VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2009

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures										Letter
Words										

CHEMISTRY

Written examination 2

Thursday 12 November 2009

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	7	7	56
			Total 76

- 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 20 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

The addition of a catalyst to a chemical reaction

A. lowers the activation energy required for the reaction to occur.

B. lowers the chemical energy of the products.

C. lowers the chemical energy of the reactants.

D. lowers the value of the enthalpy change for the reaction.

Question 2

The two statements below give possible explanations for changes that occur when the temperature of a reaction mixture is increased.

I At a higher temperature, particles move faster and the reactant particles collide more frequently.

II At a higher temperature, more particles have energy greater than the activation energy.

Which alternative below best explains why the observed reaction rate is greater at higher temperatures?

A. I only

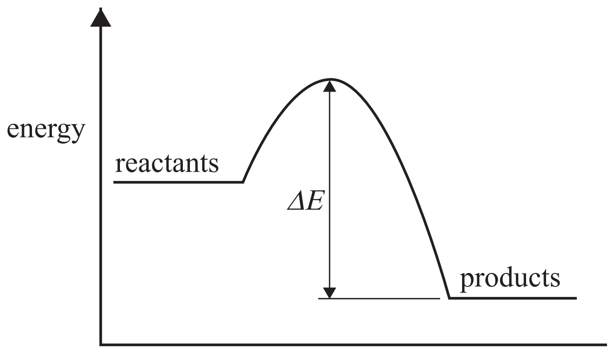
B. II only

C. I and II to an equal extent

D. I and II, but II to a greater extent than I

Question 3

The change in energy during a reaction is represented in the following energy profile diagram.



The change in energy labelled ΔE above is

A. the energy absorbed when bonds in the reactants break.

B. the activation energy of the forward reaction.

C. the activation energy for the reverse reaction.

D. the heat of reaction.

Question 4

If, for the reaction

$$C_2H_5OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l); \quad \Delta H = -1364 \text{ kJ mol}^{-1}$$

then the ΔH value for

$$4CO_2(g) + 6H_2O(l) \rightarrow 2C_2H_5OH(g) + 6O_2(g)$$

would be

A. +2728 kJ mol^{-1}

B. +1364 kJ mol^{-1}

C. +682 kJ mol^{-1}

D. –1364 kJ mol^{-1}

Question 5

The concentrations of reactants and products were studied for the following reaction.

$$H_2(g) + F_2(g) \rightleftharpoons 2HF(g); \quad K = 313 \text{ at } 25°C$$

In an experiment, the initial concentrations of the gases were

$$[H_2] = 0.0200 \text{ M}, \ [F_2] = 0.0100 \text{ M and } [HF] = 0.400 \text{ M}$$

When the reaction reaches equilibrium at 25°C, the concentration of HF will be

A. 0.400 M

B. 0.420 M

C. between 0.400 M and 0.420 M

D. less than 0.400 M

Question 6

The anaesthetic, nitrous oxide, N_2O, decomposes to form an equilibrium mixture of N_2O, N_2 and O_2 according to the following equation.

$$2N_2O(g) \rightleftharpoons 2N_2(g) + O_2(g)$$

At 25°C, $K = 7.3 \times 10^{37}$ M and at 40°C, $K = 2.7 \times 10^{36}$ M

What valid conclusion can be made from this?

A. The equilibrium concentrations of N_2 and O_2 are equal at 25°C.

B. The equilibrium concentration of N_2O is higher at 25°C than at 40°C.

C. N_2O is less stable at the higher temperature.

D. The forward reaction is exothermic.

Question 7

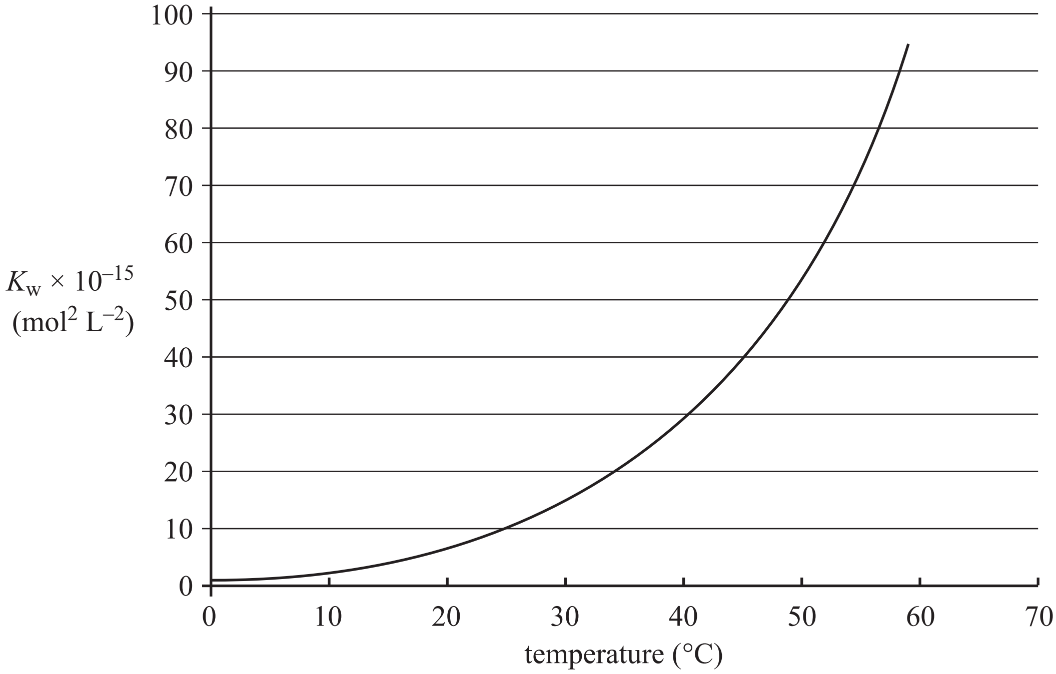
In a flask, 10.0 mL of a 0.100 M HCl solution is diluted to 1.00 L. In a second flask, 10.0 mL of a 0.100 M KOH solution is also diluted to 1.00 L.

