Chemistry 2008–2011
Written examination – End-of-year

Examination Specifications

Overall conditions

The examination will be sat at an end-of-year time and date to be set annually by the Victorian Curriculum and Assessment Authority.

There will be 15 minutes reading time and 90 minutes writing time.

VCAA examination rules will apply. Details of these rules are published annually in the *VCE and VCAL Administrative Handbook.*

The examination will be marked by a panel appointed by the VCAA.

The examination will contribute 33 per cent to the Study Score.

Content

All of the key knowledge in Unit 4 is examinable. All the key skills, as outlined on page 12 of the *Chemistry VCE Study Design*, are examinable.

Approved materials and equipment

Dictionaries are not allowed in the examination room in this study.

A scientific calculator is allowed in the examination room for this study.

Format

The examination paper will be in the form of a question and answer book. There will be a Data Book supplied with the examination.

The examination will consist of two sections, Section A and Section B.

Section A will contain approximately 20 multiple-choice questions. Each question in Section A will be worth one mark, and all questions will be compulsory.

Section B will contain compulsory short answer questions worth 45–60 marks.

Advice

The VCE study, Chemistry, has been reaccredited for implementation in Units 3 and 4 in 2008.

During the 2007(8)–2011 accreditation period for VCE Chemistry, examinations will be prepared according to the Examination specifications above. Each examination will conform to these specifications and will test a representative sample of the key knowledge and skills.

Version 2 – May 2008

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2008

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures									Letter
Words									

CHEMISTRY

Written examination 2

Day Date 2008

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (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	59
			Total 79

- 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 21 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.

November 2007

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.

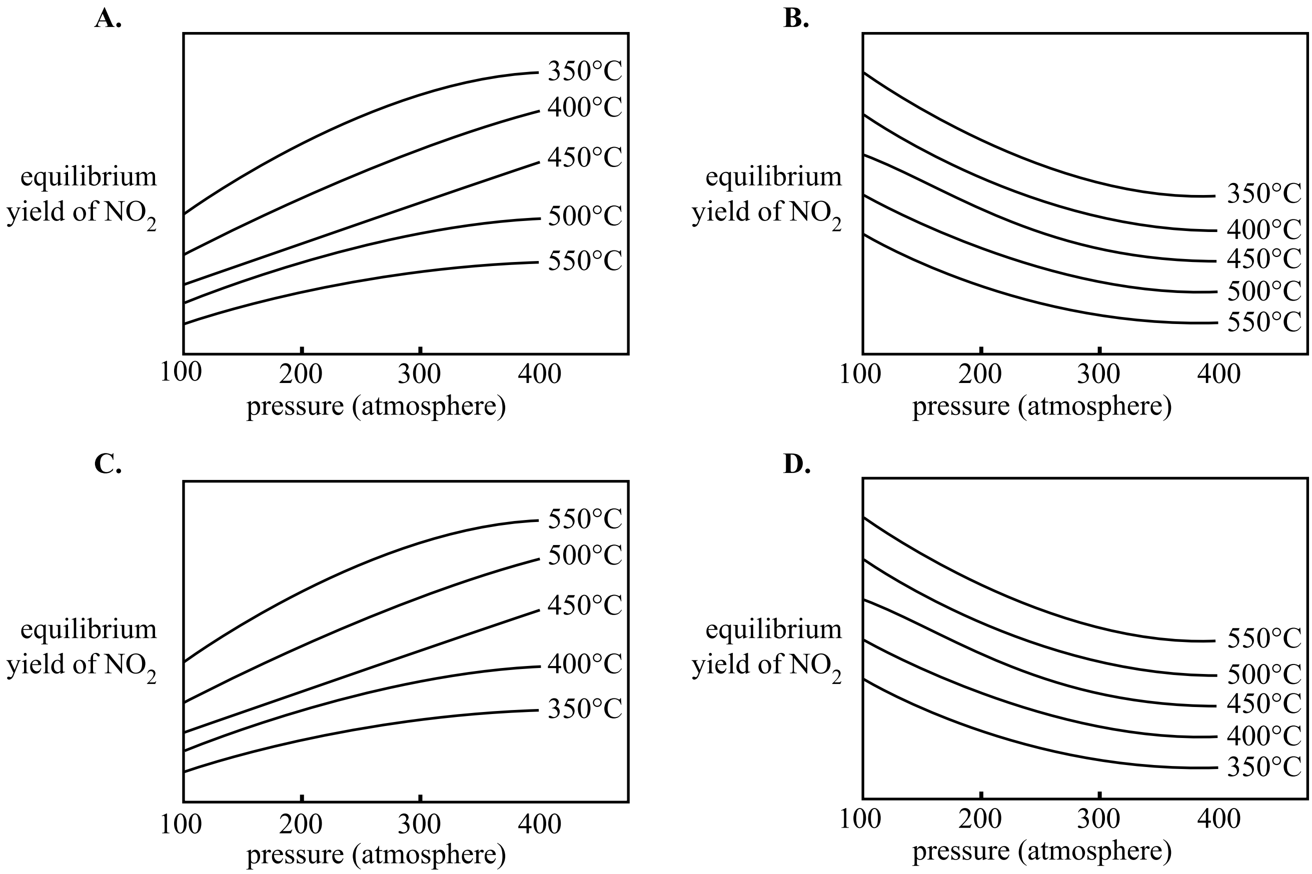
No marks will be given if more than one answer is completed for any question.

