VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2012

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures										Letter
Words										

CHEMISTRY

Written examination 2

Tuesday 13 November 2012

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 10.45 am (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	9	9	52
			Total 72

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

Materials supplied
- Question and answer book of 25 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

A solvent has the following risk statement printed on its label.

'Inhalation of fumes may cause dizziness.'

To minimise the risk associated with the effects of exposure when using this solvent, a student should

A. use gloves.
B. wear a laboratory coat.
C. keep the solvent away from flames.
D. use the solvent in a well-ventilated area.

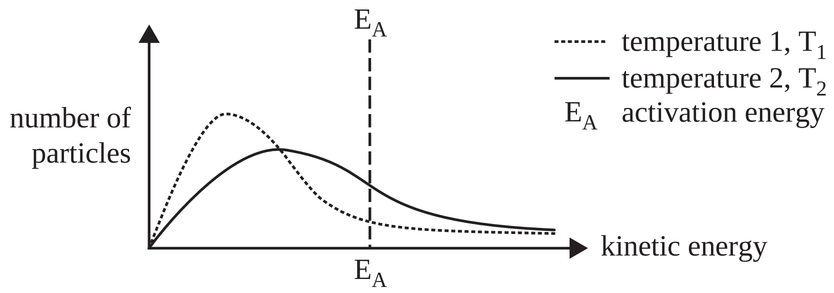
Question 2

Which one of the following fuels is the most sustainable?

A. biodiesel
B. uranium
C. brown coal
D. natural gas

Question 3

The diagram below represents the distribution of the kinetic energy of reactant particles at two different temperatures. Assume that the areas under the curves are equal.



From this diagram it can be concluded that

A. at T_1 a greater number of particles have sufficient energy to react. T_1 is greater than T_2.

B. at T_1 a greater number of particles have sufficient energy to react. T_2 is greater than T_1.

C. at T_2 a greater number of particles have sufficient energy to react. T_1 is greater than T_2.

D. at T_2 a greater number of particles have sufficient energy to react. T_2 is greater than T_1.

Question 4

Enthalpy changes for the melting of iodine, I_2, and for the sublimation of iodine are provided below.

$$I_2(s) \rightarrow I_2(l) \qquad \Delta H = +16 \text{ kJ mol}^{-1}$$

$$I_2(s) \rightarrow I_2(g) \qquad \Delta H = +62 \text{ kJ mol}^{-1}$$

The enthalpy change for the vaporisation of iodine that is represented by the equation $I_2(l) \rightarrow I_2(g)$ is

A. -78 kJ mol^{-1}

B. -46 kJ mol^{-1}

C. $+46$ kJ mol^{-1}

D. $+78$ kJ mol^{-1}

Question 5

Nitrogen dioxide decomposes as follows.

$$2NO_2(g) \rightarrow N_2(g) + 2O_2(g) \qquad \Delta H = -66 \text{ kJ mol}^{-1}$$

The enthalpy change for the reaction represented by the equation $\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ is

A. -66 kJ mol^{-1}

B. -33 kJ mol^{-1}

C. $+33$ kJ mol^{-1}

D. $+66$ kJ mol^{-1}

Question 6

Pure water at 100 °C has a pH of 6.14.

This is because

A. the self-ionisation of water is endothermic.

B. pH measurements at this temperature are unreliable.

C. pH measurements are affected by the bubbles of hydrogen gas that form in boiling water.

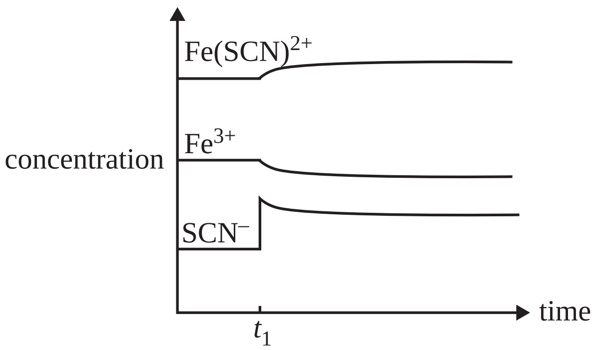
D. the concentration of H_3O^+ ions is not equal to the concentration of OH^- ions at this temperature.

Use the following information to answer Questions 7 and 8.

$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$
yellow deep red

Question 7

The concentration profile below represents a change to the above equilibrium system at time t_1.



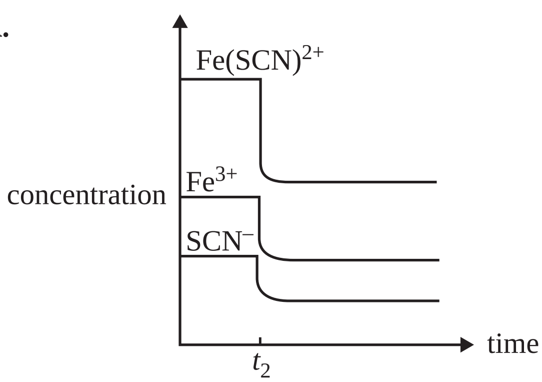
Which one of the following would account for the changes in concentration at time t_1?

