VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2011

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

CHEMISTRY

Written examination 2

Monday 14 November 2011

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	8	8	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

Consider the following equilibrium expression.

$$K = \frac{[L]\,[M]^4}{[J]^6\,[K]}$$

The equation of the forward reaction for this equilibrium expression is

A. $6\,J + K \rightleftharpoons L + 4\,M$
B. $L + M_4 \rightleftharpoons J_6 + K$
C. $J_6 + K \rightleftharpoons L + M_4$
D. $L + 4\,M \rightleftharpoons 6\,J + K$

Question 2

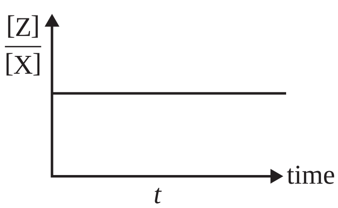
Consider the following equilibrium.

$$2X(g) + Y(g) \rightleftharpoons 2Z(g) \qquad \Delta H \text{ is positive}$$

A catalyst is added to the equilibrium mixture at time *t*. The temperature and volume of the mixture remain constant.

Which one of the following graphs best represents the change in the equilibrium ratio $\frac{[Z]}{[X]}$?

A.



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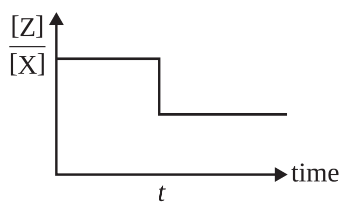

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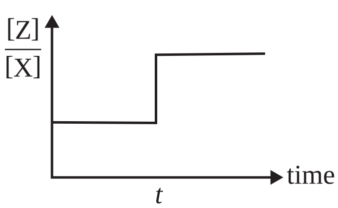
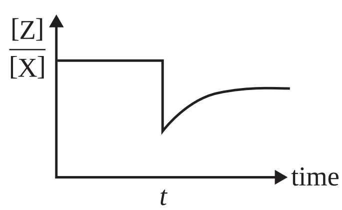


D.



Use the following information to answer Questions 3 and 4.

Hydrogen and fluorine react according to the following equation.

$$\frac{1}{2}H_2(g) + \frac{1}{2}F_2(g) \rightleftharpoons HF(g) \qquad \Delta H = -271 \text{ kJ mol}^{-1}$$

In an experiment, 0.250 mol of hydrogen and 0.340 mol of fluorine were placed in a reaction vessel that had a volume of V litres. Once equilibrium was established, there was 0.220 mol of HF present in the reaction vessel.

Question 3

Which one of the following expressions can be used to calculate the value of the equilibrium constant for this reaction?

A. $\dfrac{[HF]}{\frac{1}{2}[H_2] + \frac{1}{2}[F_2]}$

B. $\dfrac{[HF]}{[H_2][F_2]}$

C. $\dfrac{n(HF)}{n(H_2) \times n(F_2)}$

D. $\dfrac{n(HF)}{n(H_2)^{\frac{1}{2}} \times n(F_2)^{\frac{1}{2}}}$

Question 4

The reaction vessel is surrounded by a heat exchanger that keeps the reaction mixture at a constant temperature.

The amount of heat energy absorbed by the heat exchanger in order to keep a constant temperature in the reaction vessel is

A. 24.4 kJ

B. 59.6 kJ

C. 67.8 kJ

D. 92.1 kJ

Question 5

It is proposed to indirectly determine the concentration of Fe^{3+} ions in a solution by using UV-visible spectroscopy to measure the concentration of red-coloured $FeSCN^{2+}$ ions generated by the equilibrium reaction

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq) \qquad \Delta H = \text{negative}$$

colourless red

This procedure would provide the **most** accurate estimate of the concentration of Fe^{3+} ions in the original solution if

A. the value of the equilibrium constant is small, an excess of SCN^{-} is used, and the analysis is carried out at a low temperature.

B. the value of the equilibrium constant is large, an excess of Fe^{3+} is used, and the analysis is carried out at a high temperature.

C. the value of the equilibrium constant is small, an excess of Fe^{3+} is used, and the analysis is carried out at a high temperature.

D. the value of the equilibrium constant is large, an excess of SCN^{-} is used, and the analysis is carried out at a low temperature.

Question 6

In an endothermic reaction the

A. reaction system loses energy to the surroundings.

B. addition of a catalyst increases the activation energy.

C. activation energy is greater than the enthalpy of reaction.

D. energy required to break bonds in the reactants is less than the energy released when bonds are formed in the products.