Question 1

Dinitrogen tetroxide exists in equilibrium with nitrogen dioxide according to the equation

$$N_2O_4\,(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +58 \text{ kJ mol}^{-1}$$

Which one of the following graphs best shows the effect of increasing pressure and temperature on the equilibrium yield of nitrogen dioxide?



Question 2

The OCl^- ion acts as a base in water according to the equation

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

When two drops of 5.0 M NaOH are added to an equilibrium mixture of OCl^- in water at constant temperature

A. the pH of the solution decreases.

B. the concentration of OH^- increases.

C. the concentration of HOCl increases.

D. the ratio $[OCl^-]/[HOCl][OH^-]$ increases.

SECTION A – continued

Question 3

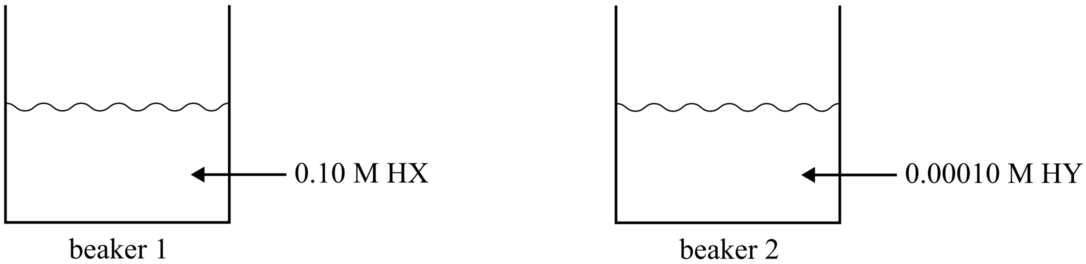
Which of the following changes in conditions will **always** ensure an increase in the amount of product present at equilibrium?

I increasing the proportion of a reactant in the reaction mixture
II increasing temperature
III decreasing pressure
IV adding a catalyst

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

Question 4

HX and HY are acids. Beaker 1 contains 100 mL of 0.10 M HX(aq) and beaker 2 contains 100 mL of 0.00010 M HY(aq). Both solutions have a pH of 4.0.



Which of the following statements about HX and HY is/are correct?

I HY is a stronger acid than HX.
II Both acids have the same K_a value but HX is more concentrated than HY.
III The concentration of H^+(aq) in beaker 1 is greater than that in beaker 2.

A. I only
B. II only
C. III only
D. II and III only

Question 5

Benzoic acid, C_6H_5COOH, molar mass 122 g mol^{-1}, is a weak monoprotic acid.

The pH of a solution formed when 500 mg of benzoic acid is dissolved completely in water to form 200 mL of solution is closest to

A. 1.0
B. 1.7
C. 3.0
D. 4.2

Question 6

The equation for the self ionisation of water is given below.

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

At 90°C, water is

A. neutral and has a pH smaller than 7

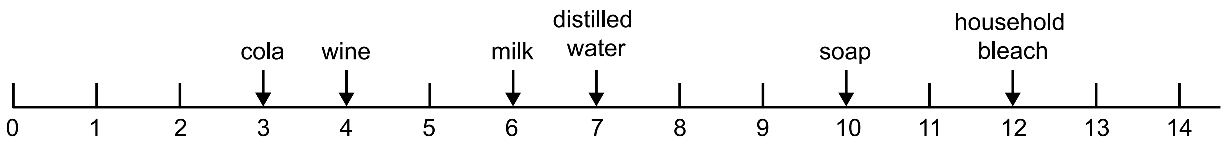
B. acidic and has a pH equal to 7

C. neutral and has a pH equal to 7

D. acidic and has a pH smaller than 7

Question 7

The pH of several substances is given below.



From the above pH values, we can deduce that the concentration of hydrogen ions is about

A. twice as great in household bleach than in milk.

B. 1 000 000 times greater in soap than in wine.

C. four times greater in cola than in household bleach.

D. 1 000 times greater in distilled water than in soap.

Question 8

A galvanic cell being trialled in electric vehicles is the sodium-sulfur cell. It operates at around 350°C, sulfur being a liquid at this temperature. The half equations for this cell are

	$E°$
$3S(l) + 2e^- \rightarrow S_3^{2-}(l)$	– 0.7 V
$Na^+(l) + e^- \rightarrow Na(l)$	– 2.7 V

Select the alternative which correctly lists the reactant at the anode and the anode's polarity.

	reactant and polarity	
A.	sodium	negative
B.	sulfur	negative
C.	sulfur ions	positive
D.	sodium	positive

Question 9

Lithium-ion cells are excellent power sources for high-drain devices such as portable computers and mobile phones. These consist of an anode of lithium metal absorbed into graphite, a solid metal oxide cathode such as CoO_2, and a polymer electrolyte containing a dissolved metal salt.