A. the addition of SCN^{-}
B. the removal of $Fe(SCN)^{2+}$
C. an increase in temperature
D. a decrease in temperature

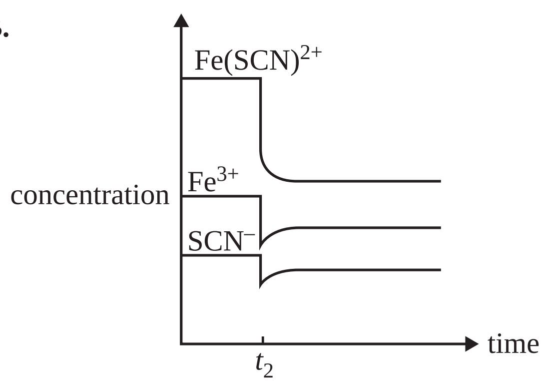
Question 8

Which one of the following best represents the changes in concentration when the equilibrium mixture is diluted at time t_2?

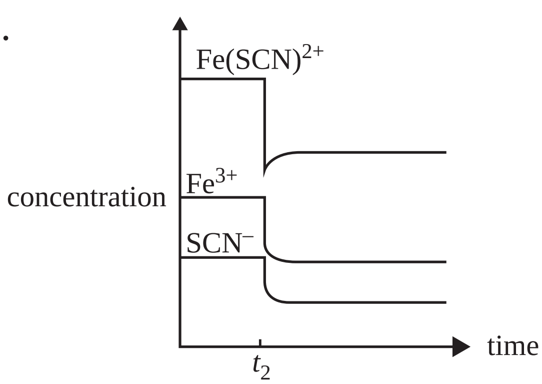
A.



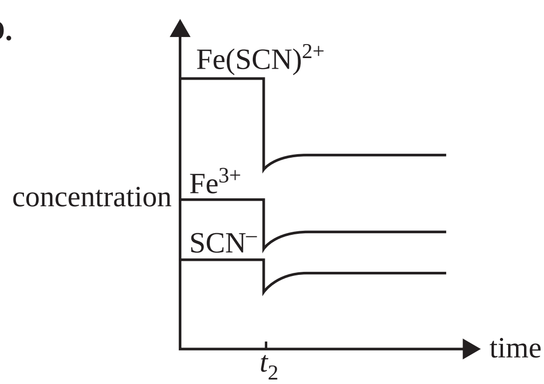
B.



C.



D.



Use the following information to answer Questions 9–11.

The following reaction is used in some industries to produce hydrogen.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}$$

Question 9

Carbon monoxide, water vapour, carbon dioxide and hydrogen were pumped into a sealed container that was maintained at a constant temperature of 200 °C. After 30 seconds, the concentration of gases in the sealed container was found to be [CO] = 0.1 M, [H_2O] = 0.1 M, [H_2] = 2.0 M, [CO_2] = 2.0 M.

The equilibrium constant at 200 °C for the above reaction is K = 210.

Which one of the following statements about the relative rates of the forward reaction and the reverse reaction at 30 seconds is true?

A. The rate of the forward reaction is greater than the rate of the reverse reaction.

B. The rate of the forward reaction is equal to the rate of the reverse reaction.

C. The rate of the forward reaction is less than the rate of the reverse reaction.

D. There is insufficient information to allow a statement to be made about the relative rates of the forward and reverse reactions.

Question 10

The reaction between carbon monoxide and water vapour is carried out in a sealed container.

The equilibrium yield of hydrogen will be increased by

A. an increase in pressure at constant temperature.

B. a decrease in temperature.

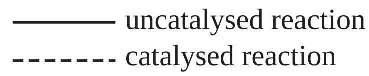
C. the addition of an inert gas at constant temperature.

D. the use of a suitable catalyst at constant temperature.

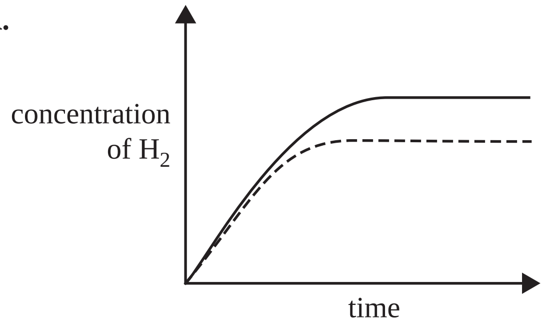
Question 11

In trials, the reaction is carried out with and without a catalyst in the sealed container. All other conditions are unchanged. The change in hydrogen concentration with time between an uncatalysed and a catalysed reaction is represented by a graph.

Which graph is correct?



A.



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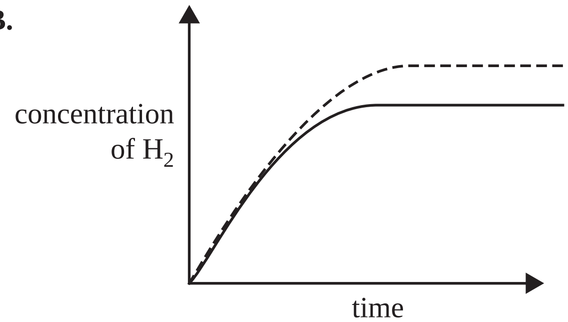