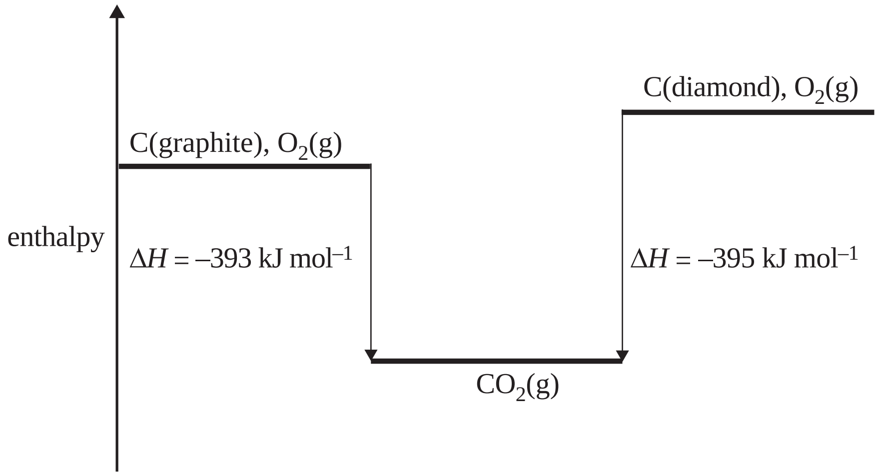
Question 7

Consider the following combustion reactions for graphite and diamond.

$$C(graphite) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393 \text{ kJ mol}^{-1}$$

$$C(diamond) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395 \text{ kJ mol}^{-1}$$

The following diagram summarises this information.



From the data provided it can be determined that the enthalpy change, ΔH, for the conversion of graphite to diamond

$$C(graphite) \rightarrow C(diamond)$$

is

A. -2 kJ mol^{-1}

B. $+2$ kJ mol^{-1}

C. -788 kJ mol^{-1}

D. $+788$ kJ mol^{-1}

Question 8

What mass of butane (M = 58.0 g mol^{-1}) must undergo complete combustion to raise the temperature of 100.0 g of water by 1.00 °C? Assume that there is no heat loss.

A. 8.44 g

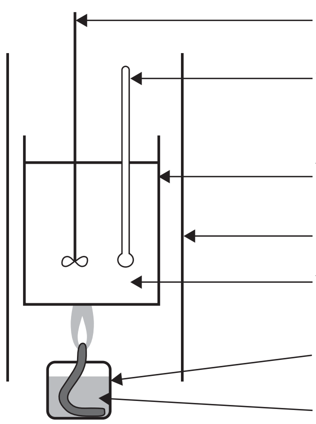
B. 6.88 g

C. 0.399 g

D. 8.44×10^{-3} g

Question 9

A student experimentally determined the molar enthalpy of combustion of ethanol (M = 46.0 g mol^{-1}) using the equipment shown in the following simplified diagram.



The student made the following experimental measurements.

Mass of water in beaker	=	100.0 g
Amount of ethanol combusted	=	0.0200 mol
Temperature rise of the water	=	40.0 °C

The molar enthalpy of combustion of ethanol calculated from the student's results is

A. –16.7 kJ mol^{-1}

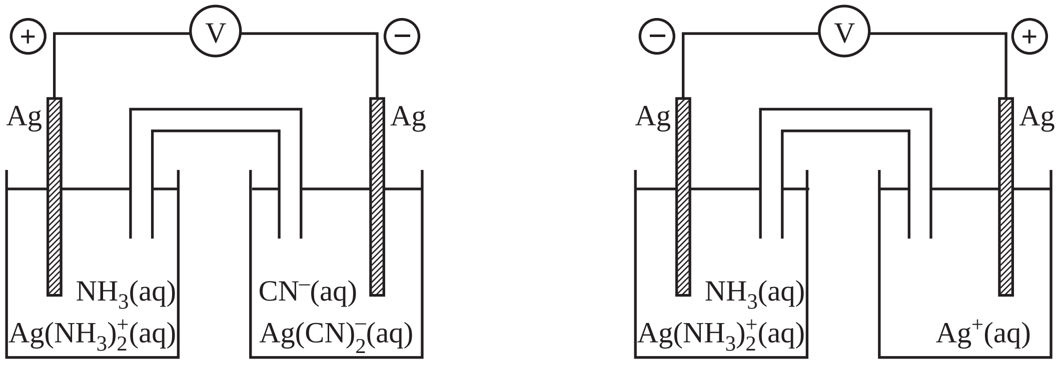
B. –18.2 kJ mol^{-1}

C. –334 kJ mol^{-1}

D. –836 kJ mol^{-1}

Question 10

Two galvanic cells were constructed under standard conditions in an experiment to determine the relative positions in the electrochemical series of the standard electrode potential, *E*°, for the following reactions. Both cells generate a potential difference.



$$Ag(NH_3)_2^+(aq) + e^- \rightleftharpoons Ag(s) + 2NH_3(aq) \qquad E^\circ_1$$

$$Ag^+(aq) + e^- \rightleftharpoons Ag(s) \qquad E^\circ_2$$

$$Ag(CN)_2^-(aq) + e^- \rightleftharpoons Ag(s) + 2CN^-(aq) \qquad E^\circ_3$$

The values of the electrode potentials in order from highest to lowest would be

A. $E^\circ_1, E^\circ_2, E^\circ_3$

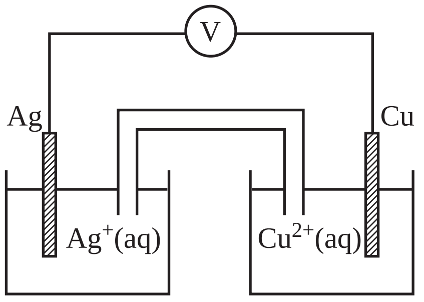
B. $E^\circ_1, E^\circ_3, E^\circ_2$

C. $E^\circ_2, E^\circ_1, E^\circ_3$

D. $E^\circ_3, E^\circ_2, E^\circ_1$

Use the following information to answer Questions 11 and 12.