Which statement best describes the changes in pH in these flasks?

	pH change of the HCl solution	pH change of the KOH solution
A.	increases by 2	decreases by 2
B.	increases by 2	increases by 2
C.	decreases by 2	increases by 2
D.	decreases by 2	decreases by 2

Question 8

The value of the ionisation constant, K_w, of a sample of pure water at different temperatures is shown in the graph below.



Which one of the following statements about the effect of increasing temperature on the pH and acidity of water is correct?

A. The pH is always 7 and the water remains neutral.

B. The pH decreases and the water remains neutral.

C. The pH decreases and the water becomes acidic.

D. The pH increases and the water remains neutral.

Question 9

The following table contains information about three experiments. In each experiment 0.10 mol of an alkane is burned completely and all the energy released is used to heat 1.00 L of water which was initially at 20°C.

experiment	alkane	molecular formula
I	butane	C_4H_{10}
II	pentane	C_5H_{12}
III	hexane	C_6H_{14}

In which experiment(s) will the water be heated to its boiling temperature?

A. III only

B. II and III only

C. I and II only

D. I, II and III

Question 10

Potassium hydroxide and hydrochloric acid react in aqueous solution according to the following equation.

$$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$$

A 50 mL solution containing 0.025 mol of KOH was mixed rapidly in an insulated vessel with a 50 mL solution containing 0.025 mol of HCl. The temperature increased by 3.5°C.

Assuming that the specific heat capacity of the solution is the same as that of water, the enthalpy change, ΔH, of this reaction, in **kJ mol^{-1}**, is closest to

A. –29

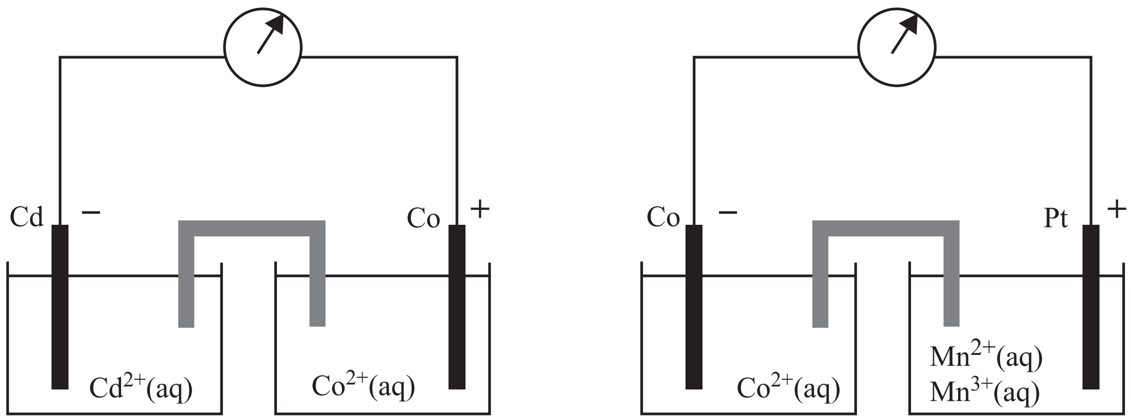
B. –59

C. -2.9×10^4

D. -5.9×10^4

Question 11

Two standard galvanic cells are shown below.



On the basis of the polarity of the electrodes shown above, which one of the following reactions would **not** be expected to occur spontaneously?

