes

Student's Name: _____

Teacher's Name: _____

Structure of booklet

Section	Number of questions	Number of questions to be answered	Number of marks
A	20	20	20
B	5	5	55
			Total 75

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 booklet of 17 pages

Data booklet

Answer sheet for multiple-choice questions

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page, and on the answer sheet for multiple-choice questions.

Unless otherwise indicated, the diagrams in this booklet 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 booklet.

You may keep the data booklet.

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

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2021 VCE Chemistry Unit 3&4 Written Examination.

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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 booklet are **not** drawn to scale.

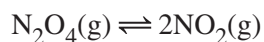
Question 1

Coal seam gas

- A. is not classified as a fossil fuel and is renewable.
- B. is produced in industry from extracted coal.
- C. consists mainly of methane, with some other gases present.
- D. deposits are only found under the ocean.

Use the following information to answer Questions 2 and 3.

A gaseous equilibrium of the following endothermic reaction was set up in a 1.00 L vessel:



The magnitude of the equilibrium constant for the reaction is 4.5 at 80°C.

Question 2

What is magnitude of the equilibrium constant for the reaction $\text{NO}_2(\text{g}) \rightleftharpoons \frac{1}{2}\text{N}_2\text{O}_4(\text{g})$ at 80°C?

- A. 0.22
- B. 0.47
- C. 1.5
- D. 4.5

Question 3

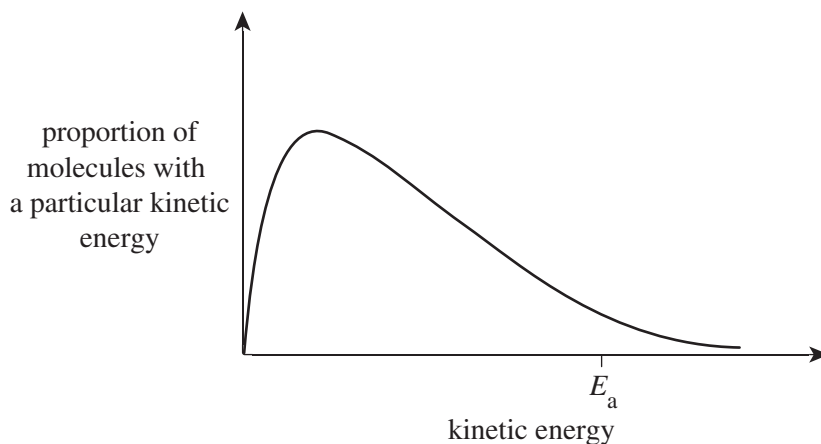
In a 1.00 L vessel, the original gaseous equilibrium was set up at 160°C.

What is the magnitude of the equilibrium constant for the reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$?

- A. 2.3
- B. 4.5
- C. 9.0
- D. Insufficient information is provided to determine the exact value.

Use the following information to answer Questions 4 and 5.

The distribution of energies of the reactant gas particles in a chemical reaction at a particular temperature is shown below. E_a represents the activation energy for the reaction.



Question 4

Which one of the following would occur if the temperature of the reactant gases was lowered?

- A. The height of the peak would change but not the position of E_a .
- B. The area under the curve would change but not the position of E_a .
- C. The height of the peak and the position of E_a would both change.
- D. The area under the curve and the position of E_a would both change.

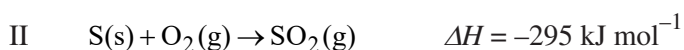
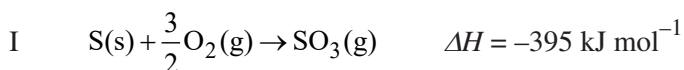
Question 5

If a suitable catalyst for the reaction was included at the original temperature, a change that would occur is that the

- A. position of E_a would move to the right.
- B. position of E_a would move to the left.
- C. height of the peak would increase.
- D. height of the peak would decrease.

Question 6

Two thermochemical equations are shown below.



For the reaction $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{SO}_3\text{(g)}$ under the same conditions, the value of ΔH (in kJ mol^{-1}) is

- A. -100
- B. -200
- C. -690
- D. -1380

Use the following information to answer Questions 7 and 8.

The K_c values of a particular chemical reaction at different temperatures are shown in the table below.

Temperature (K)	298	400	500	600
K_c value	$7.6 \times 10^7 \text{ M}^{-1}$	$1.2 \times 10^4 \text{ M}^{-1}$	75 M^{-1}	2.5 M^{-1}

Question 7

The components of the homogenous equilibrium reaction are X, Y and Z.

Which one of the following is most likely to be the chemical equation for the reaction?

- A. $2X \rightleftharpoons Y + Z$
- B. $X + 2Y \rightleftharpoons Z$
- C. $X + 2Y \rightleftharpoons 2Z$
- D. $3X + Y \rightleftharpoons 2Z$

Question 8

Which one of the following correctly shows the type of chemical reaction described above and the substances that have the higher enthalpy?

	Type of reaction	Higher enthalpy
A.	endothermic	reactants
B.	endothermic	products
C.	exothermic	products
D.	exothermic	reactants

Question 9

An equilibrium mixture of nitrogen, hydrogen and ammonia gases is held in a sealed container.