Which of the following reactions could **not** occur as the cell is discharging?

A. $Li \rightarrow Li^+ + e^-$

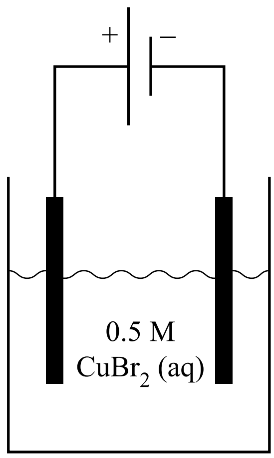
B. $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$

C. $Li + CoO_2 \rightarrow LiCoO_2$

D. $LiCoO_2 \rightarrow Li + CoO_2$

Question 10

Consider the following electrolytic cell which operates at 25°C.



An observer of the cell would see

A. no reaction at all because the process is endothermic.

B. a colourless gas at the cathode and a metallic coating on the anode.

C. a coloured liquid at the anode and a metallic coating on the cathode.

D. a colourless gas at the anode and a coloured liquid at the cathode.

Question 11

Information supplied on the electrochemical series about Fe^{2+}(aq) indicates that Fe^{2+}(aq)

A. can act an oxidant but not a reductant.

B. can act as a reductant but not an oxidant.

C. can oxidise solid zinc and reduce liquid bromine.

D. will always react to form Fe(s) in redox reactions.

Question 12

5.0 g of ethanol undergoes complete combustion in a bomb calorimeter with a calibration factor of 3.34 kJ K^{-1}.

The temperature change of the water in the calorimeter, in °C, is closest to

A. 24

B. 34

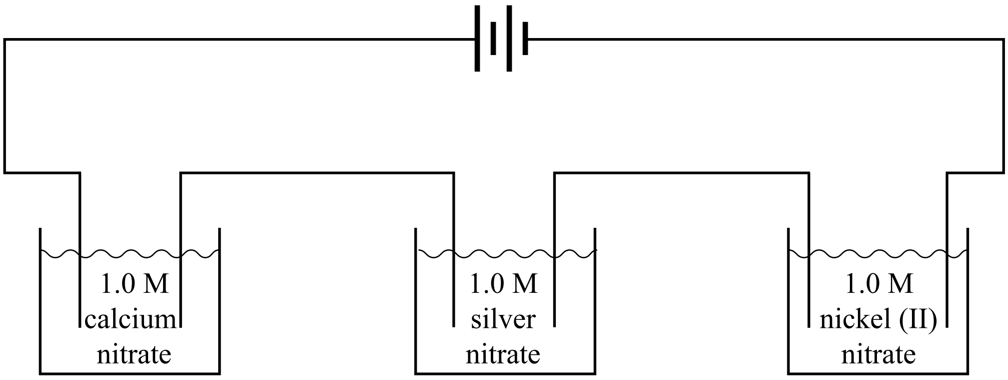
C. 44

D. 54

Question 13

An electric current is passed through three cells connected in series.

The cells contain 1.0 M aqueous solutions of calcium nitrate, silver nitrate and nickel (II) nitrate respectively. Each cell also contains a pair of platinum electrodes.



The ratio of the amount, in mole, of Ca(s), Ag(s) and Ni(s) deposited at the negative electrode in each cell, under standard conditions, is

	n(Ca)	n(Ag)	n(Ni)
A.	2	1	2
B.	0	2	1
C.	1	2	1
D.	0	1	2

Question 14

Which one of the following statements about primary and secondary galvanic cells as they are discharging is correct?

A. Anions flow towards the negative electrode in both types of cells.

B. The anode is positive in one type of cell and negative in the other.

C. Oxidation occurs at the positive electrode in one type of cell and reduction occurs in the other.

D. Chemical energy is converted into electrical energy in one type of cell and the reverse process occurs in the other.

Question 15

Three half cells are constructed as follows.

Half cell 1: a cobalt electrode in a solution containing 1.0 M Co^{2+}(aq) ions

Half cell 2: a graphite electrode in a solution containing both 1.0 M Fe^{2+}(aq) and 1.0 M Fe^{3+}(aq)

Half cell 3: an electrode of metal X in a solution containing 1.0 M X^{2+}(aq)

When half cells 1 and 3 are joined to form a galvanic cell, the cobalt electrode is the negative electrode.

When half cells 2 and 3 are joined to form a galvanic cell, the electrode of metal X is the negative electrode.