A. $Co^{2+}(aq) + Cd(s) \rightarrow Co(s) + Cd^{2+}(aq)$

B. $2Mn^{3+}(aq) + Co(s) \rightarrow 2Mn^{2+}(aq) + Co^{2+}(aq)$

C. $2Mn^{3+}(aq) + Cd(s) \rightarrow 2Mn^{2+}(aq) + Cd^{2+}(aq)$

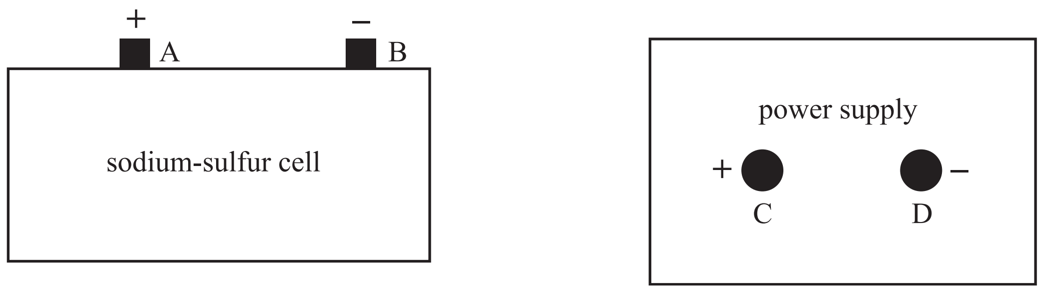
D. $2Mn^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Mn^{3+}(aq) + Co(s)$

Question 12

The sodium-sulfur cell shown below is a secondary galvanic cell with the overall cell reaction

$$2Na(l) + S(l) \rightleftharpoons Na_2S(l)$$

The cell produces 2.1 volts.



The cell is to be recharged by connecting it to the power supply.

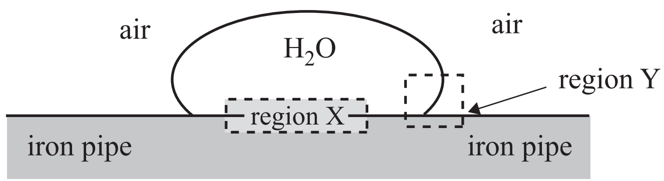
Which one of the following best describes the arrangement for recharging the cell?

	Power supply voltage	Connect terminals
A.	2.1 volts	A to C and B to D
B.	2.1 volts	A to D and B to C
C.	more than 2.1 volts	A to C and B to D
D.	more than 2.1 volts	A to D and B to C

Questions 13 and 14 refer to the following information.

Iron pipes are used to transport natural gas to cities. Corrosion occurs when water droplets sit on the outer surface of the iron pipe.

Miniature galvanic cells are created, with regions such as those shown below, that act as anodes and cathodes.



Question 13

The type of region and reaction occurring at X in the cell is

	Region	Reaction
A.	anode	$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
B.	cathode	$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
C.	anode	$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
D.	cathode	$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

Question 14

Corrosion of an iron pipe can be prevented by connecting it to a magnesium bar buried in the ground. The magnesium corrodes in preference to the iron.

If the average current flowing between the two metals is 2.0×10^{-6} A, the amount of magnesium metal, in mol, reacting each second, would be

A. 1.0×10^{-11}

B. 2.1×10^{-11}

C. 4.1×10^{-11}

D. 0.19

Questions 15 and 16 refer to the following information.

A fuel cell can be constructed that uses the following two half-reactions.

$$CO_2(g) + 6H^+(aq) + 6e^- \rightleftharpoons CH_3OH(aq) + H_2O(l) \qquad E^o = +\,0.05\text{ V}$$

$$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l) \qquad E^o = +1.23\text{ V}$$

Question 15

Which one of the following would occur at the negative electrode of the cell as it generates electricity?

A. production of H^+

B. formation of H_2O

C. consumption of CO_2

D. reduction of CH_3OH

Question 16

Which one of the following statements about this fuel cell is most likely to be correct?

A. An external power supply is used to recharge the cell.

B. Gaseous products are recycled into the cell to improve efficiency.

C. Chemical energy is not completely converted into electrical energy.

D. More H^+ ions are produced at the anode than are consumed at the cathode.

Question 17

Many reactions occurring in plant and animal cells involve a chemical called nicotinamide adenine dinucleotide, NAD^+. One such reaction is

$$2NADH(aq) + 2H^+(aq) + O_2(g) \rightleftharpoons 2NAD^+(aq) + 2H_2O(l)$$

It has been suggested that this reaction could be used in biochemical fuel cells to power pacemakers used to control irregular heartbeats.

If this reaction were performed in a fuel cell, NADH would

A. undergo oxidation at the anode.

B. undergo reduction at the cathode.

C. undergo reduction at the anode.

D. undergo oxidation at the cathode.

Question 18

Which one of the following describes the polarity of the anodes in electrolytic and galvanic cells?

	electrolytic cells	**galvanic cells**
A.	positive	positive
B.	positive	negative
C.	negative	negative
D.	negative	positive

Question 19

An aqueous solution containing a mixture of 1.0 M KI and 1.0 M $CaBr_2$ was electrolysed using unreactive electrodes.

Which one of the following reactions is most likely to occur at the anode?

A. $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

B. $2Br^-(aq) \rightarrow Br_2(aq) + 2e^-$

C. $Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$

D. $2I^-(aq) \rightarrow I_2(aq) + 2e^-$

Question 20

Lithium metal is manufactured by electrolysis of lithium salts.

Which of the following would be the best choice for the electrolyte and the anode in a commercial cell?

	electrolyte	**anode**
A.	LiCl solution	iron rod
B.	molten LiCl	iron rod
C.	LiCl solution	carbon rod
D.	molten LiCl	carbon rod

END OF SECTION A

SECTION B – Short answer questions

Instructions for Section B

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

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 credit 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

a. Use information from the electrochemical series in the Data Book to write a balanced overall equation that shows hydrogen peroxide, H_2O_2, reacting as a reductant.

2 marks

b. Using data from the electrochemical series, a student suggests that a reaction will occur between Cu^{2+} ions and H_2 gas. To test this prediction, hydrogen gas was bubbled into an aqueous solution of copper(II) sulfate, $CuSO_4$. No reaction was observed after 5 minutes. Provide one possible chemical reason that explains why the predicted reaction was not observed.

1 mark

Total 3 marks

Question 2

A 'QwikCure' pack, used to treat sporting injuries, contains a bag of water inside a larger bag of finely powdered ammonium nitrate, NH_4NO_3. Squeezing the pack causes the bag of water to break and the NH_4NO_3 to dissolve. The change of energy that occurs can be used to treat an injury.

$$NH_4NO_3(s) \rightarrow NH_4NO_3(aq); \qquad \Delta H = +25 \text{ kJ mol}^{-1}$$

a. Suppose the activation energy of the **reverse reaction** is 35 kJ mol^{-1}.

i. Explain the meaning of the term 'activation energy'.

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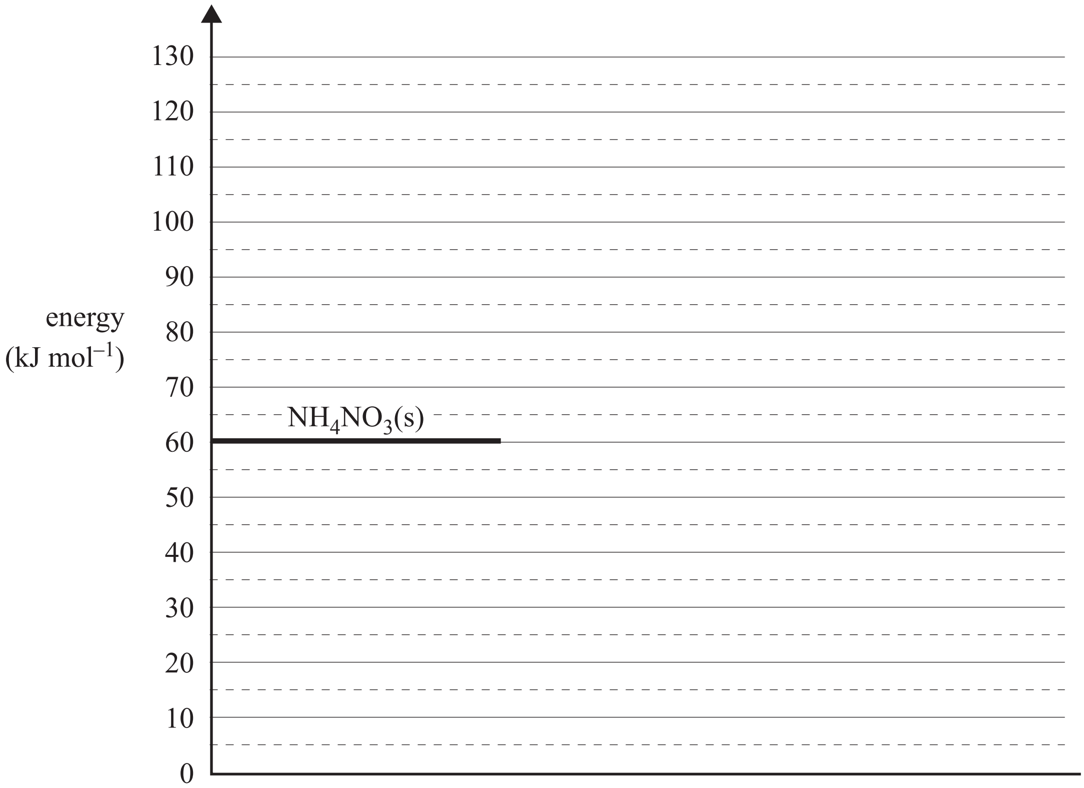
ii. On the graph below, sketch an energy profile diagram showing the changes that occur in chemical energy as the NH_4NO_3 powder dissolves.



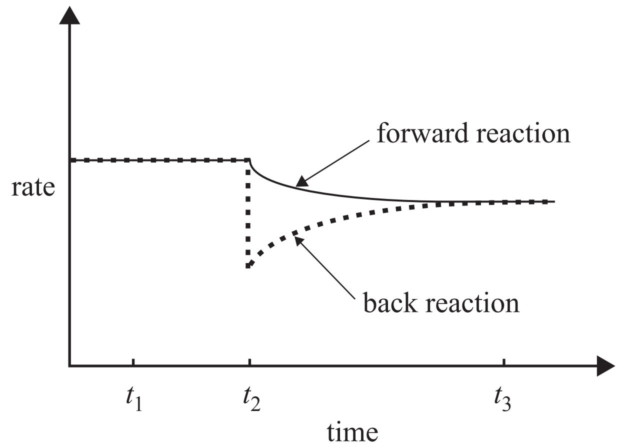
1 + 2 = 3 marks

b. A chemist investigates the equilibrium reaction of ammonium ions with water. In this reaction the ammonium ion acts as a weak acid.

i. Write an equation for the equilibrium reaction of ammonium ions with water.

___

While keeping the **temperature constant**, the chemist makes a change to a solution of ammonium ions in water that is initially at equilibrium. The following graph shows the effect of this change, which was made at time t_2, on the **rates** of the forward and back reactions.



ii. What could have caused the change that occurred at time t_2? Explain why the rate of the back reaction is affected by this change.

___

___

___

___

___

iii. Would the value of the equilibrium constant at time t_3 **be less than**, **equal to** or **greater than** the value of the equilibrium constant at time t_1? Circle the correct response.

less than equal to greater than

1 + 2 + 1 = 4 marks

c. The NH_4NO_3 powder in a QwikCure pack dissolves completely to form 300 mL of solution, with a pH of 5.04.

i. Write an expression for the acidity constant, K_a, for the reaction between ammonium ions and water.

ii. Calculate the concentration, in mol L^{-1}, of H_3O^+ ions in the 300 mL of solution.

iii. Calculate the mass, in grams, of NH_4NO_3 in the pack.

1 + 1 + 3 = 5 marks

Total 12 marks

Question 3

Dimethyl ether, CH_3OCH_3, is used as an environmentally friendly propellant in spray cans. It can be synthesised from methanol according to the following equation.

$$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g); \qquad \Delta H = -24 \text{ kJ mol}^{-1}$$

The equilibrium constant, K, for this reaction at 350°C is 5.74.

a. Write an expression for K for this reaction.

1 mark

b. Calculate the value of K at 350°C for the following reaction.

$$CH_3OCH_3(g) + H_2O(g) \rightleftharpoons 2CH_3OH(g)$$

1 mark

c. Methanol is pumped into an empty 20.0 L reactor vessel. At equilibrium the vessel contains 0.340 mol of methanol at 350°C.

i. Calculate the concentration, in mol L^{-1}, of methanol at equilibrium.

ii. Calculate the amount, in mol, of dimethyl ether present at equilibrium.

iii. Calculate the amount, in mol, of methanol initially pumped into the reaction vessel.

1 + 2 + 2 = 5 marks

Total 7 marks

Question 4

Methyl palmitate, $C_{17}H_{34}O_2$, is a component of one type of biochemical fuel. It is a liquid at room temperature.

The molar enthalpy of combustion of methyl palmitate was determined using a bomb calorimeter.

The calorimeter was calibrated by passing a current of 4.40 amperes at a potential difference of 5.61 volts through an electric heater for 240 seconds. The temperature of the calorimeter rose by 1.75°C.

a. Calculate the calibration factor of the calorimeter. Include the units of the calibration factor with your answer.

3 marks

A 0.529 g sample of methyl palmitate was then burned in excess oxygen in the calorimeter and the temperature rose by a further 6.19°C. The molar mass of methyl palmitate is 270 g mol^{-1}.

b. Calculate the amount of energy, in kJ, absorbed by the calorimeter when the sample of methyl palmitate was burned.

1 mark

c. Calculate the amount of energy released, in kJ, by the combustion of 1.00 mol of methyl palmitate.

2 marks

d. The balanced equation for the combustion of liquid methyl palmitate in excess oxygen is

$$2C_{17}H_{34}O_2(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(l).$$

Write the value of ΔH for this reaction, in kJ mol^{-1}.

2 marks

Most of Victoria's electricity is generated by burning fossil fuels such as coal and natural gas. Alternative methods of generating electricity are currently being developed.

e. Biochemical fuels are an alternative fuel for generating electricity.

i. Name one biochemical fuel, other than methyl palmitate, and the raw material used in its production.

Biochemical fuel ______________________________

Raw material used in its production ______________________________

ii. Identify **one** disadvantage or limitation of the use of this biochemical fuel for the large-scale generation of electricity.

____

____

2 + 1 = 3 marks

f. Some countries rely on nuclear fission for the large-scale production of electricity.

i. State one advantage of using nuclear fission.

____

ii. State one disadvantage of using nuclear fission.

____

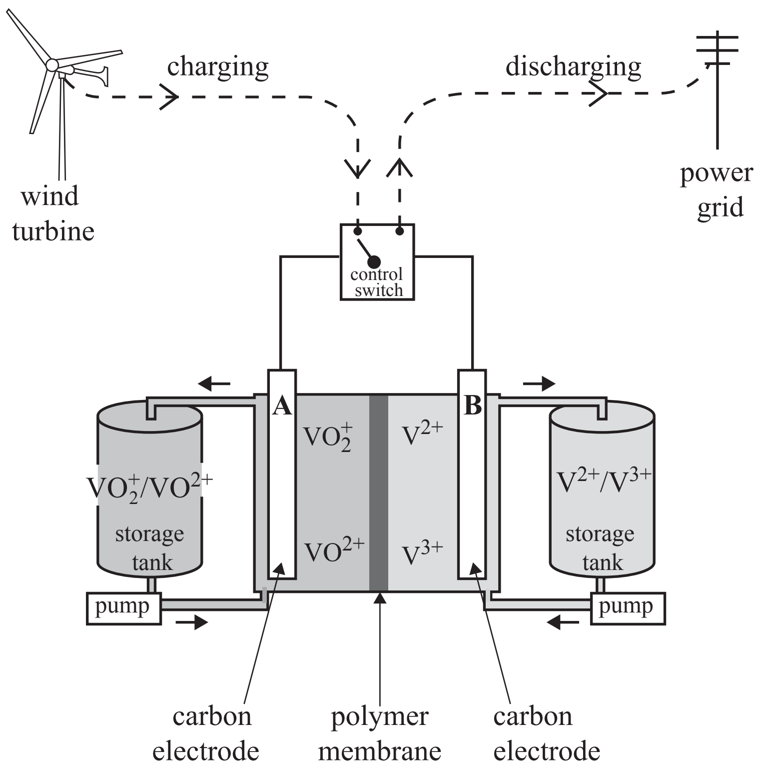
1 + 1 = 2 marks

Total 13 marks

Question 5

A vanadium redox battery is used to store electrical energy generated at a wind farm in Tasmania. The battery supplies electricity to the power grid as required through a control switch.

The diagram below shows the structure of a cell in a vanadium redox battery. The reactants are dissolved in an acidic solution, stored in large tanks and pumped through the cell. The cell is recharged using electricity generated by the wind turbines. A polymer membrane allows the movement of particular ions.



The two relevant half-equations for the vanadium redox battery are

$$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l) \qquad E^o = +1.004 \text{ V}$$

$$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq) \qquad E^o = -0.255 \text{ V}$$

a. State the polarity of each electrode as the battery is discharged.

Electrode A ______________________________

Electrode B ______________________________

1 mark

b. Circle the vanadium-containing ion that would have the highest concentration at the anode when the cell is **fully charged**.

VO_2^+ VO^{2+} V^{3+} V^{2+}

1 mark

c. Write a balanced overall equation for the reaction that occurs when the cell is being **recharged**.

1 mark

d. Compare the vanadium redox cell to a fuel cell by describing **one** major way in which they differ.

1 mark

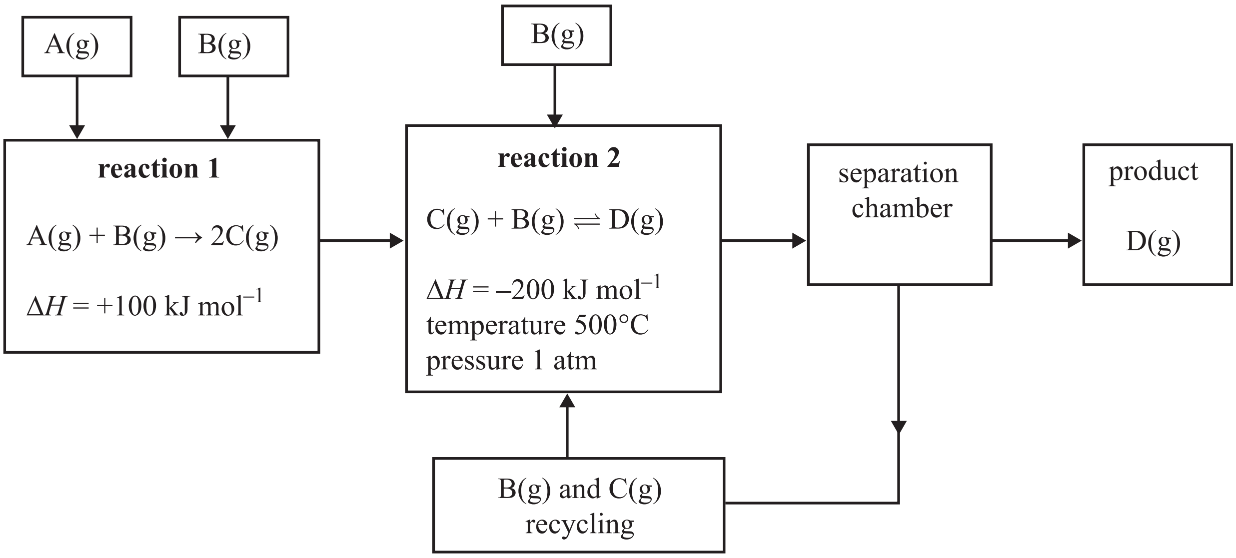
e. Write a balanced overall equation to show why iron would be an unsuitable material to use as electrode B in the vanadium redox cell.

1 mark

Total 5 marks

Question 6

A particular industrial process involves the following steps.



a. It is possible to alter the temperature and pressure at which reaction 2 occurs.

In the table below, indicate what effect the following changes to temperature and pressure would have on the **rate**, **equilibrium yield** and value of the **equilibrium constant**, ***K***, for reaction 2.