An expression for the equilibrium constant, K_c , can be written for the system at equilibrium. A similar expression, the reaction quotient or concentration fraction, Q_c , can be written for the system at any time before equilibrium is reached or when a change is made to the system. Several changes can be made separately to the equilibrium system as follows:

- I addition of argon at constant volume
- II decreasing the size of the equilibrium container
- III adding more hydrogen gas to the equilibrium mixture
- IV increasing the temperature of the system

Which of the above changes, made separately to the equilibrium system, will alter the value of the concentration fraction (Q_c) but **not** alter the value of the equilibrium constant (K_c) when the change is made?

- A. I and II only
- B. II and III only
- C. I, II and III only
- D. I, II, III and IV

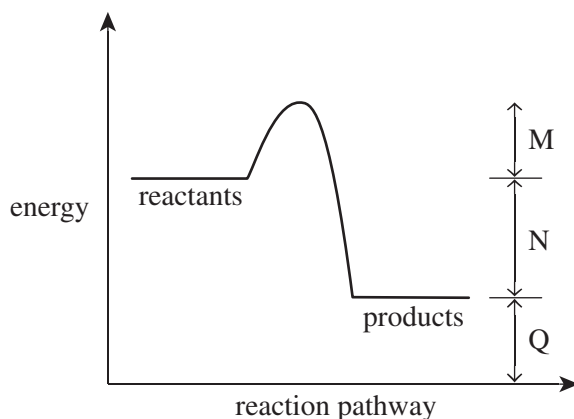
Question 10

Which one of these predictions is **not** made using the electrochemical series?

- A. whether a redox reaction is spontaneous or not
- B. which one of two chemical species is the stronger reducing agent
- C. which one of two redox reactions has a higher reaction rate
- D. whether the stronger oxidising agent is a reactant or product in a chemical reaction

Use the following information to answer Questions 11 and 12.

The energy profile for a chemical reaction is shown below. Certain energy values are denoted as M, N and Q.

**Question 11**

The enthalpy change for the forward reaction is

- A. $+(M + N)$
- B. $-(M + N)$
- C. $+N$
- D. $-N$

Question 12

The activation energy for the reverse reaction is

- A. $-M$
- B. $M + N$
- C. $N + Q$
- D. $M + N + Q$

Question 13

Which one of the following features is **not** common to all fuel cells?

- A. Oxidation occurs at the positively charged anode.
- B. Electrodes are porous and have a catalytic function.
- C. Gaseous reactants are continually supplied to the cell.
- D. The nature of the electrolyte affects the reactions occurring at each electrode.

Use the following information to answer Questions 14 and 15.

The electrolytic cells shown in the table below were set up using inert negative electrodes and 0.50 M aqueous solutions as electrolytes.

Cell	1	2	3	4
Positive electrode	silver	zinc	gold	nickel
Electrolyte	AgNO ₃	Zn(NO ₃) ₂	AuCl ₃	NiSO ₄

Question 14

In each cell, metal was deposited on the

- A. cathode where reduction occurred.
- B. anode where oxidation occurred.
- C. cathode where oxidation occurred.
- D. anode where reduction occurred.

Question 15

The cells operated at the same current for identical durations.

Which cell deposited the smallest mass of metal?

- A. 1
- B. 2
- C. 3
- D. 4

Question 16

In which one of the following lists of aqueous solutions can all solutions be predicted to react with cadmium (Cd)?

- A. Mg(NO₃)₂(aq); AgNO₃(aq); NaNO₃(aq)
- B. Ni(NO₃)₂(aq); Zn(NO₃)₂(aq); KNO₃(aq)
- C. AgNO₃(aq); Cu(NO₃)₂(aq); Pb(NO₃)₂(aq)
- D. Pb(NO₃)₂(aq); Ni(NO₃)₂(aq); Mg(NO₃)₂(aq)

Question 17

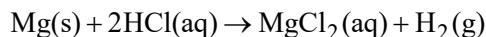
During a study of incomplete combustion of a fuel, 1.5 g of CO was captured in a container at a temperature of 25°C.

If the container volume was 4.00 L, what was the pressure exerted by the CO gas?

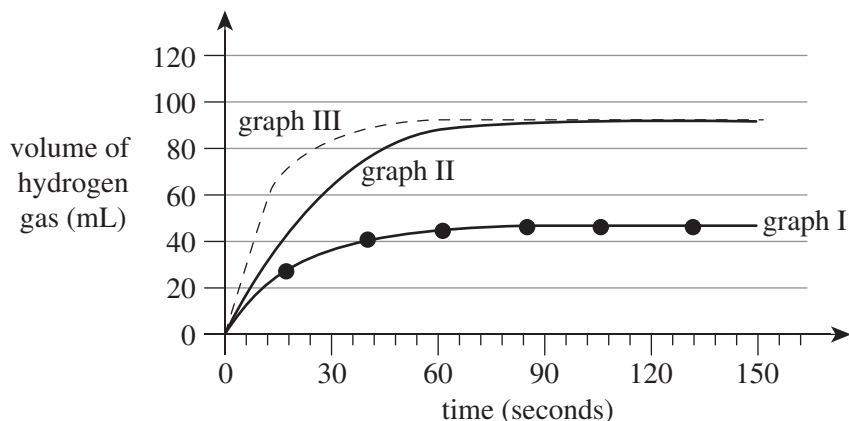
- A. 2.8 kPa
- B. 21 mmHg
- C. 33 kPa
- D. 928 mmHg

Use the following information to answer Questions 18 and 19.

A series of experiments was conducted to measure the rate of the following chemical reaction using excess hydrochloric acid:



The results of the initial experiment are shown in graph I below.



Question 18

In a second experiment, the initial experimental procedure was repeated under identical conditions, except for one change.