The species that is the strongest oxidant is

A. Co^{2+}(aq)

B. Fe^{2+}(aq)

C. Fe^{3+}(aq)

D. X^{2+}(aq)

Question 16

Phosphorus reacts with excess chlorine according to the following equation.

$$P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(g)$$

When 6.49 g of $PCl_5(g)$ is produced, 11.7 kJ of energy is released.

ΔH for this reaction, in kJ mol^{-1}, is closest to

A. 0.364

B. 1.46

C. 375

D. 1500

Question 17

Which one of these fuels, when undergoing complete combustion, releases most energy for each **mole of carbon dioxide** produced?

A. methane

B. butane

C. octane

D. ethanol

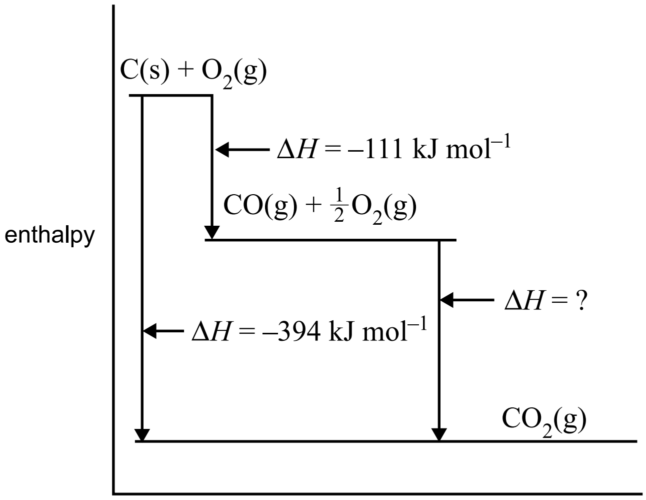
END OF SECTION A
TURN OVER

Question 18

The following energy profile relates to the two reactions

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H = -111 \text{ kJ mol}^{-1}$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -394 \text{ kJ mol}^{-1}$$



Consider the reaction $CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g)$

The value of ΔH, in kJ mol^{-1}, is

A. 222

B. –283

C. –394

D. –505

Question 19

In a particular reaction, a large volume of carbon dioxide is evolved.

Which of the following could be used to best trap the carbon dioxide in order to avoid releasing it into the atmosphere?

A. $H_2O(l)$

B. NaOH(aq)

C. NaCl(aq)

D. HCl(aq)

Question 20

Which statement about the behaviour of a catalyst in a chemical reaction is correct?

A catalyst provides an alternative pathway with

A. a lower activation energy for the forward reaction only.

B. a higher activation energy for the forward reaction only.

C. a lower activation energy for both the forward and back reactions.

D. a higher activation energy for both the forward and back reactions.

END OF SECTION A

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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

In the industrial production of a particular chemical, chemical engineers introduce a new catalyst. The catalyst is introduced as a finely ground powder. The engineers are surprised to find that the rate of reaction gradually decreased over a number of days. Investigation of the catalyst shows that it has fused into large clumps.

a. In terms of collision theory, explain why this would affect the reaction rate.

1 mark

The permanganate ion (MnO_4^-), in acid solution, is a strong oxidant capable of oxidising the oxalate ion ($C_2O_4^{2-}$) to carbon dioxide. The half equations for this reaction are given below.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$

b. **i.** Write an overall equation for this reaction.

ii. In terms of collision theory, explain why the rate of reaction is generally expected to decrease as a reaction proceeds.

The rate of this particular reaction between MnO_4^- and $C_2O_4^{2-}$ is observed to **increase** as the reaction proceeds.

iii. Propose a hypothesis to explain why the rate of this reaction might increase as the reaction proceeds and explain how your hypothesis supports this observation.

1 + 1 + 2 = 4 marks

Total 5 marks

Question 2

Ethanol is not the only alcohol gaining in popularity as a fuel. Methanol, CH_3OH, is also the subject of considerable research; especially for use in fuel cells. The commercial production of methanol, however, is quite different to that of ethanol and involves a two step process.

Step 1 Production of hydrogen gas

Large quantities of hydrogen, for industrial use, are produced through steam methane reforming (SMR). Steam reforming converts methane (and other hydrocarbons in natural gas) into hydrogen and carbon monoxide by reaction with steam over a nickel catalyst.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

Temperatures of about 850°C and pressures of 1000 kPa to 2000 kPa are used in this step.

Step 2 Reaction of hydrogen and carbon monoxide to form methanol using a mixture of ZnO and CrO_3 as a catalyst.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Temperatures of about 300ºC and pressures of 5000 kPa to 10 000 kPa are used in this step.

a. Write an expression for the equilibrium constant, *K*, for the reaction in step 2.

1 mark

b. In terms of equilibrium **and** rate, explain why

i. elevated temperatures are used in both steps with the temperature used in step 1 being much higher than in step 2

ii. pressures higher than atmospheric are used in both steps, with the pressure used in step 2 being much higher than in step 1

iii. a catalyst is used in both steps.