	Would the **rate** of reaction 2 become **higher**, **lower** or **remain unchanged**?	Would the **equilibrium yield** of reaction 2 become **higher**, **lower** or **remain unchanged**?	Would the **value of the equilibrium constant**, ***K***, of reaction 2 become **higher**, **lower** or **remain unchanged**?
The temperature of reaction 2 is lowered to 150°C.			
The pressure of reaction 2 is increased to 5 atm by pumping more B(g) and C(g) into the reaction vessel, at constant temperature.			

6 marks

b. Heat energy is released by reaction 2. Describe how the heat energy could be used within this industrial process.

____

____

____

1 mark

c. During this semester you have studied the production of one of the following chemicals.
Circle the chemical you have studied in detail this semester.

ammonia ethene sulfuric acid nitric acid

i. Describe one waste management strategy, other than recycling heat, employed in the industrial production of your selected chemical.

____

____

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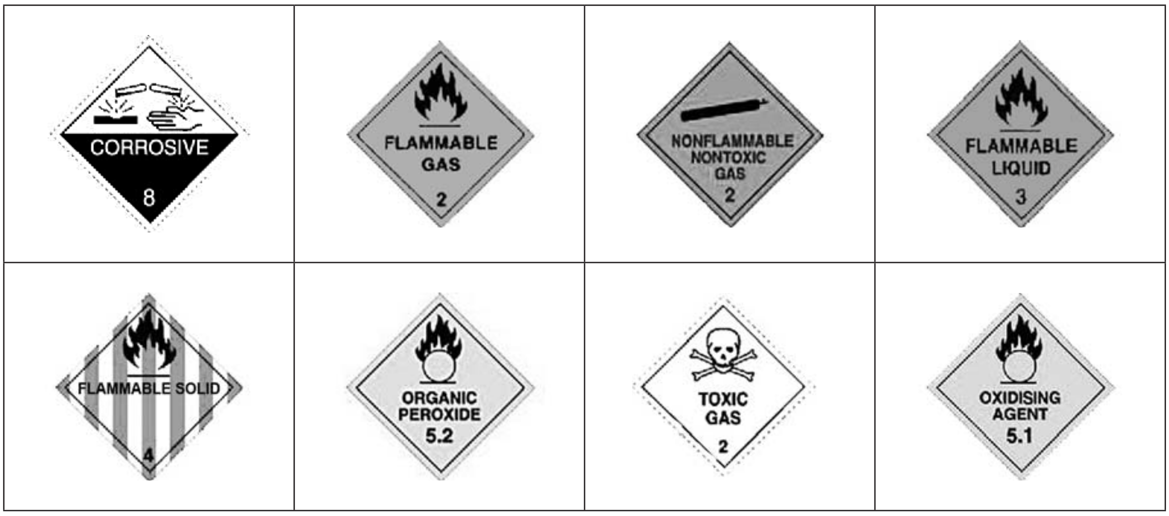
ii. The following table includes a selection of HAZCHEM labels used to identify dangerous goods.



Circle one label that could be used to identify the hazardous nature of your selected chemical.

iii. State two uses of your selected chemical.

Use 1 ____

Use 2 ____

1 + 1 + 2 = 4 marks

Total 11 marks

Question 7

A classroom experiment was set up to simulate the industrial extraction of zinc metal from an aqueous solution of zinc ions by electrolysis. In this experiment 150 mL of 1.00 M $ZnSO_4$ solution was electrolysed at 25°C using inert carbon electrodes.

a. Write a half-equation for the oxidation reaction.

1 mark

b. A mass of 0.900 g of zinc is produced in 30.0 minutes.

Calculate the electric current, in A, supplied to the cell during the electrolysis. Express your answer to an appropriate number of significant figures.

4 marks

Total 5 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2009

CHEMISTRY

Written examination

Thursday 12 November 2009

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.

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1. Periodic table of the elements

atomic number	79	symbol of element
relative atomic mass	**Au** 197.0 Gold	name of element

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) = 6.02×10^{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

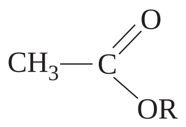
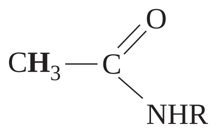
4. SI prefixes, their symbols and values

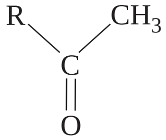
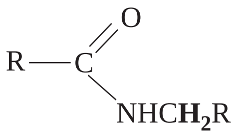
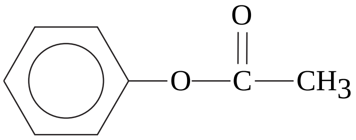
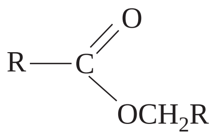
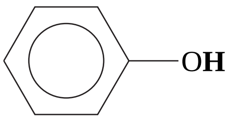
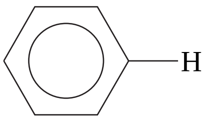
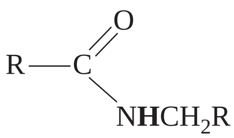
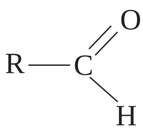
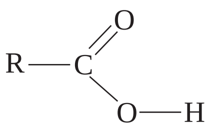
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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)
$R{-}CH_3$	0.9
$R{-}CH_2{-}R$	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
$R–C\mathbf{H_2}–OH$	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