The following galvanic cell was set up under standard conditions.



Question 11

The overall equation for the reaction occurring in this galvanic cell is

A. $Ag^+(aq) + Cu(s) \rightarrow Ag(s) + Cu^{2+}(aq)$

B. $Ag(s) + Cu^{2+}(aq) \rightarrow Ag^+(aq) + Cu(s)$

C. $2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$

D. $2Ag(s) + Cu^{2+}(aq) \rightarrow 2Ag^+(aq) + Cu(s)$

Question 12

The predicted maximum voltage produced by this cell under standard conditions is

A. 0.46 V

B. 1.14 V

C. 1.26 V

D. 1.94 V

Use the following information to answer Questions 13–16.

The lead-acid battery is made up of a series of secondary cells in which the following half-reactions are utilised.

$$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq) \qquad E° = -0.36 \text{ V}$$
$$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l) \qquad E° = 1.69 \text{ V}$$

Question 13

When the battery is discharging the

A. H^+ concentration decreases resulting in a higher pH.

B. H^+ concentration increases resulting in a higher pH.

C. H^+ concentration decreases resulting in a lower pH.

D. H^+ concentration increases resulting in a lower pH.

Question 14

When the lead-acid battery is recharging the energy transformation occurring is

A. chemical → electrical + heat.

B. kinetic → chemical + electrical + heat.

C. electrical → chemical + heat.

D. electrical → light + kinetic + heat.

Question 15

The reaction which occurs at the anode when the battery is recharging is

A. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

B. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

C. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

D. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Question 16

When recharging the lead-acid battery the positive terminal of the power supply should be connected to the

A. positive terminal of the battery where oxidation will occur.

B. positive terminal of the battery where reduction will occur.

C. negative terminal of the battery where oxidation will occur.

D. negative terminal of the battery where reduction will occur.

Question 17

If we compare a galvanic cell with an electrolytic cell, it is true to state that

A. in a galvanic cell reduction occurs at the negative electrode.

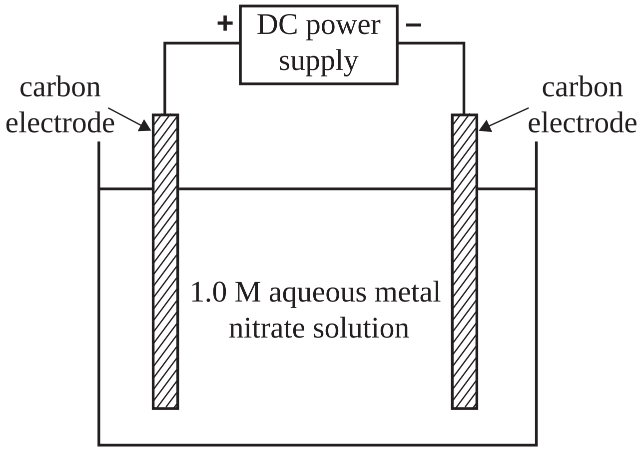
B. in both cells the anode is positive and the cathode is negative.

C. in an electrolytic cell oxidation occurs at the cathode.

D. in both cells reduction occurs at the cathode.

Question 18

A series of electrolysis experiments is conducted using the apparatus shown below.



An electric charge of 0.030 faraday was passed through separate solutions of 1.0 M $Cr(NO_3)_3$, 1.0 M $Cu(NO_3)_2$ and 1.0 M $AgNO_3$. In each case the corresponding metal was deposited on the negative electrode.

The amount, in mol, of each metal deposited is

	Amount, in mol, of chromium deposited	Amount, in mol, of copper deposited	Amount, in mol, of silver deposited
A.	0.030	0.030	0.030
B.	0.010	0.015	0.030
C.	0.090	0.060	0.030
D.	0.030	0.020	0.010

Question 19

An ornament was coated with a metal, M, by electrolysis of a solution of the metal ion, M^{x+}. During the electrolysis, a current of 1.50 amperes was applied for 180 seconds. The ornament was coated in 0.0014 mol of metal.

The value of *x* in M^{x+} is

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

Question 20

Which 0.1 M solution of the following acids has the highest pH?

A. nitrous acid
B. ethanoic acid
C. methanoic acid
D. hypobromous acid

END OF SECTION A
TURN OVER

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

During this semester you have studied the production, properties and uses of one of the following industrial chemicals. Circle the chemical you have studied this semester.

ammonia ethene nitric acid sulfuric acid

a. A Material Safety Data Sheet (MSDS) gives risk and safety phrases that are applicable to a specific chemical.

For example: the MSDS for calcium carbide includes

- the risk phrase, 'Contact with water liberates an extremely flammable gas'
- the safety phrase 'Keep the container dry'.

i. From the list of risk phrases provided below, circle **one** that is applicable to your selected industrial chemical.