3 + 3 + 1 =7 marks

c. Identify one way in which the energy efficiency of this method of methanol production can be maximised.

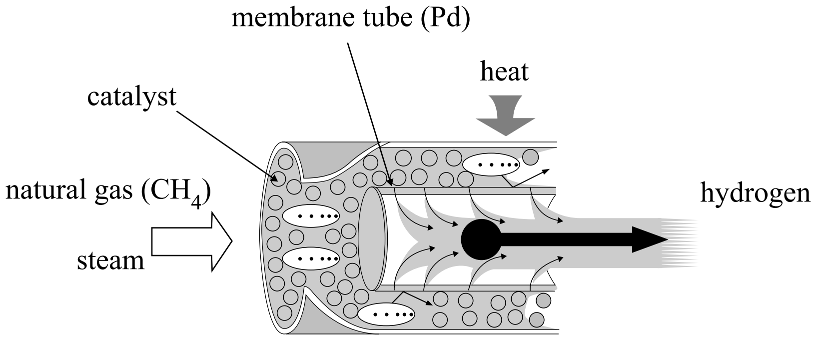
1 mark

Methanol is reacted with oxygen in a fuel cell to produce electrical energy.

d. Write a half equation for the oxidation of methanol using an acidic electrolyte in a fuel cell.

2 marks

In a newer version of the steam methane reforming (SMR) process described in step 1, the reforming reactions occur in a tube surrounding a palladium membrane. The membrane selectively separates hydrogen from the gas mixture.



e. i. Explain why the separation of hydrogen in this way increases the yield of hydrogen obtained.

ii. Identify one disadvantage of this method of steam methane reforming (SMR).

iii. Hydrogen can also be produced by electrolysis of a dilute solution of potassium chloride.
Give the overall equation for this reaction.

1 + 1 + 1 = 3 marks

Total 14 marks

Question 3

When phosgene, $COCl_2$, is introduced into a reactor, equilibrium is attained according to the reaction

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

The chlorine gas is light green in colour, while the other gases are colourless.

0.30 mol of $COCl_2$(g) and 0.20 mol of CO(g) are introduced in a 5.0 L container at 40°C. When equilibrium is reached, 0.10 mol of Cl_2(g) has formed. The temperature is maintained at 40°C throughout the experiment.

a. **i.** Calculate the numerical value of the equilibrium constant, *K*, for the forward reaction at 40°C.

ii. Calculate the numerical value of the equilibrium constant for the reverse reaction at 40°C.

3 + 1 = 4 marks

b. Explain why constant pressure may be seen as an indication that the reaction is at equilibrium.

1 mark

c. Equilibrium mixtures of these gases are subjected to the changes listed in the table.

i. Complete the table by predicting the effect of each of the following changes on the colour of the gas mixture. The temperature is kept constant throughout.

change	**final colour of mixture in comparison with that in initial equilibrium (unchanged, deeper green or lighter green)**
1. increase in volume	
2. addition of more carbon monoxide at constant volume	
3. addition of a non-reacting gas at constant volume	

ii. Which of the above changes, if any, would lead to an **increase** in the value of the equilibrium constant, *K*, for this reaction?

____

3 + 1 = 4 marks

d. Briefly describe how you could determine, experimentally, whether the forward reaction is exothermic or endothermic.

____

____

____

2 marks

Total 11 marks

Question 4

In VCE Chemistry Unit 4, you investigated the industrial production of a selected chemical.

a. i. Write the chemical formula of the chemical you studied.

____

ii. Write a balanced chemical equation for a reaction involved in the production of this chemical in which the **chemical itself is a product**.

____

____

2 marks

Octane, C_8H_{18}, is a major constituent of petrol used in cars.

b. i. Write a balanced equation for the complete combustion of octane.

____

____

ii. Give the value and sign of ΔH for this reaction.

____

3 marks

Lithium has emerged as a preferred reactant for a range of innovative, new galvanic cells. One such example is the lithium-thionyl chloride ($SOCl_2$) cell. In this cell, $SOCl_2$ is a liquid and acts as a reactant as well as the electrolyte.

c. Lithium is one of the reactants in this cell.

i. Write the equation for the half reaction involving lithium. State symbols are not required for this equation.

____

The equation for the other half reaction is

$$2SOCl_2(aq) + 4e^- \rightarrow 4Cl^-(aq) + SO_2(g) + S(s)$$

ii. Write an overall balanced equation for this cell. State symbols are not required for this equation.

____

____

The sulfur dioxide, SO_2, produced in the cell dissolves in the electrolyte.

iii. Give one reason why this might be important to the continued operation of the cell.