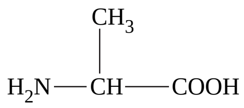
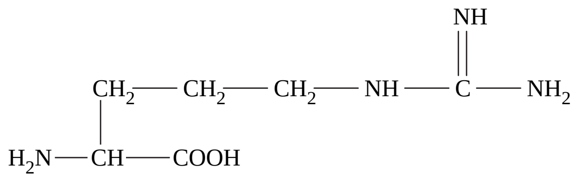
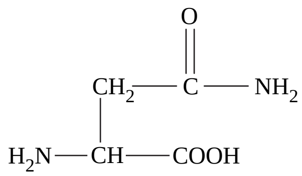
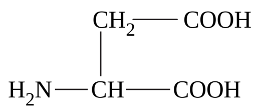
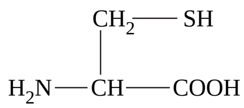
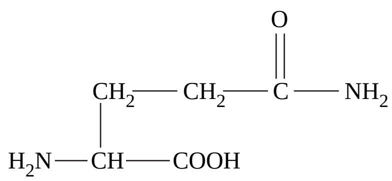
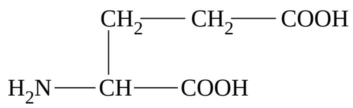
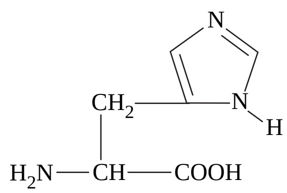
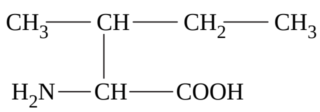
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

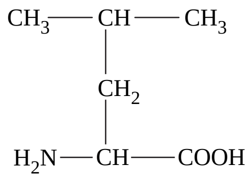
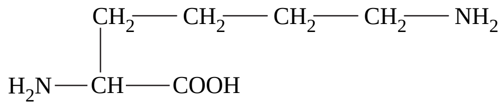
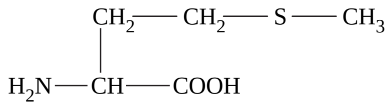
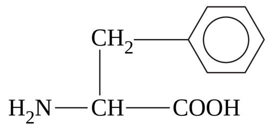
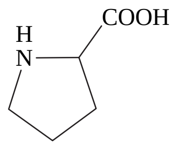
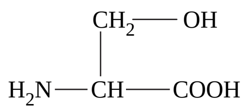
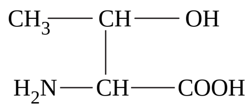
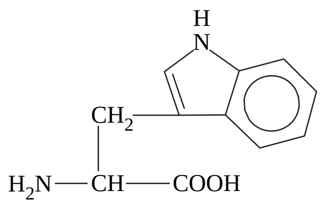
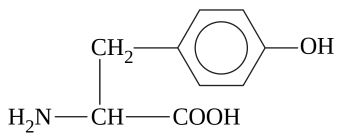
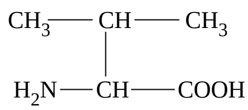
7. Infrared absorption data

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	

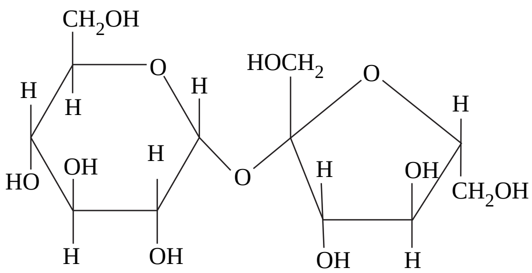
Name	**Symbol**	**Structure**
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

TURN OVER

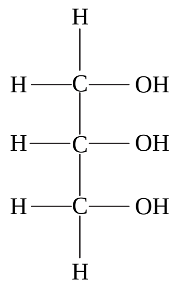
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

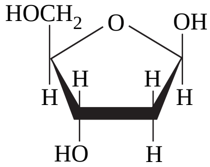
10. Structural formulas of some important biomolecules



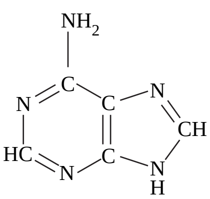
sucrose



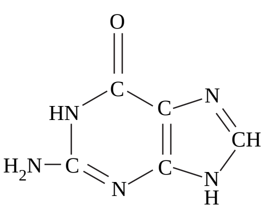
glycerol



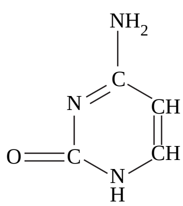
deoxyribose



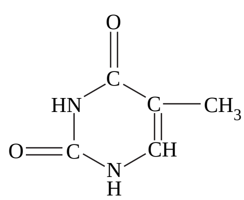
adenine



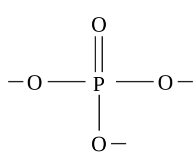
guanine



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

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