Flammable	Toxic by inhalation
Toxic in contact with skin	Toxic if swallowed
Causes burns	Irritating to eyes
Irritating to respiratory system	Irritating to skin
Risk of serious damage to the eyes	Vapours may cause drowsiness and dizziness

ii. Write a safety phrase that is appropriate for the risk phrase you have identified in **part a. i.**

1 + 1 = 2 marks

b. The industrial chemical you have studied is used to make other useful chemicals.

i. Identify one useful industrial chemical that is produced from the chemical you have circled on page 10.

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ii. Write an equation for the formation of this useful chemical identified in **part b. i.** You must include your selected industrial chemical as a reactant in this equation.

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1 + 2 = 3 marks

Total 5 marks

Question 2

Energy resources utilised by society often involve a reaction that produces large amounts of heat. This heat energy can be transformed into another form of energy that is useful to society.

Consider the following list of equations. Each equation represents a reaction that takes place when a fuel is used to generate heat energy.

Reaction 1 $C(s) + O_2(g) \rightarrow CO_2(g)$

Reaction 2 $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

Reaction 3 ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

Reaction 4 $CH_3(CH_2)_{14}COOCH_3(l) + \frac{49}{2}O_2(g) \rightarrow 17CO_2(g) + 17H_2O(g)$

Select **one** of these reactions and answer the following questions.

Indicate your selection by circling **one** of the following.

Reaction 1 Reaction 2 Reaction 3 Reaction 4

a. i. Identify an energy resource that provides the fuel used in your selected reaction.

____

ii. Describe the major difference between a renewable energy resource and a nonrenewable energy resource.

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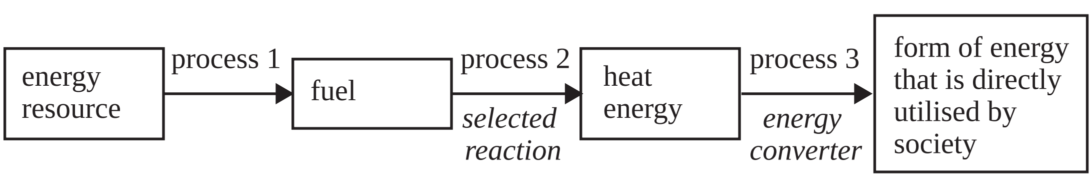
iii. Consider the following simplified flow chart.



During process 3, heat energy from your selected fuel source is converted into another form of energy that is useful to society. Identify this form of energy and provide one example that describes how this form of energy is used in society.

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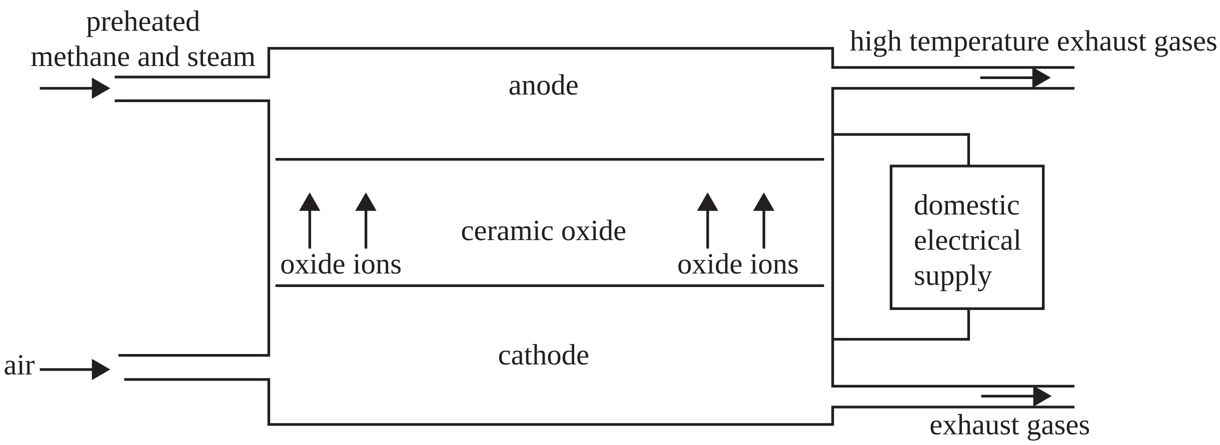
1 + 1 + 2 = 4 marks

b. A Victorian company produces solid oxide fuel cells for use in the home. These fuel cells use natural gas to produce electricity through an electrochemical process summarised in the diagram below.



i. Suggest one way in which a fuel cell differs from other galvanic cells.

ii. Write an equation for the reaction at the cathode where atmospheric oxygen is converted to oxide ions.

iii. A complex series of reactions takes place at the anode. These may be summarised by the half-equation

$$4O^{2-}(g) + CH_4(g) \rightarrow CO_2(g) + 2H_2O(g) + 8e^-$$

Write an equation that represents the overall reaction that takes place in this fuel cell.

1 + 1 + 1 = 3 marks

Total 7 marks

NO WRITING ALLOWED IN THIS AREA

Question 3

A solution calorimeter was calibrated by passing an electric current through the heating coil at a potential difference of 5.10 volts. This caused the water in the calorimeter to increase in temperature by 9.50 °C. The calibration factor for this calorimeter was previously determined to be 0.354 kJ $°C^{-1}$.