____

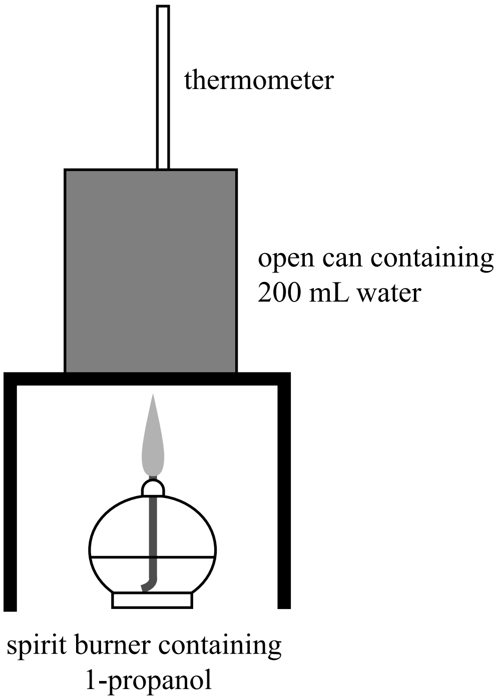
____

1 + 1 + 1= 3 marks

Total 8 marks

Question 5

A laboratory experiment is set up to determine the heat of combustion of 1-propanol. 1-propanol is burned in a 'spirit burner' and heat released is used to heat 200 mL of water. The equipment was set up as shown below.



The following data was recorded.

Mass of spirit burner before heating: 125.62 g
Mass of spirit burner after heating: 122.89 g
Temperature of water before heating: 22.7°C
Temperature of water after heating: 85.6°C

a. Use the change in the temperature of the water to determine the amount of energy, in kJ, added during heating.

2 marks

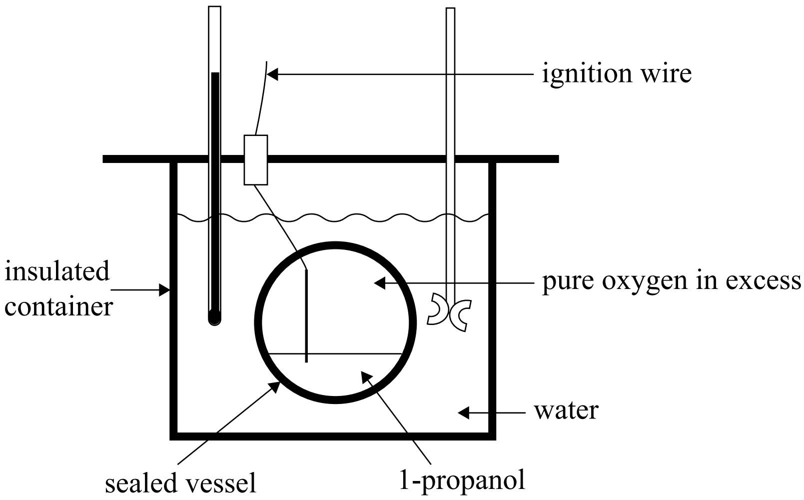
b. Determine an experimental value of the enthalpy of combustion, in kJ mol^{-1}, of 1-propanol.

2 marks

c. By comparing the experimentally determined value of the enthalpy of combustion with the theoretical one given in your data sheet, determine the percentage of chemical energy of the 1-propanol which ends up as heat energy in the water.

1 mark

d. The molar enthalpy of combustion of 1-propanol was then determined using a bomb calorimeter as shown below.



bomb calorimeter

Give two reasons why the numerical value of the heat of combustion of 1-propanol obtained using a bomb calorimeter would be larger than that obtained using the 'spirit burner'.

2 marks

Total 7 marks

Question 6

Give concise explanations for the following.

a. Hydrogen gas is bubbled through a solution of 1.0 M Fe^{3+} ions. On the basis of the electrochemical series, a redox reaction is predicted to occur. In practice, no reaction occurs at room temperature.

1 mark

b. Less electricity is generated by burning methane in a gas power station than if the same amount of methane were used in a fuel cell.

1 mark

c. Commercial production of magnesium involves the electrolysis of a molten magnesium chloride. Aqueous solutions of magnesium chloride cannot be used.

1 mark

d. The quantity of electricity required to produce 1 mole of magnesium by the electrolysis of molten magnesium bromide is significantly greater than that required to produce 1 mole of potassium by electrolysis from molten potassium bromide.