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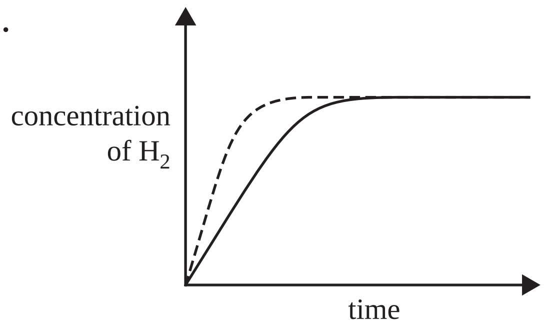

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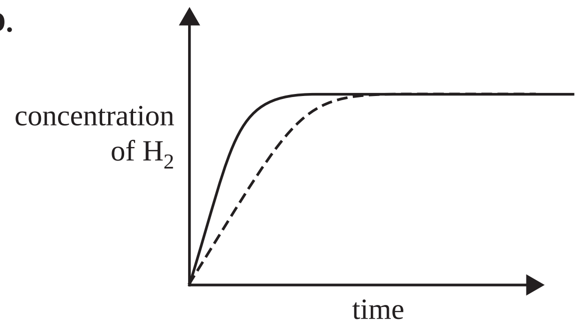
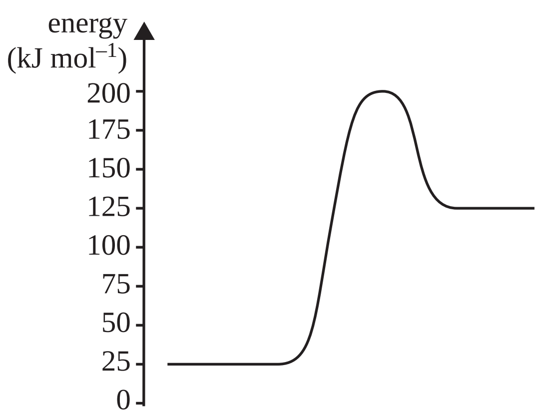


Question 12

Consider the following energy profile diagram for a reaction represented by the equation $X + Y \rightarrow Z$.



Which one of the following provides the correct values of the activation energy and enthalpy for the reaction $X + Y \rightarrow Z$?

	Activation energy (kJ mol^{-1})	Enthalpy (kJ mol^{-1})
A.	+75	+100
B.	+100	+175
C.	+175	+100
D.	+200	–125

Question 13

1.30 g of glucose ($M = 180 \text{ g mol}^{-1}$) underwent complete combustion. The energy released was used to heat an unknown mass of water.

If the temperature of the water increased by 24.3 °C and it is assumed no heat was lost, the mass of the water heated was

A. 2.00×10^{-1} g

B. 1.02×10^{2} g

C. 2.00×10^{2} g

D. 3.84×10^{3} g

Question 14

When 50 g of water at 90 °C is added to a calorimeter containing 50 g of water at 15 °C, the temperature increases to 45 °C.

Assuming no energy is lost to the environment, the energy absorbed by the calorimeter is equal to the

A. energy lost by the hot water.

B. energy gained by the cold water.

C. sum of the energy gained by the cold water and the energy lost by the hot water.

D. difference between the energy lost by the hot water and the energy gained by the cold water.

Question 15

If 54.0 kJ of energy is required to convert 1.00 mol of liquid water to steam at 100 °C, the amount of heat energy, in kilojoule, required to convert 100 g of water at 20 °C to steam at 100 °C is

A. 3.34×10^{1} kJ

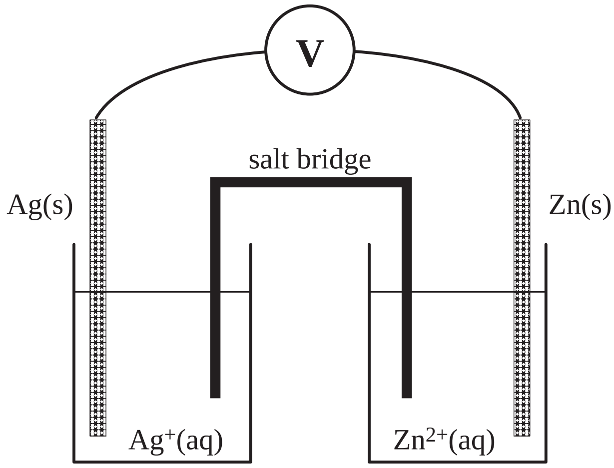
B. 2.67×10^{2} kJ

C. 3.00×10^{2} kJ

D. 3.33×10^{2} kJ

Use the following information to answer Questions 16–18.

A galvanic cell set up under standard conditions is shown below.



Question 16

Which one of the following is correct?

As the cell discharges

	electrons would flow from the	in the salt bridge
A.	zinc electrode to the silver electrode.	anions migrate to the Ag^+/Ag half-cell.
B.	silver electrode to the zinc electrode.	cations migrate to the Zn^{2+}/Zn half-cell.
C.	silver electrode to the zinc electrode.	cations migrate to the Ag^+/Ag half-cell.
D.	zinc electrode to the silver electrode.	anions migrate to the Zn^{2+}/Zn half-cell.

Question 17

In this cell

A. Ag^+(aq) is reduced and the Zn(s) is oxidised.

B. Ag(s) is oxidised and the Zn^{2+}(aq) is reduced.

C. Ag(s) is reduced and the Zn^{2+}(aq) is oxidised.

D. Ag^+(aq) is oxidised and the Zn(s) is reduced.

Question 18

The cathode in this cell and the maximum voltage produced by this cell, under standard conditions, are respectively

A. Ag and 0.16 V

B. Ag and 1.56 V

C. Zn and 0.16 V

D. Zn and 1.56 V

Question 19

Which one of the following statements is true for both galvanic cells and electrolytic cells?

A. Reduction occurs at the negative electrode in both cells.

B. Reduction occurs at the cathode in both cells.

C. Anions migrate to the cathode in both cells.

D. The anode is positive in both cells.

Question 20

Fuel cells have a number of applications that offer advantages over conventional methods of electricity generation.

Which one of the following is **not** a feature of modern fuel cells?

A. They generate very little noise.

B. They are a cheap source of electricity.

C. They enable electricity to be generated on site.

D. They have the potential to reduce emissions of carbon dioxide into the atmosphere.

END OF SECTION A

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SECTION B – Short answer questions

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, $H_2(g)$; $NaCl(s)$

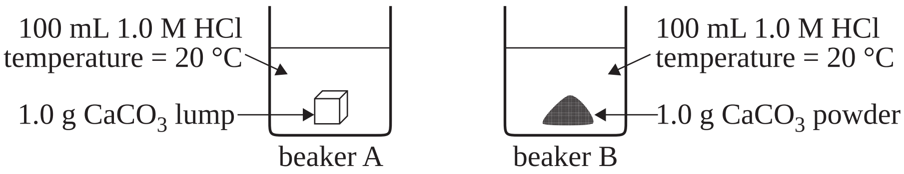
Question 1

Two experiments were conducted to investigate various factors that affect the rate of reaction between calcium carbonate and dilute hydrochloric acid.

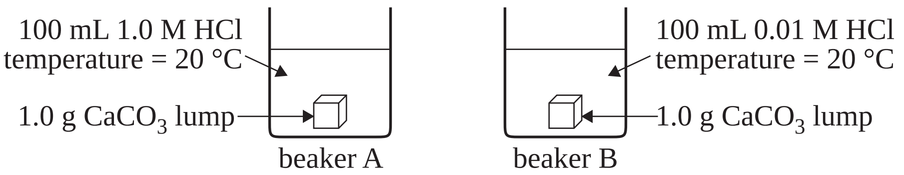
$$CaCO_3(s) + 2HCl(aq) \rightleftharpoons CO_2(g) + CaCl_2(aq) + H_2O(l)$$

The two experiments are summarised in the diagrams below.

experiment 1



experiment 2



a. How could the rate of this reaction be measured in these experiments?

1 mark

b. **i.** Identify the rate determining factor that is investigated in experiment 1.

ii. In experiment 2, will the rate of reaction be faster in beaker A or beaker B? Explain your selection in terms of collision theory.

1 + 2 = 3 marks

c. Why is the following statement **incorrect**?

'Collision theory states that all collisions between reactant particles will result in a chemical reaction.'

2 marks

Question 2

The reaction between 2-bromo-2-methylpropane and hydroxide ions occurs in two steps.

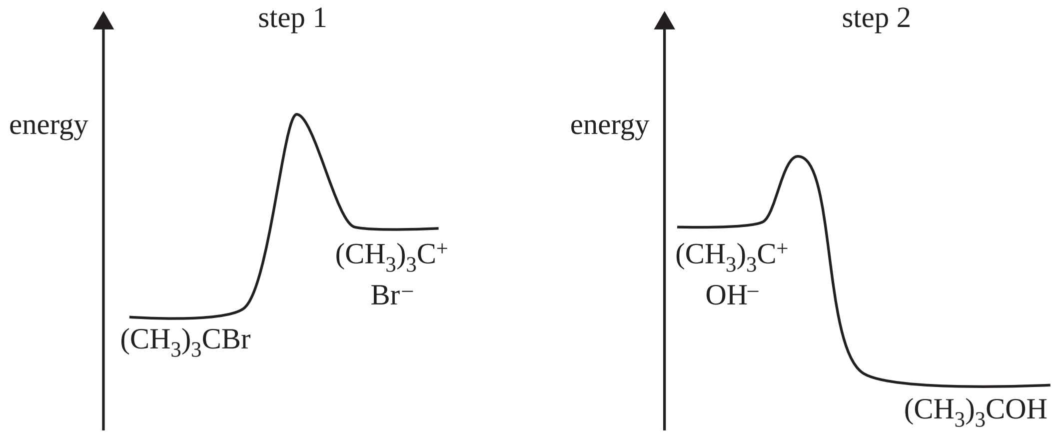
step 1 $(CH_3)_3CBr(aq) \rightarrow (CH_3)_3C^+(aq) + Br^-(aq)$

step 2 $(CH_3)_3C^+(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq)$

a. Write an equation that represents the overall reaction between 2-bromo-2-methylpropane and hydroxide ions.

1 mark

The energy profile diagrams for step 1 and step 2 are shown below. Both are drawn to the same scale.



b. **i.** Which step involves an endothermic reaction? Provide a reason for your answer.

The reaction at step 1 occurs at a different rate to the reaction at step 2.

ii. Which step is slower? Justify your answer.

1 + 2 = 3 marks

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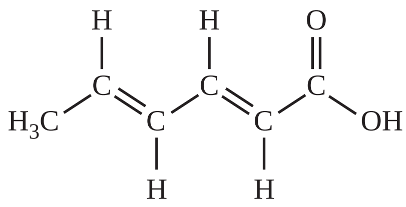
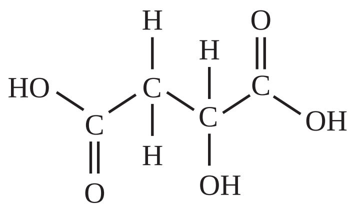
Question 3

The following weak acids are used in the food industry.

Acid	Common use	Formula	Structure	K_a values
sorbic	preservative	$C_6H_8O_2$		1.73×10^{-5}
malic	low-calorie fruit drinks	$C_4H_6O_5$		3.98×10^{-4} 8.91×10^{-6}

a. What does the term 'weak acid' mean?

1 mark

b. **i.** Why are two K_a values listed for malic acid?

The equation related to the first K_a value of malic acid is

$$HOOCCH_2CH(OH)COOH(aq) + H_2O(l) \rightleftharpoons HOOCCH_2CH(OH)COO^-(aq) + H_3O^+(aq)$$

ii. Write an appropriate chemical equation that relates to the second K_a of malic acid.

1 + 1 = 2 marks

c. Sorbic acid, $CH_3(CH)_4COOH$, has antimicrobial properties that are used to inhibit yeast and mould growth. However, its solubility is very low. The more soluble potassium sorbate is used instead. The antimicrobial activity of sorbic acid is retained because an equilibrium exists according to the equation

$$\underset{\text{sorbate ion}}{CH_3(CH)_4COO^-(aq)} + H_2O(l) \rightleftharpoons \underset{\text{sorbic acid}}{CH_3(CH)_4COOH(aq)} + OH^-(aq)$$

How would the addition of a small amount of 1.0 M hydrochloric acid affect the concentration of sorbic acid in solution? Justify your answer in terms of equilibrium principles.

2 marks

d. Calculate the percentage dissociation of sorbic acid when the pH = 4.76.

3 marks

Question 4

In an experiment, 1.0 mol of pure phosgene, $COCl_2$, is placed in a 3.0 L flask where the following reaction takes place.

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g) \qquad K = 2.1 \times 10^{-8} \text{ M}$$

a. It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol. On the basis of the data provided, explain why this assumption is justified.

2 marks

b. **i.** Calculate the equilibrium concentration, in mol L^{-1}, of carbon monoxide, CO. Assume that the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol.

ii. What is the equilibrium concentration of chlorine gas?

3 + 1 = 4 marks

Question 5

Circle the industrial chemical that you have studied in detail this semester.

ammonia ethene nitric acid sulfuric acid

a. State one application of your selected chemical that is useful to society.

1 mark

Strict environmental guidelines are attached to the industrial production of your selected chemical.

b. **i.** State one undesirable effect that the production of your selected chemical has on the environment.

ii. Outline one procedure that would be appropriate to avoid this damage to the environment during the production of your selected chemical.

1 + 1 = 2 marks

Question 6

Methanol, CH_3OH, undergoes combustion according to the equation

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

In an experiment to determine its suitability as a fuel, a sample of methanol underwent complete oxidation in a bomb calorimeter.

The calorimeter was first calibrated by passing a current through an electric heater placed in the water surrounding the reaction vessel. A potential of 5.25 volts was applied for 3.00 minutes. The measured current was 1.50 amperes and the temperature of the water and reaction vessel increased by 0.593 °C.

a. **i.** Determine the calibration constant, in kJ $°C^{-1}$, for the calorimeter and its contents.

A student then used this calorimeter to determine the molar heat of combustion of methanol.

0.934 g of methanol was placed in the reaction vessel and excess oxygen was added. An electric ignition heater provided the energy required to initiate the combustion reaction. On this occasion, the temperature of the water increased by 8.63 °C.

ii. Use this experimental data to determine the value of ΔH for the combustion of methanol given by the following equation.

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

Include appropriate units in your answer.

2 + 5 = 7 marks

b. The value of ΔH, calculated using the enthalpy of combustion provided in the data book, is different from the value of ΔH calculated from the experimental data provided in **part a.ii.**

Provide a reason for this difference.

1 mark

Methanol is suitable for use in a micro fuel cell that is used to power laptop computers and similar small electrical items. The methanol is oxidised to carbon dioxide and water. The half-equation for the anode reaction is

$$CH_3OH(l) + H_2O(l) \rightarrow 6H^+(aq) + CO_2(g) + 6e^-$$

c. i. Write a balanced half-equation for the cathode reaction.

ii. A finely divided platinum/ruthenium catalyst is used in this cell.

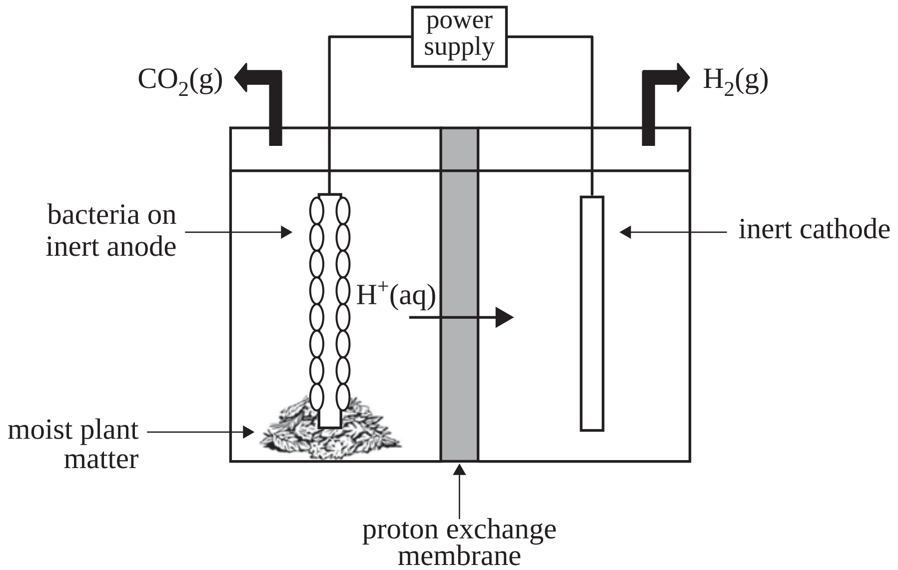
Give a reason why it is important to have a catalyst that will significantly reduce the activation energy for the cell reaction.

1 + 1 = 2 marks

Question 7

Hydrogen gas is an energy source. Researchers are investigating the production of hydrogen gas in a microbial electrolysis cell.

The cell is made up of an anode half-cell and a cathode half-cell. The half-cells are separated by a proton exchange membrane, as shown in the diagram below.



A number of reactions take place in the cell, resulting in the production of hydrogen. These reactions are summarised below.

Anode half-cell

- The anode half-cell contains moist plant matter and electrochemically active bacteria that live on an inert anode.
- The gaseous mixture that is present in the half-cell does not contain oxygen.
- The moist plant matter ferments to produce ethanoic acid (CH_3COOH). Bacteria on the anode consume the ethanoic acid and release hydrogen ions, electrons and carbon dioxide gas. A small voltage is then applied to reduce the H^+ ions.

Cathode half-cell

- The cathode half-cell contains an inert cathode.
- The gaseous mixture that is present in the half-cell does not contain oxygen.
- The released hydrogen ions and electrons react to form hydrogen gas, as shown in the equation below.

$$2H^+(aq) + 2e^- \rightarrow H_2(g)$$

a. Ethanoic acid is converted to carbon dioxide gas and H^+ ions at the anode.

Write an equation for this reaction.

____

____

1 mark

b. On the diagram above, use one arrow to indicate the direction of electron flow in the cell when an external voltage is supplied to the cell by the power supply.

1 mark

NO WRITING ALLOWED IN THIS AREA

c. Hydrogen gas is not produced at the cathode if oxygen is present in the half-cell.

Write a balanced half-equation to show the product that would be produced at the cathode if oxygen were present in the half-cell.

1 mark

d. Describe one difference between an electrolysis cell and a traditional fuel cell.

1 mark

Question 8

Decisions about clean energy with reduced carbon dioxide emissions will have an impact on electricity generation from brown coal. However, there will be a much smaller impact on the use of black coal for electricity generation.

The following table compares the energy and carbon content of three different coal samples.

	Percentage carbon* by mass	**Energy content (kJ g^{-1})**
Black coal	93	36.0
Brown coal (dried)	66	28.0
Brown coal (wet – as mined)	40	5.0

*Coal is not a pure substance and the composition of samples will vary even within one mine.

From the data in this table, it can be deduced that the complete combustion of 1 tonne of black coal will generate 3.6×10^7 kJ of energy.

a. **i.** Calculate the mass, in tonne, of wet brown coal that is required to generate 3.6×10^7 kJ of energy.

ii. Calculate the mass, in tonne, of carbon dioxide that is produced from the complete combustion of this mass of wet brown coal.

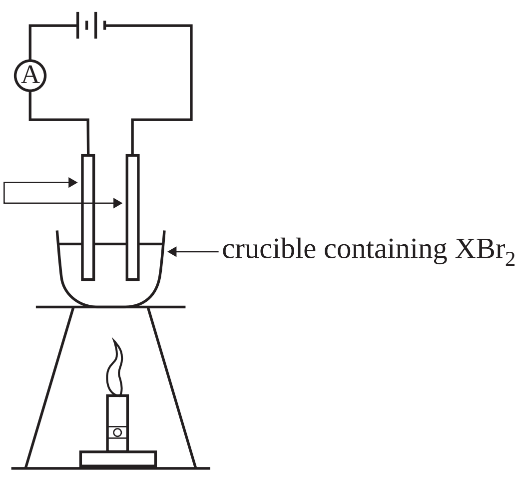
1 + 2 = 3 marks

b. What are the most likely reasons for the energy content of wet brown coal being so much lower than the energy content of dried brown coal? Justify your answer.

2 marks

Question 9

A teacher demonstrated the process of electrolysis of a molten salt using an unknown metal salt, XBr_2.
The apparatus was set up as shown below.



At the conclusion of the demonstration, the students were provided with the following information.

- A current of 1.50 amperes was applied for 30.0 minutes.
- 2.90 g of metal X was produced.

a. Write a balanced half-equation for the anode reaction in this electrolytic cell.

1 mark

b. **i.** Determine the amount, in mol, of metal X that was deposited on the cathode.

ii. Identify metal X.

3 + 2 = 5 marks

END OF QUESTION AND ANSWER BOOK

Victorian Certificate of Education 2012

CHEMISTRY

Written examination

Tuesday 13 November 2012

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 10.45 am (1 hour 30 minutes)

DATA BOOK

Directions to students

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

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

Table of contents

1. Periodic table of the elements

atomic number	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** **La** 138.9 Lanthanum	**72** **Hf** 178.5 Hafnium	**73** **Ta** 180.9 Tantalum	**74** **W** 183.8 Tungsten	**75** **Re** 186.2 Rhenium	**76** **Os** 190.2 Osmium	**77** **Ir** 192.2 Iridium	**78** **Pt** 195.1 Platinum	**79** **Au** 197.0 Gold	**80** **Hg** 200.6 Mercury	**81** **Tl** 204.4 Thallium	**82** **Pb** 207.2 Lead	**83** **Bi** 209.0 Bismuth	**84** **Po** (210) Polonium	**85** **At** (210) Astatine	**86** **Rn** (222) Radon
87 **Fr** (223) Francium	**88** **Ra** (226) Radium	**89** **Ac** (227) Actinium	**104** **Rf** (261) Rutherfordium	**105** **Db** (262) Dubnium	**106** **Sg** (266) Seaborgium	**107** **Bh** (264) Bohrium	**108** **Hs** (267) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Cn** (285) Copernicium	**113** **Uut** (284)	**114** **Uuq** (289)	**115** **Uup** (288)	**116** **Uuh** (293)	**117** **Uus** (294)	**118** **Uuo** (294)

58 **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.4 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.3 Gadolinium	**65** **Tb** 158.9 Terbium	**66** **Dy** 162.5 Dysprosium	**67** **Ho** 164.9 Holmium	**68** **Er** 167.3 Erbium	**69** **Tm** 168.9 Thulium	**70** **Yb** 173.1 Ytterbium	**71** **Lu** 175.0 Lutetium

90 **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237) Neptunium	**94** **Pu** (244) Plutonium	**95** **Am** (243) Americium	**96** **Cm** (247) Curium	**97** **Bk** (247) Berkelium	**98** **Cf** (251) Californium	**99** **Es** (252) Einsteinium	**100** **Fm** (257) Fermium	**101** **Md** (258) Mendelevium	**102** **No** (259) Nobelium	**103** **Lr** (262) Lawrencium

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

TURN OVER

2. The electrochemical series

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

3. Physical constants

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

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

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

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

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

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

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

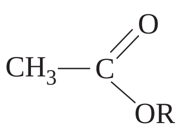
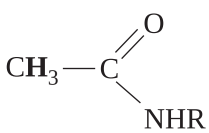
1 atm = 101.3 kPa = 760 mm Hg
0 °C = 273 K

4. SI prefixes, their symbols and values

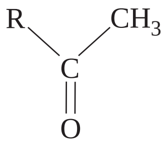
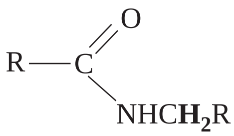
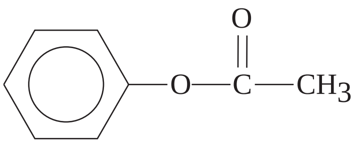
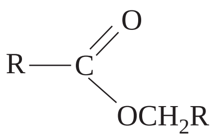
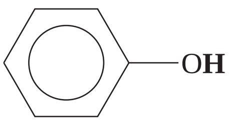
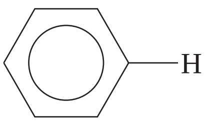
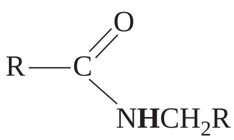
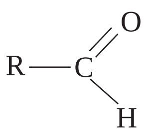
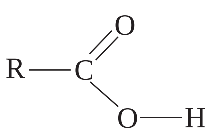
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0
These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

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

TURN OVER

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

6. ^{13}C NMR data

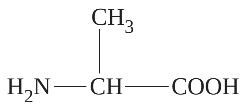
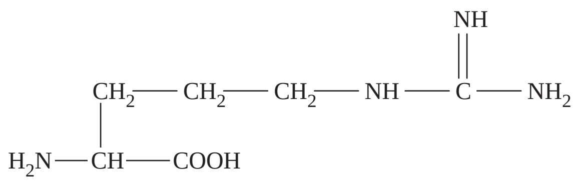
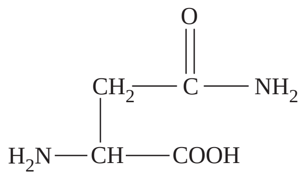
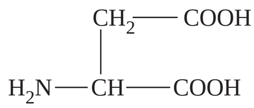
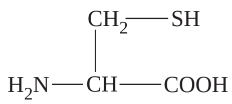
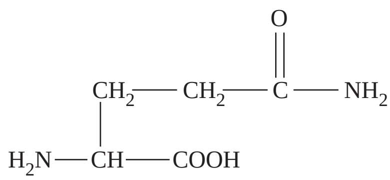
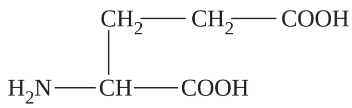
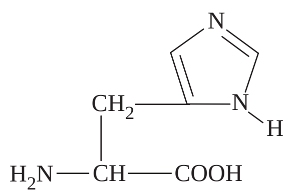
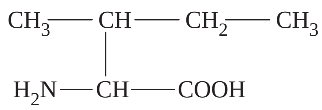
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

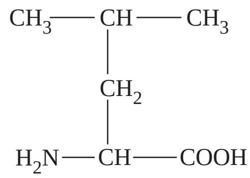
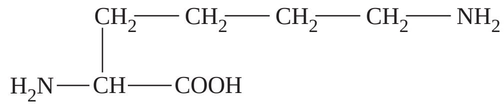
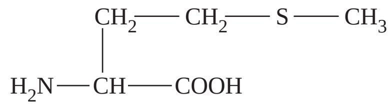
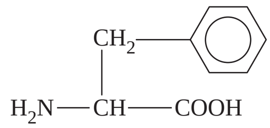
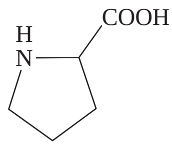
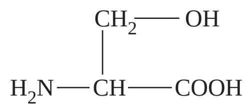
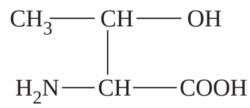
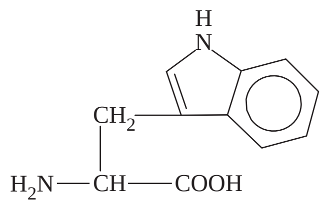
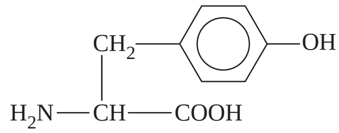
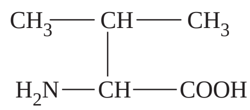
7. Infrared absorption data

Characteristic range for infrared absorption

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

8. 2-amino acids (*α*-amino acids)

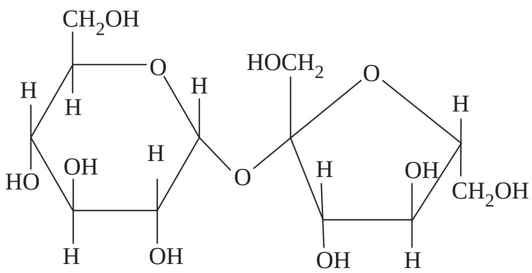
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	

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

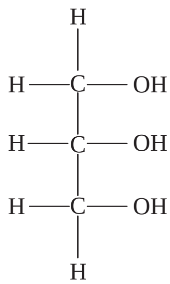
9. Formulas of some fatty acids

Name	Formula
Lauric	$C_{11}H_{23}COOH$
Myristic	$C_{13}H_{27}COOH$
Palmitic	$C_{15}H_{31}COOH$
Palmitoleic	$C_{15}H_{29}COOH$
Stearic	$C_{17}H_{35}COOH$
Oleic	$C_{17}H_{33}COOH$
Linoleic	$C_{17}H_{31}COOH$
Linolenic	$C_{17}H_{29}COOH$
Arachidic	$C_{19}H_{39}COOH$
Arachidonic	$C_{19}H_{31}COOH$

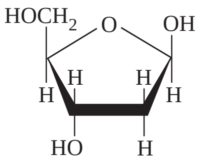
10. Structural formulas of some important biomolecules



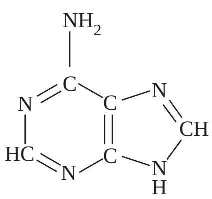
sucrose



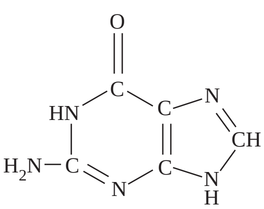
glycerol



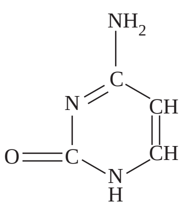
deoxyribose



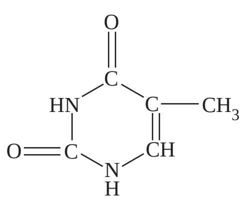
adenine



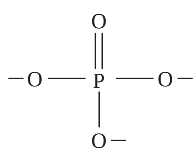
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
Thymol blue	1.2–2.8	red	yellow	2×10^{-2}
Methyl orange	3.1–4.4	red	yellow	2×10^{-4}
Bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
Methyl red	4.2–6.3	red	yellow	8×10^{-6}
Bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
Phenol red	6.8–8.4	yellow	red	1×10^{-8}
Phenolphthalein	8.3–10.0	colourless	red	5×10^{-10}

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

Name	Formula	K_a
Ammonium ion	NH_4^+	5.6×10^{-10}
Benzoic	C_6H_5COOH	6.4×10^{-5}
Boric	H_3BO_3	5.8×10^{-10}
Ethanoic	CH_3COOH	1.7×10^{-5}
Hydrocyanic	HCN	6.3×10^{-10}
Hydrofluoric	HF	7.6×10^{-4}
Hypobromous	HOBr	2.4×10^{-9}
Hypochlorous	HOCl	2.9×10^{-8}
Lactic	$HC_3H_5O_3$	1.4×10^{-4}
Methanoic	HCOOH	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	C_2H_5COOH	1.3×10^{-5}

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

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

END OF DATA BOOK