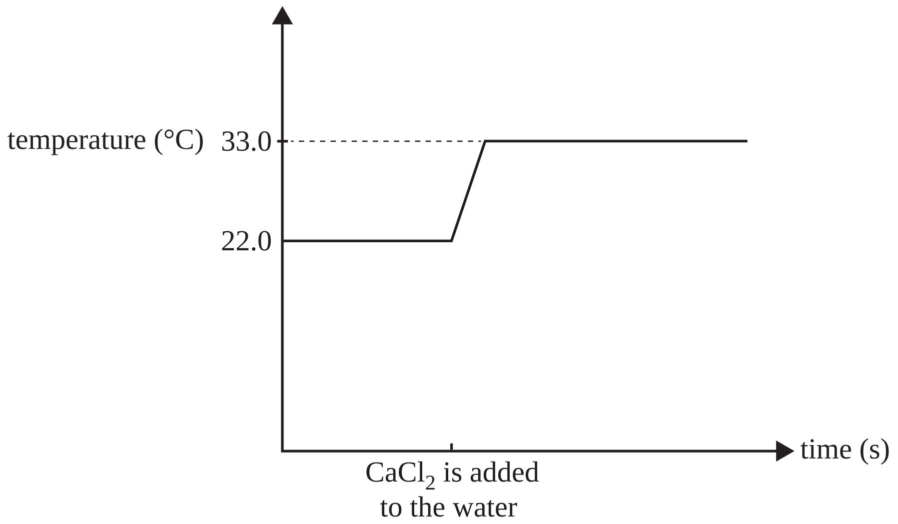
a. Use the calibration factor to determine the electrical charge, in coulombs, that passed through the heating coil.

2 marks

This calorimeter is then used to determine the enthalpy change for the dissolution of one mol of anhydrous calcium chloride, $CaCl_2$, in water.

$$CaCl_2(s) \rightarrow CaCl_2(aq)$$

6.038 g of solid anhydrous calcium chloride, $CaCl_2$, was added to the water. The mixture was stirred until all the solid had dissolved. The temperature was monitored before and after the addition of the calcium chloride. The results are shown in the graph below.



b. **i.** Is this reaction exothermic or endothermic?

Explain your answer.

ii. Use the calibration factor to calculate the enthalpy change for the dissolution of 1.00 mol of $CaCl_2(s)$. The molar mass of $CaCl_2$ = 111.1 g mol^{-1}.

2 + 4 = 6 marks

Total 8 marks

Question 4

a. This question requires you to refer to the Data Book and the information in the table below.

	Standard electrode potential $E°$ in volts
$HOBr(aq) + H^+(aq) + 2e^- \rightleftharpoons Br^-(aq) + H_2O(l)$	+1.33
$2HOBr(aq) + 2H^+(aq) + 2e^- \rightleftharpoons Br_2(l) + 2H_2O(l)$	+1.60

Explain why the following reaction between chlorine gas and bromide ions is **not** predicted to occur to any significant extent under standard conditions.

$$Cl_2(g) + Br^-(aq) + H_2O(l) \rightleftharpoons 2Cl^-(aq) + H^+(aq) + HOBr(aq)$$

2 marks

b. Chlorine can be manufactured in the laboratory by reacting concentrated hydrochloric acid with solid manganese(IV) oxide.

$$MnO_2(s) + 4HCl(aq) \rightleftharpoons MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

Write the oxidation half-equation for this reaction.

1 mark

Total 3 marks

CONTINUES OVER PAGE

Question 5

Nitrogen oxides are commonly found in the atmosphere in areas where there is serious atmospheric pollution.

Nitrogen monoxide, NO, is generated from the reaction between nitrogen and oxygen.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = +180.8 \text{ kJ mol}^{-1}$$

a. A sealed container is filled with 1.00 mole of NO(g) and equilibrium is established. The temperature is maintained at 1500 °C.

Explain why the rate of the reaction

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

will never be greater than the rate of the reaction

$$2NO(g) \rightarrow N_2(g) + O_2(g)$$

i. while the system is reaching equilibrium

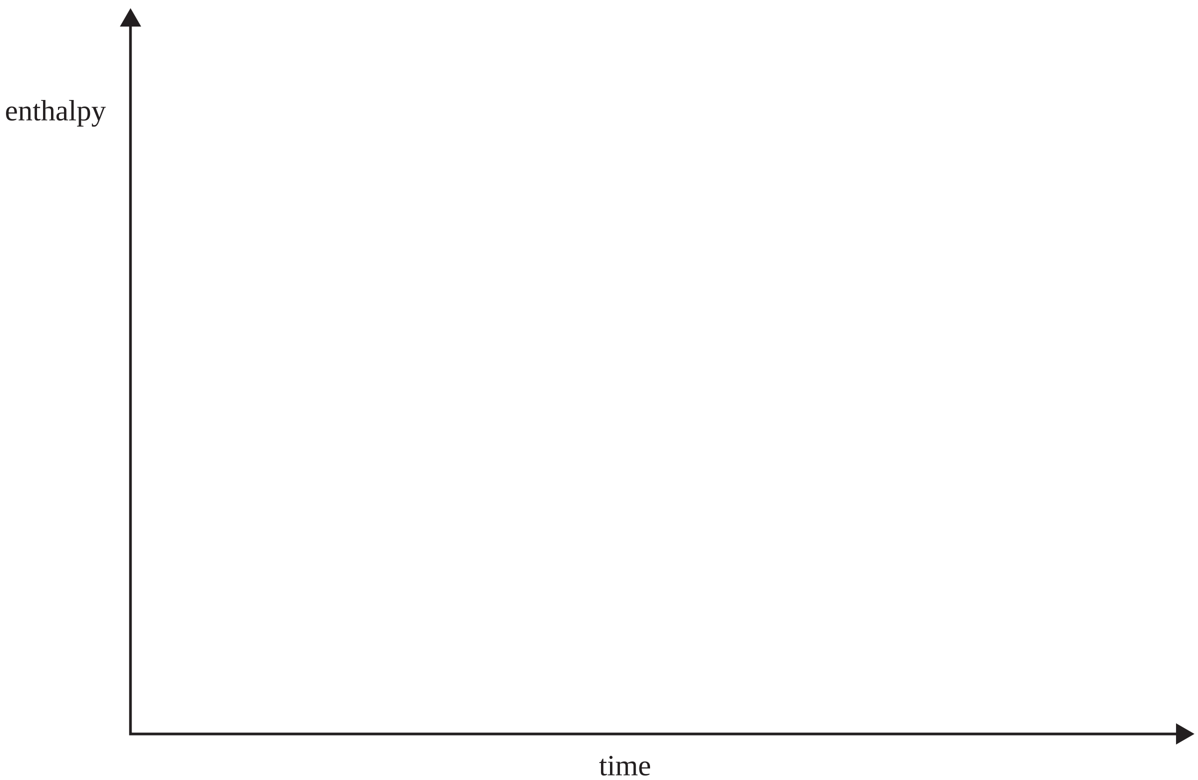
ii. once equilibrium is established.

1 + 1 = 2 marks

b. NO(g) is produced in combustion engines such as a car engine. Catalysts based on platinum and palladium are used in the exhaust system to decompose NO(g) into N_2(g) and O_2(g).

i. Based on the information provided, explain why combustion engines are such good chemical environments for the production of NO(g).

ii. Sketch, on the axes provided below, a fully labelled energy profile diagram for the decomposition reaction of NO. Indicate on the diagram the effect of using a catalyst in this reaction.



2 + 3 = 5 marks

Total 7 marks

Question 6

a. **i.** Write an equation for the reaction of methanoic acid with water.

ii. Write an equilibrium expression for the acidity constant, K_a, for the reaction in **part i.**

1 + 1 = 2 marks

b. A solution is prepared by adding 0.500 mol of methanoic acid, HCOOH, and 0.100 mol of sodium methanoate, HCOONa, to 2.00 L of water.

i. Determine the concentration of H_3O^+ ions in this solution.

In your calculations assume that

- the equilibrium concentration of HCOOH is approximately equal to the initial concentration of HCOOH
- the equilibrium concentration of $HCOO^-$ is approximately equal to the initial concentration of $HCOO^-$

ii. Calculate the pH of this solution.

iii. The following two solutions are prepared.

- Solution A: 1.00 L solution contains 0.500 mole of methanoic acid.
- Solution B: 1.00 L solution contains 0.500 mole of methanoic acid and 0.100 mole of sodium methanoate.

Which solution has the higher pH? Justify your answer in terms of the equilibria involved.

3 + 1 + 2 = 6 marks

Total 8 marks

Question 7

Methanol is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen and carbon monoxide gases at a temperature of 520 K and a pressure of 50 to 100 atmospheres.

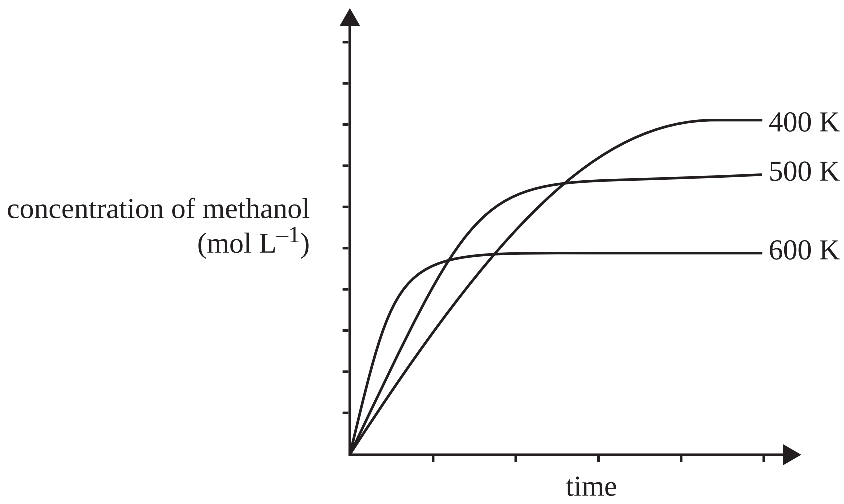
The reaction that occurs in the methanol converter is

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

a. Carbon monoxide gas and hydrogen gas are mixed in a reaction vessel and equilibrium is established.

The graph below shows how the concentration of methanol in this vessel changes with time at three different temperatures.

The pressure is the same at each temperature.



i. Is the reaction exothermic or endothermic?

Explain your answer.

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___

___

ii. Explain why a moderately high temperature of 520 K is used although the equilibrium concentration of methanol is greater at a lower temperature.

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iii. Explain why, at a given temperature, the use of high pressures results in a greater equilibrium concentration of methanol.

2 + 1 + 2 = 5 marks

b. A catalyst consisting of a mixture of copper, zinc and aluminium is used to increase the rate of this reaction. Explain how a catalyst can increase reaction rate.

1 mark

Total 6 marks

Question 8

A chemical engineer designs a pilot plant to determine the conditions that will give the best results for copper plating different objects.

A range of experiments indicates that an electroplating cell with an aqueous electrolyte containing copper(I) cyanide, CuCN, potassium cyanide, KCN, and potassium hydroxide, KOH, will produce a uniform copper coating.

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

1 mark

The quality of the copper coating depends on maintaining a low, constant concentration of copper(I) ions in the electrolyte. This is achieved by making use of the following reaction which takes place in the electrolyte bath. In this reaction, copper(I) ions, Cu^+, react with the cyanide ions, CN^-, according to the equation

$$Cu^+(aq) + 4CN^-(aq) \rightleftharpoons Cu(CN)_4^{3-} \qquad K = 1 \times 10^{28}$$

b. Refer to this information to explain how the presence of excess potassium cyanide in the electrolyte maintains a low concentration of $Cu^+(aq)$ ions in solution.

1 mark

The cyanide ion, CN^-, is the conjugate base of the acid hydrogen cyanide, HCN.

$$CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq) \qquad K = 10^{-4.8}$$

Hydrogen cyanide is highly toxic and can bubble out of solution.

c. Explain how the presence of potassium hydroxide in the electrolyte is essential to the safe operation of this cell.

1 mark

Any gas produced at the cathode is found to damage the quality of the copper plate. This is avoided by maintaining a low current.

d. Write a balanced equation for the gas most likely to be produced at the cathode if the current is too high.

1 mark

e. In one trial, a medal is copper plated in the cell. The experimental data is given below.

Mass of medal before copper plating	=	25.2 g
Mass of medal after copper plating	=	36.4 g
Current	=	0.900 A

Calculate the time, in minutes, taken to copper plate the medal.

4 marks

Total 8 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2011

CHEMISTRY
Written examination

Monday 14 November 2011

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** 20.1 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** 44.9 Scandium	22 **Ti** 47.9 Titanium	23 **V** 50.9 Vanadium	24 **Cr** 52.0 Chromium	25 **Mn** 54.9 Manganese	26 **Fe** 55.9 Iron	27 **Co** 58.9 Cobalt	28 **Ni** 58.7 Nickel	29 **Cu** 63.6 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** 95.9 Molybdenum	43 **Tc** 98.1 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** (209) 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** (277) Hassium	109 **Mt** (268) Meitnerium	110 **Ds** (271) Darmstadtium	111 **Rg** (272) Roentgenium	112 **Uub**		114 **Uuq**		116 **Uuh**		118 **Uuo**

58 **Ce** 140.1 Cerium	59 **Pr** 140.9 Praseodymium	60 **Nd** 144.2 Neodymium	61 **Pm** (145) Promethium	62 **Sm** 150.3 Samarium	63 **Eu** 152.0 Europium	64 **Gd** 157.2 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** 173.0 Ytterbium	71 **Lu** 175.0 Lutetium
90 **Th** 232.0 Thorium	91 **Pa** 231.0 Protactinium	92 **U** 238.0 Uranium	93 **Np** (237.1) 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

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) $= 6.02 \times 10^{23}$ mol^{-1}

Charge on one electron $= -1.60 \times 10^{-19}$ 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) $= 1.00 \times 10^{-14}$ 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

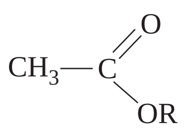
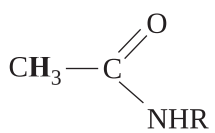
4. SI prefixes, their symbols and values

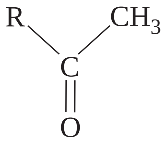
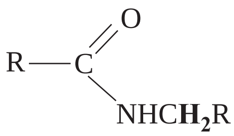
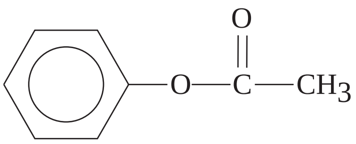
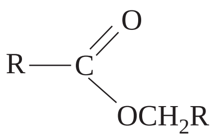
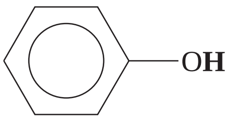
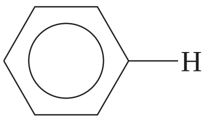
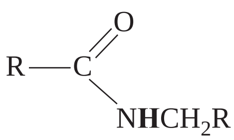
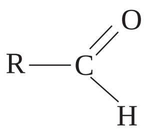
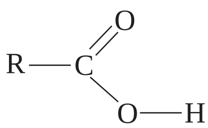
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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)
$R{-}CH_3$	0.9
$R{-}CH_2{-}R$	1.3
$RCH = CH{-}C\mathbf{H_3}$	1.7
$R_3{-}CH$	2.0
 or 	2.0

Type of proton	Chemical shift (ppm)
	2.1
$R–CH_2–X$ (X = F, Cl, Br or I)	3–4
R–C**H₂**–OH → $R–C\mathbf{H_2}–OH$	3.6
	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
	11.5

6. ^{13}C NMR data

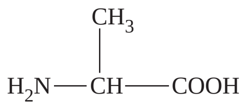
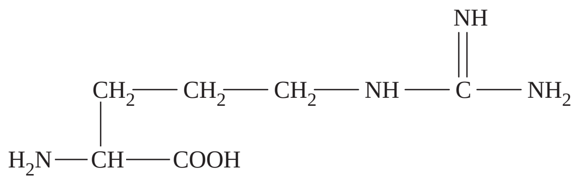
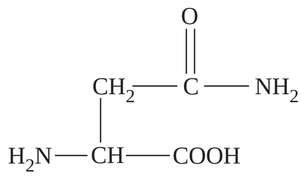
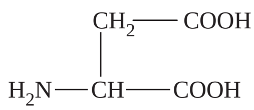
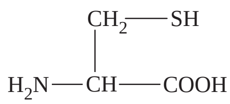
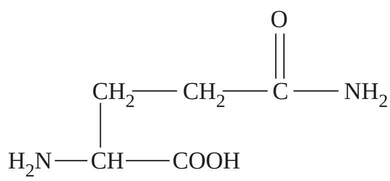
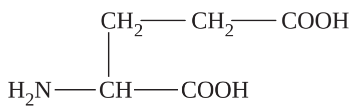
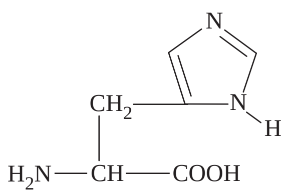
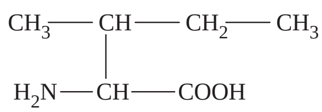
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

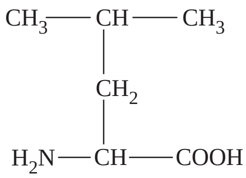
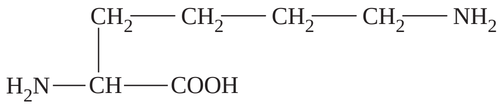
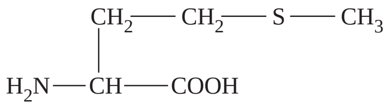
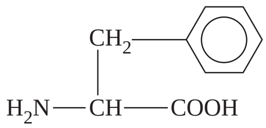
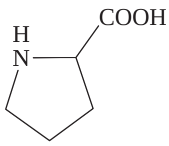
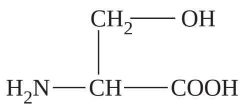
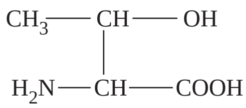
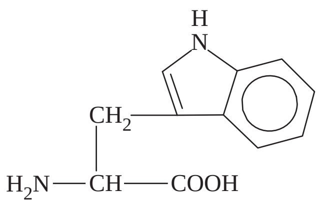
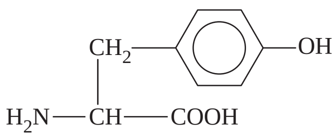
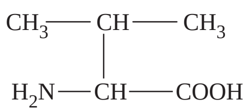
7. Infrared absorption data

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	

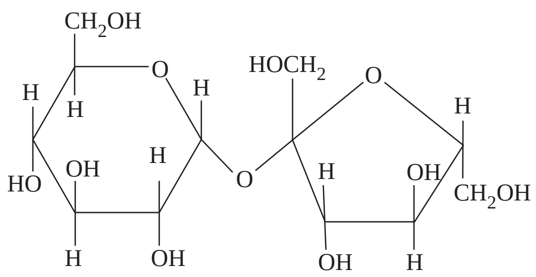
Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

TURN OVER

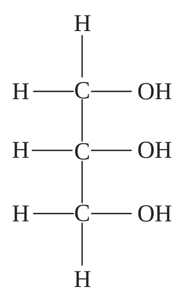
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

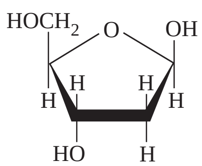
10. Structural formulas of some important biomolecules



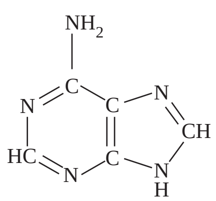
sucrose



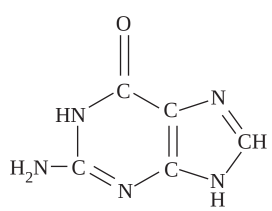
glycerol



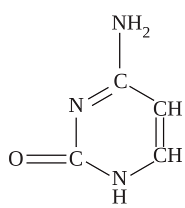
deoxyribose



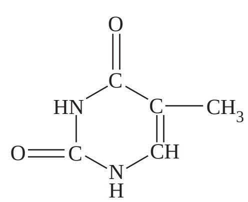
adenine



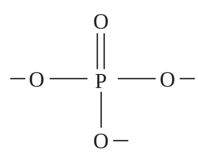
guanine



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