1 mark

Total 4 marks

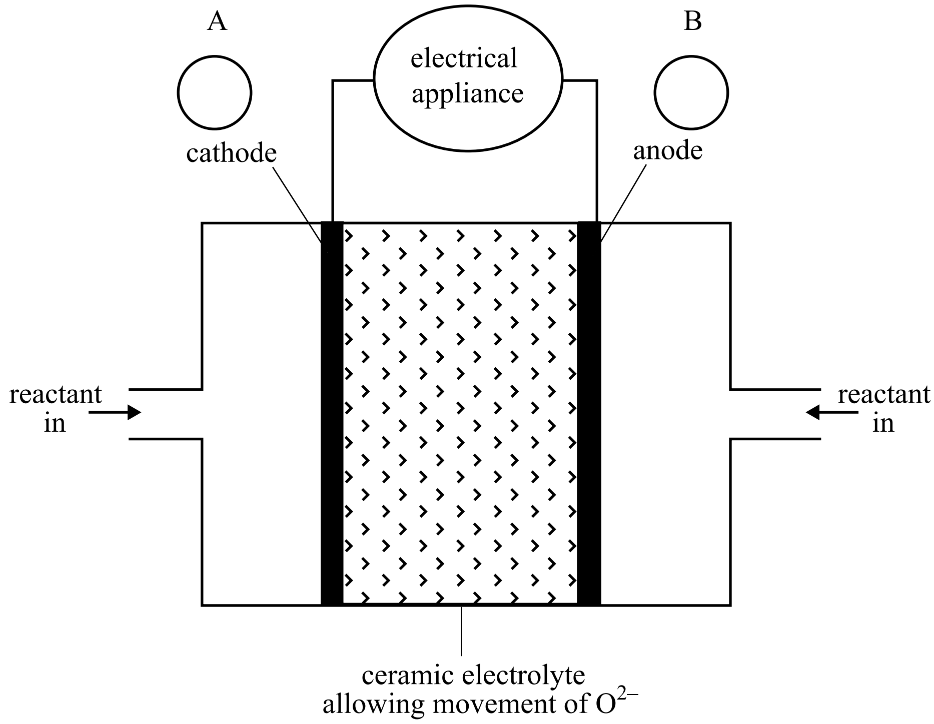
Question 7

An Internet site reporting the latest developments in fuel cell technology describes a cell that uses a solid ceramic material as the electrolyte and hydrogen gas and oxygen gas as the reactants.

Key features of this cell are

- water is the only product from the cell reaction
- the ceramic material allows the movement of oxide ions (O^{2-})
- the reaction at the anode is $H_2(g) + O^{2-}$(in ceramic) $\rightarrow H_2O(l) + 2e^-$
- operation at very high temperatures of over 1000°C means that precious metal catalysts are not required.

A representation of the cell providing electricity for an appliance is shown in the diagram below.



a. What distinguishes a fuel cell from a galvanic cell such as a dry cell or lead-acid battery?

1 mark

b. On the diagram above

i. in **circles A and B**, indicate the polarity of the cathode and anode

ii. show, by using an arrow, the direction of electron flow in the external circuit.

1 + 1 = 2 marks

c. Write an equation for each of the following reactions. You are not required to show states in these two equations.

i. the overall cell reaction

ii. the reaction at the cathode

1 + 1 = 2 marks

d. A ceramic fuel cell delivers a current of 0.500 A for 10.0 minutes at a potential of 0.600 volts.

i. How much electrical energy, in joules, would be provided by the cell?

ii. Calculate the charge, in coulomb, produced by the cell.

iii. If this particular cell operated at 60.0% efficiency, what amount of hydrogen gas (H_2), in mole, would be consumed by the fuel cell?

1 + 1 + 3 = 5 marks

Total 10 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2008

CHEMISTRY

Written examination

Day Date 2008

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (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.

Version 2 – May 2008

Table of contents

1. Periodic table of the elements

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

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

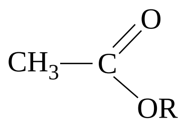
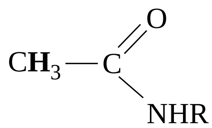
4. SI prefixes, their symbols and values

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}

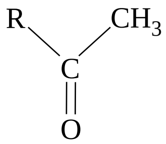
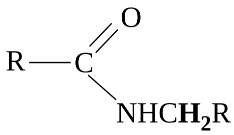
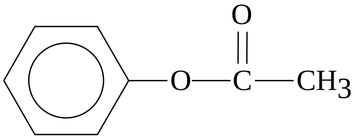
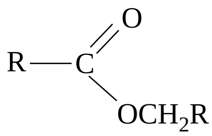
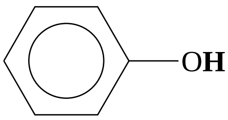
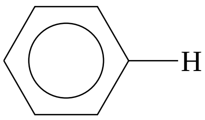
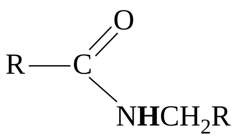
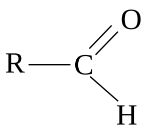
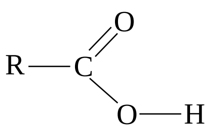
5. ^{1}H NMR data

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

TURN OVER

Type of proton	Chemical shift (ppm)
	2.1
$R{-}CH_2{-}X$ (X = F, Cl, Br or I)	3–4
R–C**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**H_2**	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	11.5