What change was made to the initial experiment's conditions to produce the results shown in graph II above?

- A. The temperature of the acid was increased.
- B. The concentration of the acid was doubled.
- C. The volume of the acid was doubled.
- D. The mass of magnesium was doubled.

Question 19

In a third experiment, the second experimental procedure was repeated under identical conditions, except for one change.

What change that could be made to the second experiment's conditions would **not** produce the result shown in graph III above?

- A. The volume of the acid was increased.
- B. The concentration of the acid was increased.
- C. The temperature of the acid was increased.
- D. The surface area of magnesium was increased.

Question 20

Which one of the following is always a feature of a secondary cell?

- A. The products of the discharge reaction are never gaseous.
- B. The electrodes are only made from a reactive metal.
- C. The reactants come into direct contact with each other in the discharge reaction.
- D. The recharge reaction only transforms electrical energy to chemical energy.

END OF SECTION A

SECTION B**Instructions for Section B**

Answer **all** questions in the spaces provided.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

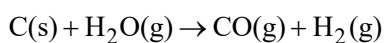
Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $\text{H}_2(\text{g})$, $\text{NaCl}(\text{s})$.

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

Question 1 (12 marks)

Two useful fuels can be produced from coal in the following reaction:



- a. Why is coal classified as non-renewable? 1 mark

- b. Both fuels, CO and H_2 , can be used to generate energy by combustion. 10.0 L of each fuel at the same conditions of temperature (above 100°C) and pressure were separately oxidised completely.

Which one of the two fuels produced the greater mass of greenhouse gas? Explain your choice.

3 marks

- c. A more efficient way of deriving energy from each fuel is to use them as the energy source in fuel cells.

i. What is the energy transformation that occurs in a fuel cell? 1 mark

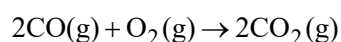
ii. Explain why using fuel cells is more efficient than using the combustion of fuels in the process of generating electricity. 2 marks

- d. One hydrogen–oxygen fuel cell uses an acidic electrolyte.

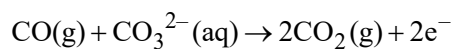
i. Write a balanced equation for the reaction occurring at the anode of this cell. 1 mark

ii. Outline **one** safety consideration when using hydrogen gas as the energy source in a fuel cell. 1 mark

- e. The carbon monoxide fuel cell uses a silver cathode and a nickel anode with an aqueous carbonate ion (CO_3^{2-}) electrolyte. The overall cell reaction is as follows:



- i. The cathode reaction occurs according to the following half-equation:

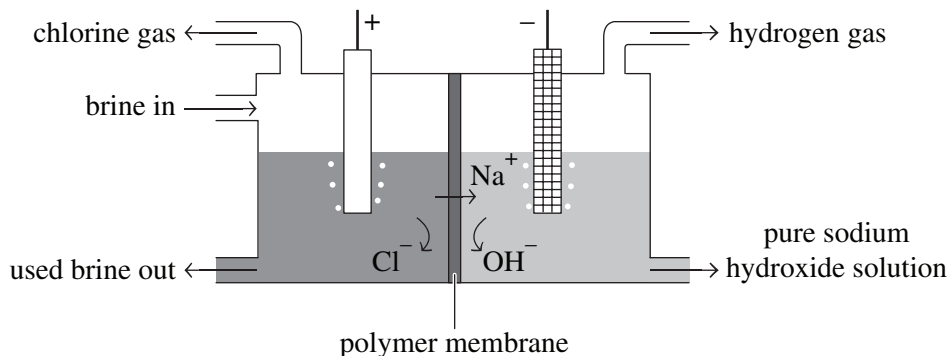


Write the balanced equation for the anode reaction. 1 mark

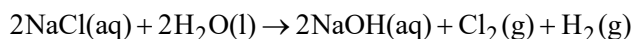
ii. If the voltage of the cell is 1.33 V at 25°C, calculate the electrical energy provided by the cell for each mole of CO consumed. 2 marks

Question 2 (10 marks)

An important industrial electrolytic cell that uses a special polymer membrane is shown in the diagram below.



The membrane allows only sodium ions to pass through from one electrode chamber to the other. Concentrated sodium chloride solution (known as brine) is electrolysed to produce the following overall chemical reaction:



- a. Write the balanced half-equation for the reaction occurring at the cathode of the above electrolytic cell. 1 mark

- b. Explain why it is important that the products in the overall reaction are kept separate from each other in the electrolytic cell. 2 marks

- c. Other industrial electrolytic cells use copper or iron electrodes, but these materials are **not** used in the cell shown. Suggest a reason to explain this. 2 marks

- d.** The production of chlorine gas during the electrolysis of aqueous sodium chloride is not predicted by the electrochemical series.
- i.** Explain why the production of chlorine gas is not predicted. 1 mark
- _____
- _____
- _____
- ii.** Outline why chlorine gas is actually produced in this cell. 1 mark
- _____
- _____
- _____
- e.** One electrolytic cell uses a current of 2000 A.
Calculate the maximum mass of chlorine gas that could be produced in 24 hours. 3 marks
- _____
- _____
- _____
- _____
- _____

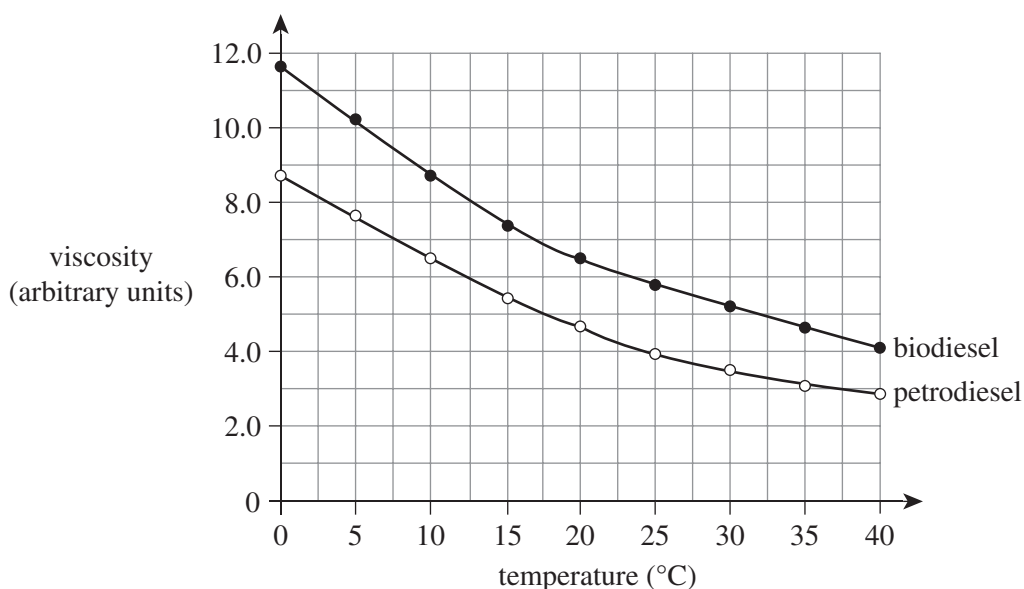
Question 3 (14 marks)

A series of experiments was conducted to investigate the properties of a sample of petrodiesel and a sample of biodiesel.

- a. i. A component of petrodiesel is $C_{12}H_{26}$, which has a heat content of 43 kJ g^{-1} .
Write the thermochemical equation for the complete combustion of this component, showing the ΔH in units of kJ mol^{-1} . 2 marks

- ii. A major component of the biodiesel is methyl palmitate.
Using information in the Data Booklet, write the semi-structural formula of methyl palmitate. 1 mark

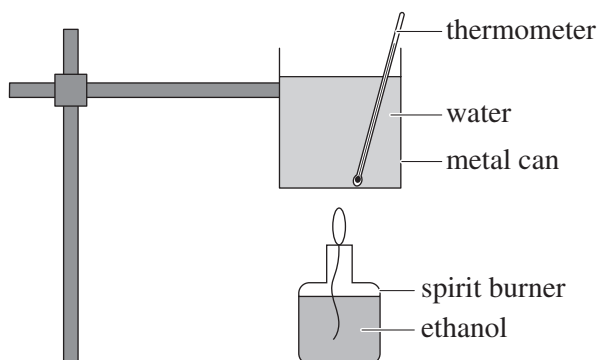
- b. The viscosity of each fuel sample was measured at different temperatures and the results are shown in the graph below.



- i. Using structure and bonding, explain why the viscosity of biodiesel is higher than that of petrodiesel at any given temperature. 3 marks

- ii. What implications does this information on viscosity have on the selection of a fuel for use in a transport vehicle in colder weather? 2 marks

- c. To determine the heat content of each fuel, an experiment was conducted using the set-up shown below. Ethanol was initially burnt in the spirit burner as it has a known heat of combustion, and so the heat loss from the apparatus could be determined.



The experiment was repeated by removing the ethanol and burning each of the fuels petrodiesel and biodiesel separately in the spirit burner to heat 100.0 g of water. The results are shown in the table.

Liquid fuel	Mass of fuel burnt (g)	Initial temperature of water (°C)	Final temperature of water (°C)
ethanol	2.15	18.0	35.9
petrodiesel	1.93	17.5	42.3
biodiesel	2.06	18.2	41.1

- i. Using information in the Data Booklet, calculate the amount of energy released by burning 2.15 g of ethanol. 1 mark

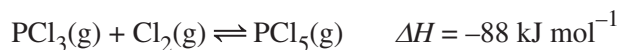
- ii. Calculate the percentage of heat released from burning ethanol that was transferred to the water in the metal can. 2 marks

- iii.** Using information from **part c.ii.** and the results table, determine the heat of combustion of petrodiesel in MJ kg^{-1} .

3 marks

Question 4 (10 marks)

The following equilibrium reaction was used in a number of experiments:



- a.** Write an expression for the equilibrium constant (K_c) for the reaction. 1 mark

- b.** In a 500 mL container, 1.15 mol of PCl_3 , 0.30 mol of Cl_2 and 0.60 mol of PCl_5 were placed and allowed to reach equilibrium at 523 K. At equilibrium, the amount of Cl_2 present had been halved.

Calculate the equilibrium constant for the reaction.

4 marks

- c.** In another experiment, 1.85 mol of PCl_3 , 0.95 mol Cl_2 and 1.60 mol of PCl_5 were present in a 1.00 L container at 523 K.

Show that the gas mixture was **not** at equilibrium.

2 marks

- d.** In a further experiment, an equilibrium mixture was established in a 2.00 L container at 523 K and a number of changes were made separately to the mixture.

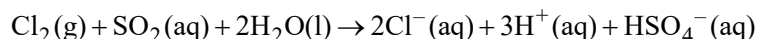
Complete each row in the table below to show the effect on the position of equilibrium and on the value of K_c for each individual change to the original mixture listed.

3 marks

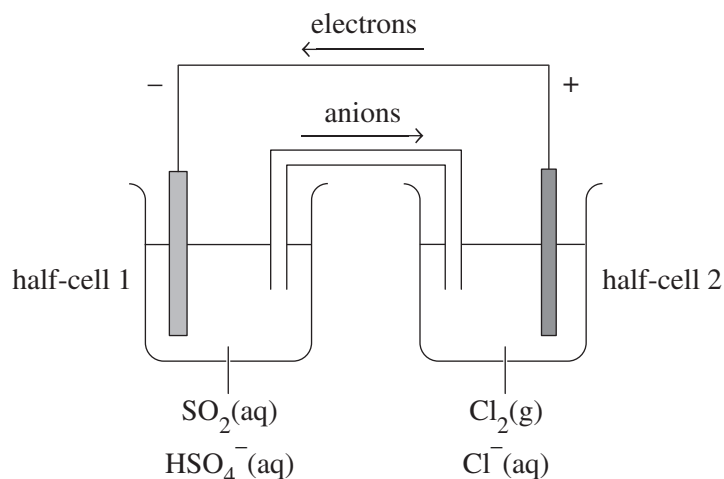
Change to original mixture	Shift in equilibrium position 'to the product side', 'to the reactant side' or 'unchanged'?	Change to value of K_c 'increases', 'decreases' or 'unchanged'?
i. 0.1 mol of Cl_2 gas injected at 523 K		
ii. 0.1 mol of He gas injected at 523 K		
iii. temperature lowered to 423 K		

Question 5 (9 marks)

A galvanic cell was set up with platinum electrodes under standard conditions using the following cell reaction:



- a. The diagram of the cell shown below has a number of fundamental errors.



Identify **two** fundamental errors shown in the diagram above.

2 marks

- b. i. Write the formula of a suitable compound that could be dissolved in water and used in preparing a salt bridge.

1 mark

- ii. Apart from solubility, name **one** other property of the compound given in **part b.i.** that makes it suitable to use in a salt bridge.

1 mark

- c. i. Write the equation for the reaction that occurs in half-cell 1 (as labelled in **part a.**).

1 mark

- ii. Tick **one** box in the table below to show the type of reaction occurring and identity of the electrode in half-cell 1 (as labelled in **part a.**).

1 mark

	Oxidation	Reduction
Anode		
Cathode		

- d.** The voltage of the cell is 1.25 V.

Calculate the standard electrode potential of the half-reaction that occurs in half-cell 1. 1 mark

- e.** Briefly describe how the cell could be recharged in a school laboratory.

2 marks

END OF QUESTION AND ANSWER BOOKLET

Trial Examination 2021

VCE Chemistry Unit 3

Written Examination

Data Booklet

Instructions

This data booklet is provided for your reference.

A question and answer booklet is provided with this data booklet.

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

1. Periodic table of the elements

1 H hydrogen 1.0		atomic number																2 He helium 4.0	
3 Li lithium 6.9		relative atomic mass																10 Ne neon 20.2	
11 Na sodium 23.0		symbol of element																17 Cl chlorine 35.5	
12 Mg magnesium 24.3		name of element																18 Ar argon 39.9	
19 K potassium 39.1		21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
37 Rb rubidium 85.5		39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 96.0	43 Tc technetium (98)	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9		57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium (210)	85 At astatine (210)	86 Rn radon (222)	
87 Fr francium (223)		89–103 actinoids		104 Rf rutherfordium (261)	105 Db dubnium (262)	106 Sg seaborgium (266)	107 Bh bohrium (264)	108 Hs hassium (267)	109 Mt meitnerium (268)	110 Ds darmstadtium (271)	111 Rg roentgenium (272)	112 Cn copernicium (285)	113 Nh nihonium (280)	114 Fl flerovium (289)	115 Mc moscovium (289)	116 Lv livermorium (292)	117 Ts tennessine (294)	118 Og oganesson (294)	
57 La lanthanum 138.9		58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (145)	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0				
89 Ac actinium (227)		90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium (237)	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (262)				

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

2. Electrochemical series

Reaction	Standard electrode potential (E^0) in volts at 25°C
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$	+2.87
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{Au}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.68
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	+1.09
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightleftharpoons 4\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{S}(\text{s}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0.14
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.25
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Co}(\text{s})$	-0.28
$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cd}(\text{s})$	-0.40
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.18
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.66
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.37
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.04

3. Chemical relationships

Name	Formula
number of moles of a substance	$n = \frac{m}{M}; \quad n = cV; \quad n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$CF = \frac{VIt}{\Delta T}$
heat energy released in the combustion of a fuel	$q = mc\Delta T$
enthalpy of combustion	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
number of moles of electrons	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	$6.02 \times 10^{23} \text{ mol}^{-1}$
charge on one electron (elementary charge)	e	$-1.60 \times 10^{-19} \text{ C}$
Faraday constant	F	$96\,500 \text{ C mol}^{-1}$
molar gas constant	R	$8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
molar volume of an ideal gas at SLC (25°C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	$4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ or $4.18 \text{ J g}^{-1} \text{ K}^{-1}$
density of water at 25°C	d	997 kg m^{-3} or 0.997 g mL^{-1}

5. Unit conversions

Measured value	Conversion
0°C	273 K
100 kPa	750 mm Hg or 0.987 atm
1 litre (L)	1 dm ³ or 1 × 10 ⁻³ m ³ or 1 × 10 ³ cm ³ or 1 × 10 ³ mL

6. Metric (including SI) prefixes

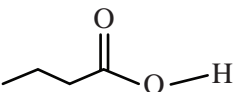
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10 ⁹	1 000 000 000
mega (M)	10 ⁶	1 000 000
kilo (k)	10 ³	1000
deci (d)	10 ⁻¹	0.1
centi (c)	10 ⁻²	0.01
milli (m)	10 ⁻³	0.001
micro (μ)	10 ⁻⁶	0.000001
nano (n)	10 ⁻⁹	0.000000001
pico (p)	10 ⁻¹²	0.000000000001

7. Acid–base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

8. Representations of organic molecules

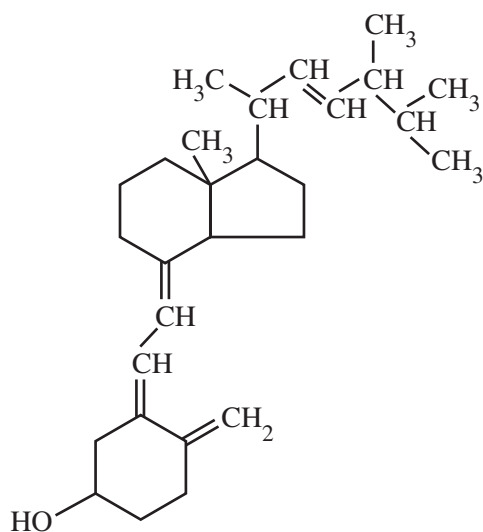
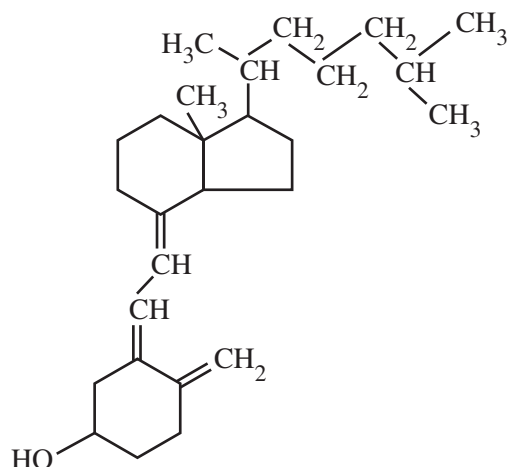
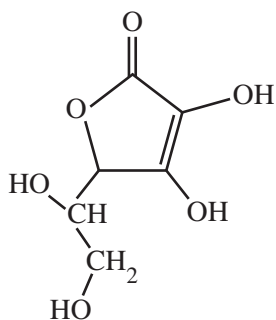
The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	$ \begin{array}{ccccccc} & H & & H & & H & \\ & & & & & & \\ H & - C & - & C & - & C & - C \\ & & & & & & // \\ & H & & H & & H & O \\ & & & & & & \backslash \\ & & & & & & O-H \end{array} $
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

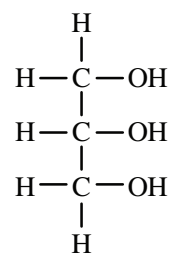
9. Formulas of some fatty acids

Name	Formula	Semi-structural formula
lauric	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{15}H_{29}COOH$	$CH_3(CH_2)_4CH_2CH=CHCH_2(CH_2)_5CH_2COOH$
stearic	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{17}H_{33}COOH$	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$
linoleic	$C_{17}H_{31}COOH$	$CH_3(CH_2)_4(CH=CHCH_2)_2(CH_2)_6COOH$
linolenic	$C_{17}H_{29}COOH$	$CH_3CH_2(CH=CHCH_2)_3(CH_2)_6COOH$
arachidic	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{17}CH_2COOH$
arachidonic	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH=CHCH_2)_3CH=CH(CH_2)_3COOH$

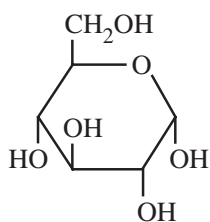
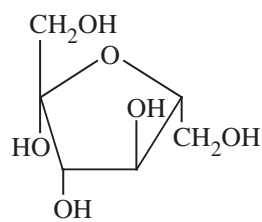
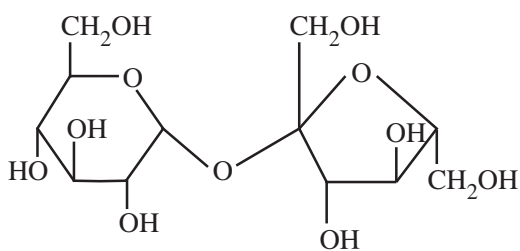
10. Formulas of some biomolecules

vitamin D₂ (ergocalciferol)vitamin D₃ (cholecalciferol)

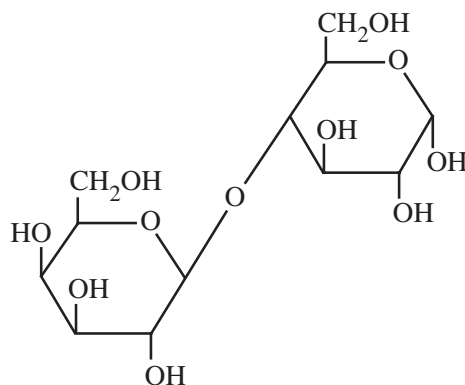
vitamin C (ascorbic acid)

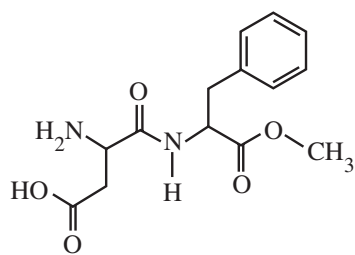


glycerol

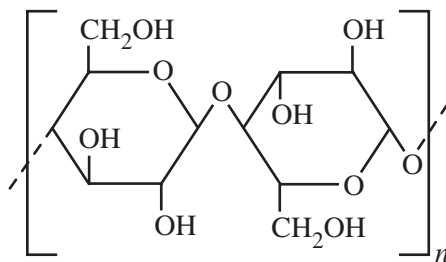
 α -glucose β -fructose

sucrose

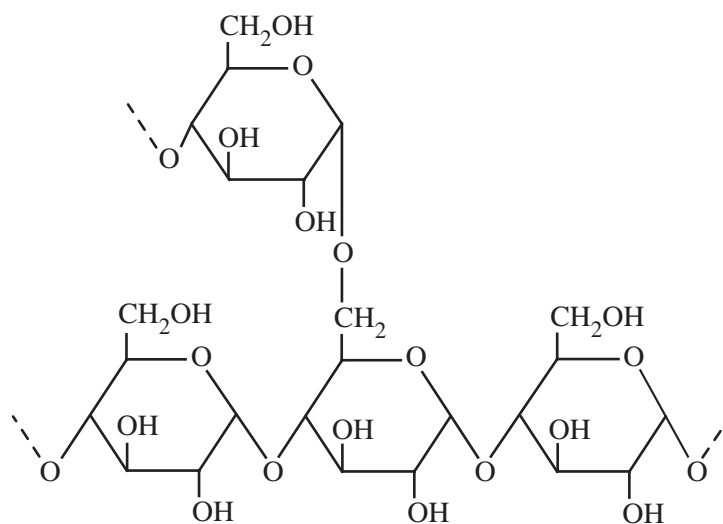
 α -lactose



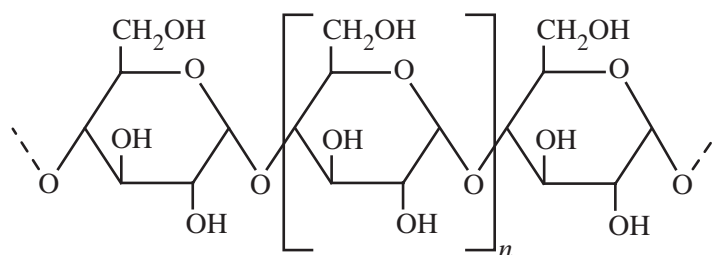
aspartame



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

The heats of combustion in the following table are calculated at SLC (25°C and 100 kPa) with combustion products being CO₂ and H₂O. Heat of combustion may be defined as the heat energy released when a specified amount of a substance burns completely in oxygen and is, therefore, reported as a positive value, indicating a magnitude. Enthalpy of combustion, ΔH , for the substances in this table would be reported as negative values, indicating the exothermic nature of the combustion reaction.

Fuel	Formula	State	Heat of combustion (kJ g ⁻¹)	Molar heat of combustion (kJ mol ⁻¹)
hydrogen	H ₂	gas	141	282
methane	CH ₄	gas	55.6	890
ethane	C ₂ H ₆	gas	51.9	1560
propane	C ₃ H ₈	gas	50.5	2220
butane	C ₄ H ₁₀	gas	49.7	2880
octane	C ₈ H ₁₈	liquid	47.9	5460
ethyne (acetylene)	C ₂ H ₂	gas	49.9	1300
methanol	CH ₃ OH	liquid	22.7	726
ethanol	C ₂ H ₅ OH	liquid	29.6	1360

12. Heats of combustion of common blended fuels

Blended fuels are mixtures of compounds with different mixture ratios and, hence, determination of a generic molar enthalpy of combustion is not realistic. The values provided in the following table are typical values for heats of combustion at SLC (25°C and 100 kPa) with combustion products being CO₂ and H₂O. Values for heats of combustion will vary depending on the source and composition of the fuel.

Fuel	State	Heat of combustion (kJ g ⁻¹)
kerosene	liquid	46.2
diesel	liquid	45.0
natural gas	gas	54.0

13. Energy content of food groups

Food	Heat of combustion (kJ g ⁻¹)
fats and oils	37
protein	17
carbohydrate	16

14. Characteristic ranges for infra-red absorption

Bond	Wave number (cm ⁻¹)	Bond	Wave number (cm ⁻¹)
C–Cl (chloroalkanes)	600–800	C=O (ketones)	1680–1850
C–O (alcohols, esters, ethers)	1050–1410	C=O (esters)	1720–1840
C=C (alkenes)	1620–1680	C–H (alkanes, alkenes, arenes)	2850–3090
C=O (amides)	1630–1680	O–H (acids)	2500–3500
C=O (aldehydes)	1660–1745	O–H (alcohols)	3200–3600
C=O (acids)	1680–1740	N–H (amines and amides)	3300–3500

15. ¹³C NMR data

Typical ¹³C shift values relative to TMS = 0

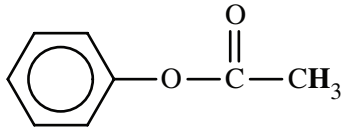
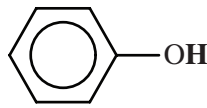
These can differ slightly in different solvents.

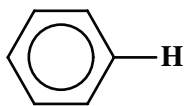
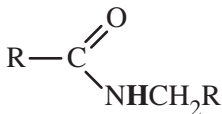
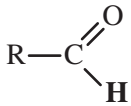
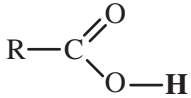
Type of carbon	Chemical shift (ppm)
R–CH ₃	8–25
R–CH ₂ –R	20–45
R ₃ –CH	40–60
R ₄ –C	36–45
R–CH ₂ –X	15–80
R ₃ C–NH ₂ , R ₃ C–NR	35–70
R–CH ₂ –OH	50–90
RC≡CR	75–95
R ₂ C=CR ₂	110–150
RCOOH	160–185
$\begin{array}{c} \text{R} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{RO} \end{array}$	165–175
$\begin{array}{c} \text{R} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array}$	190–200
R ₂ C=O	205–220

16. ^1H NMR data

Typical proton shift values relative to TMS = 0

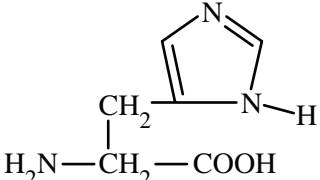
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

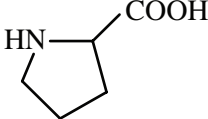
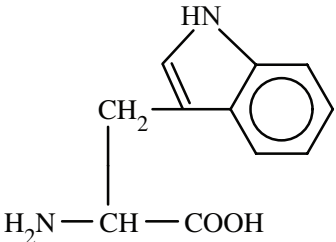
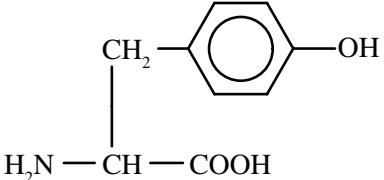
Type of proton	Chemical shift (ppm)
$\text{R}-\text{CH}_3$	0.9–1.0
$\text{R}-\text{CH}_2-\text{R}$	1.3–1.4
$\text{RCH}=\text{CH}-\text{CH}_3$	1.6–1.9
R_3-CH	1.5
$\text{CH}_3-\text{C}(=\text{O})\text{OR}$ or $\text{CH}_3-\text{C}(=\text{O})\text{NHR}$	2.0
$\text{R}-\text{C}(=\text{O})\text{CH}_3$	2.1–2.7
$\text{R}-\text{CH}_2-\text{X}$ (X = F, Cl, Br or I)	3.0–4.5
$\text{R}-\text{CH}_2-\text{OH}$, $\text{R}_2-\text{CH}-\text{OH}$	3.3–4.5
$\text{R}-\text{C}(=\text{O})\text{NHCH}_2\text{R}$	3.2
$\text{R}-\text{O}-\text{CH}_3$ or $\text{R}-\text{O}-\text{CH}_2\text{R}$	3.3–3.7
	2.3
$\text{R}-\text{C}(=\text{O})\text{OCH}_2\text{R}$	3.7–4.8
$\text{R}-\text{O}-\text{H}$	1–6 (varies considerably under different conditions)
$\text{R}-\text{NH}_2$	1–5
$\text{RHC}=\text{CHR}$	4.5–7.0
	4.0–12.0

Type of proton	Chemical shift (ppm)
	6.9–9.0
	8.1
	9.4–10.0
	9.0–13.0

17. 2-amino acids (α -amino acids)

The table below provides simplified structures to enable the drawing of zwitterions, the identification of products of protein hydrolysis and the drawing of structures involving condensation polymerisation of amino acid monomers.

Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}(=\text{NH})-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
asparagine	Asn	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
aspartic acid	Asp	$\begin{array}{c} \text{CH}_2-\text{COOH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
cysteine	Cys	$\begin{array}{c} \text{CH}_2-\text{SH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamic acid	Glu	$\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{COOH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamine	Gln	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2-\text{CH}_2-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glycine	Gly	$\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$
histidine	His	 $\begin{array}{c} \text{CH}_2-\text{C}_5\text{H}_3\text{N}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
isoleucine	Ile	$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$

Name	Symbol	Structure
leucine	Leu	$ \begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{CH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
lysine	Lys	$ \begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
methionine	Met	$ \begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{S} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
phenylalanine	Phe	$ \begin{array}{c} \text{CH}_2 - \text{C}_6\text{H}_5 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
proline	Pro	
serine	Ser	$ \begin{array}{c} \text{CH}_2 - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
threonine	Thr	$ \begin{array}{c} \text{CH}_3 - \text{CH} - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	$ \begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array} $

END OF DATA BOOKLET

VCE Chemistry Unit 3

Written Examination

Multiple-choice Answer Sheet

Student's Name: _____

Teacher's Name: _____

Instructions

Use a **pencil** for **all** entries. If you make a mistake, **erase** the incorrect answer – **do not** cross it out. Marks will **not** be deducted for incorrect answers.

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

All answers must be completed like this example:

A	B	C	D
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Use pencil only

1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
5	A	B	C	D
6	A	B	C	D
7	A	B	C	D
8	A	B	C	D
9	A	B	C	D
10	A	B	C	D

11	A	B	C	D
12	A	B	C	D
13	A	B	C	D
14	A	B	C	D
15	A	B	C	D
16	A	B	C	D
17	A	B	C	D
18	A	B	C	D
19	A	B	C	D
20	A	B	C	D