6. ^{13}C NMR data

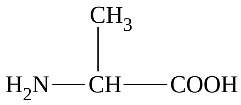
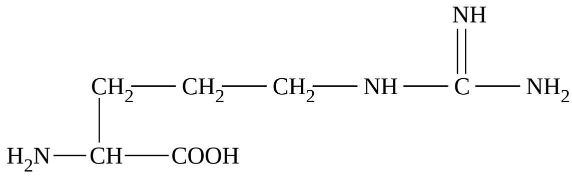
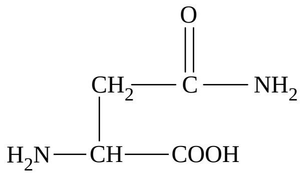
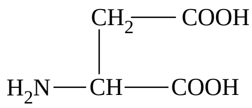
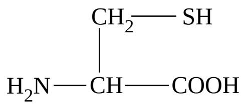
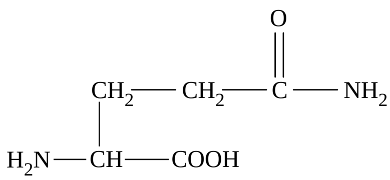
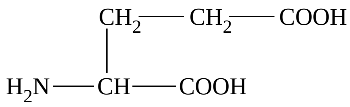
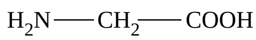
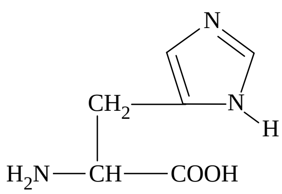
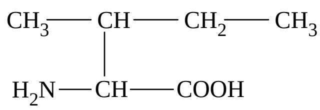
Type of carbon	**Chemical shift (ppm)**
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

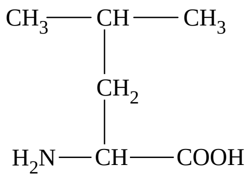
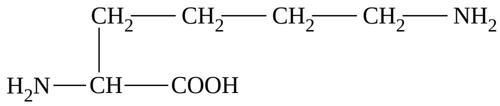
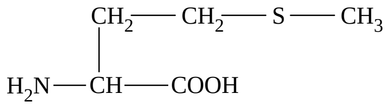
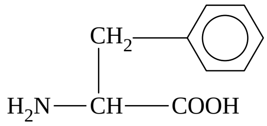
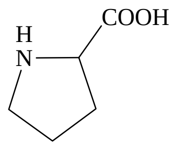
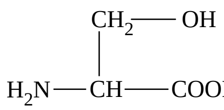
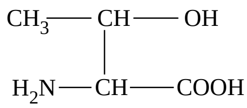
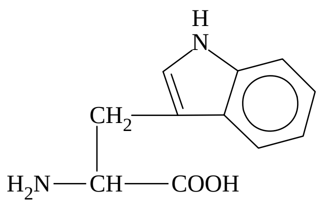
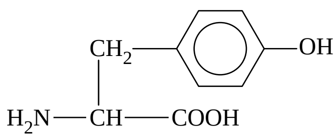
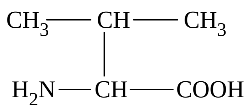
7. Infrared absorption data

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)

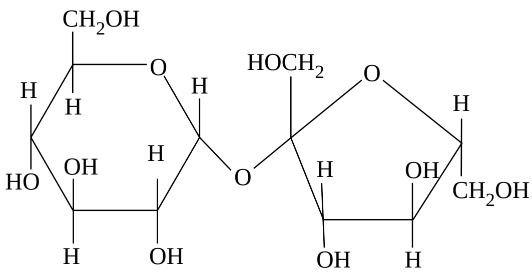
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

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

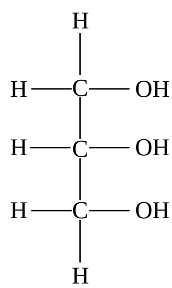
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

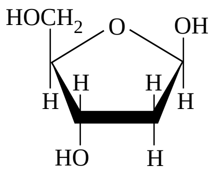
10. Structural formulas of some important biomolecules



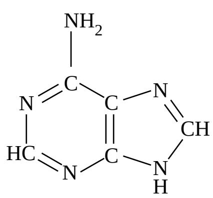
sucrose



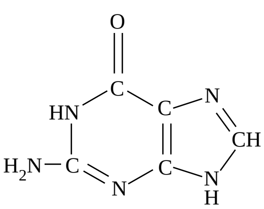
glycerol



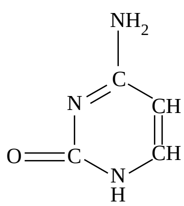
deoxyribose



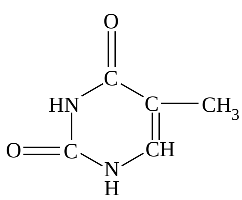
adenine



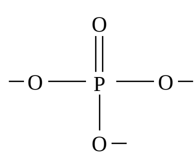
guanine



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

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. 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}	1	–3509
hexane	C_6H_{14}	1	–4158
octane	C_8H_{18}	1	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	1	–725
ethanol	C_2H_5OH	1	–1364
1-propanol	$CH_3CH_2CH_2OH$	1	–2016
2-propanol	$CH_3CHOHCH_3$	1	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK