



Victorian Certificate of Education 2011

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Letter

Figures

Words

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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

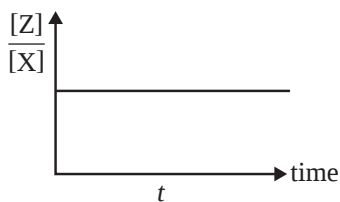
Consider the following equilibrium.



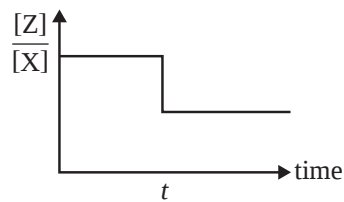
A catalyst is added to the equilibrium mixture at time t . The temperature and volume of the mixture remain constant.

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

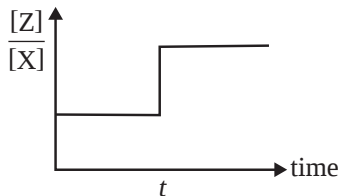
A.



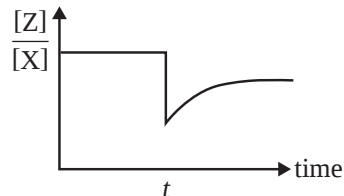
B.



C.

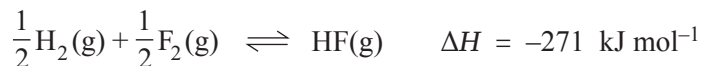


D.



Use the following information to answer Questions 3 and 4.

Hydrogen and fluorine react according to the following equation.



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. $\frac{[\text{HF}]}{\frac{1}{2}[\text{H}_2] + \frac{1}{2}[\text{F}_2]}$
- B. $\frac{[\text{HF}]}{[\text{H}_2][\text{F}_2]}$
- C. $\frac{n(\text{HF})}{n(\text{H}_2) \times n(\text{F}_2)}$
- D. $\frac{n(\text{HF})}{n(\text{H}_2)^{\frac{1}{2}} \times n(\text{F}_2)^{\frac{1}{2}}}$

Question 4

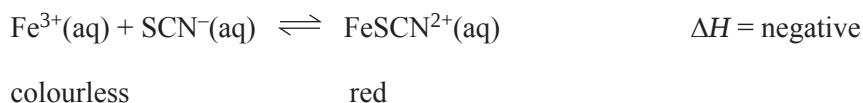
The reaction vessel is surrounded by a heat exchanger that keeps the reaction mixture at a constant temperature.

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



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

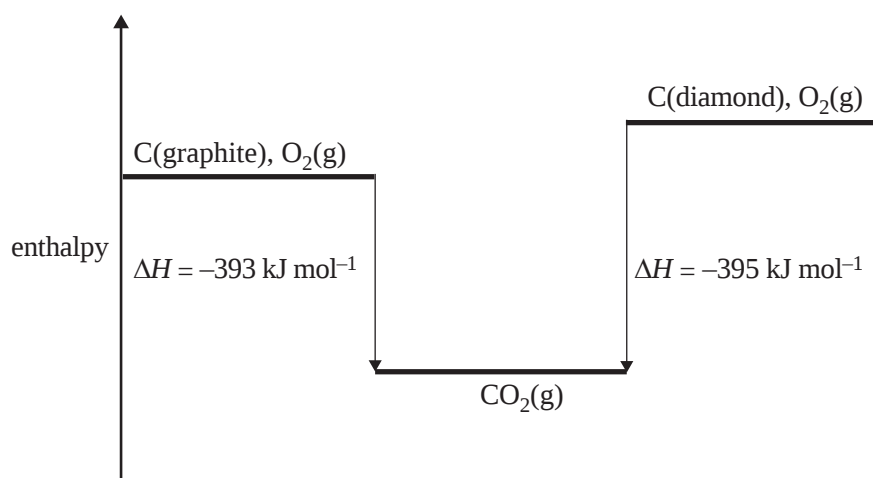
- A. reaction system loses energy to the surroundings.
- B. addition of a catalyst increases the activation energy.
- C. activation energy is greater than the enthalpy of reaction.
- D. energy required to break bonds in the reactants is less than the energy released when bonds are formed in the products.

Question 7

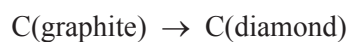
Consider the following combustion reactions for graphite and diamond.



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



is

- A. -2 kJ mol^{-1}
- B. $+2 \text{ kJ mol}^{-1}$
- C. -788 kJ mol^{-1}
- D. $+788 \text{ kJ mol}^{-1}$

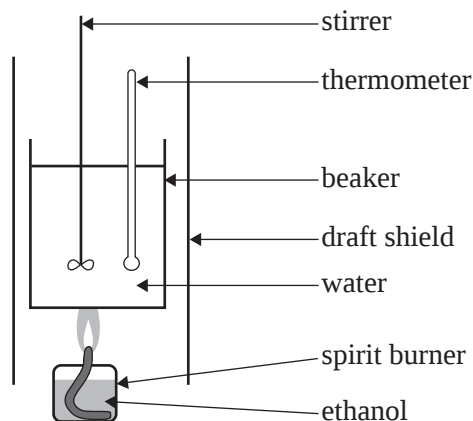
Question 8

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

- A. 8.44 g
- B. 6.88 g
- C. 0.399 g
- D. $8.44 \times 10^{-3} \text{ g}$

Question 9

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



The student made the following experimental measurements.

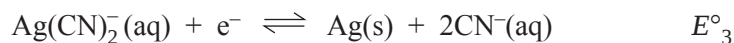
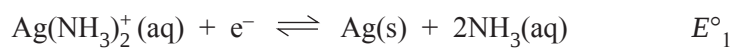
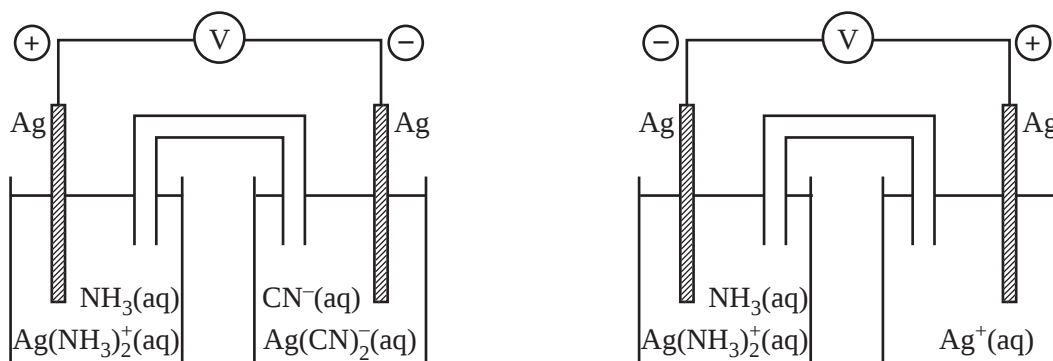
Mass of water in beaker	=	100.0 g
Amount of ethanol combusted	=	0.0200 mol
Temperature rise of the water	=	$40.0 \text{ }^{\circ}\text{C}$

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

- A. $-16.7 \text{ kJ mol}^{-1}$
- B. $-18.2 \text{ kJ mol}^{-1}$
- 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.



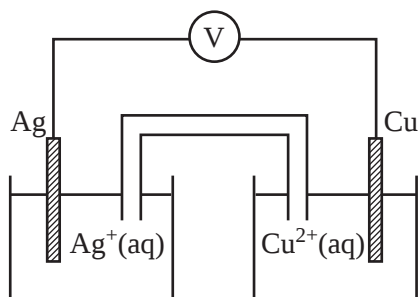
The values of the electrode potentials in order from highest to lowest would be

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

NO WRITING ALLOWED IN THIS AREA

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

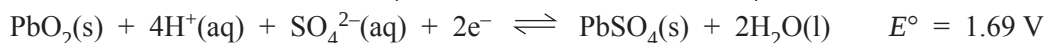
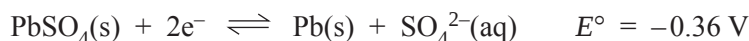
Question 12

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.



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 $\rightarrow$ electrical + heat.
- B. kinetic $\rightarrow$ chemical + electrical + heat.
- C. electrical $\rightarrow$ chemical + heat.
- D. electrical $\rightarrow$ light + kinetic + heat.

Question 15

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

- A. $\text{PbSO}_4(\text{s}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$
- B. $\text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{PbSO}_4(\text{s}) + 2\text{e}^-$
- C. $\text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^-$
- D. $\text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^- \rightarrow \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l})$

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

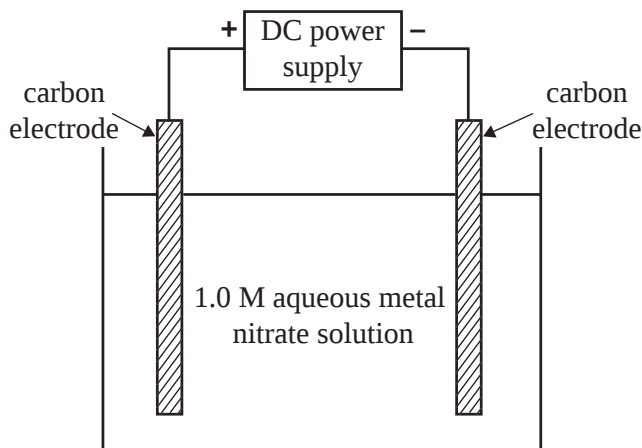
If we compare a galvanic cell with an electrolytic cell, it is true to state that

- 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.

NO WRITING ALLOWED IN THIS AREA

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 $\text{Cr}(\text{NO}_3)_3$, 1.0 M $\text{Cu}(\text{NO}_3)_2$ 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, $\text{H}_2(\text{g})$; $\text{NaCl}(\text{s})$

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.
-
- 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.
-
-

1 + 2 = 3 marks

Total 5 marks

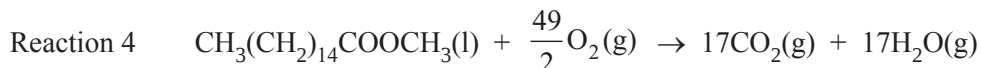
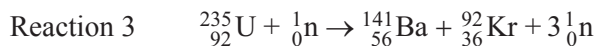
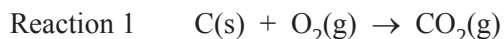
SECTION B – continued
TURN OVER

NO WRITING ALLOWED IN THIS AREA

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.



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

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

Reaction 1

Reaction 2

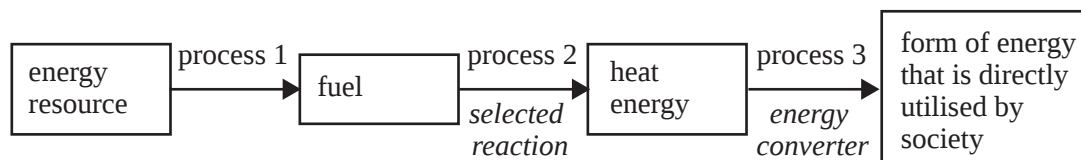
Reaction 3

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.

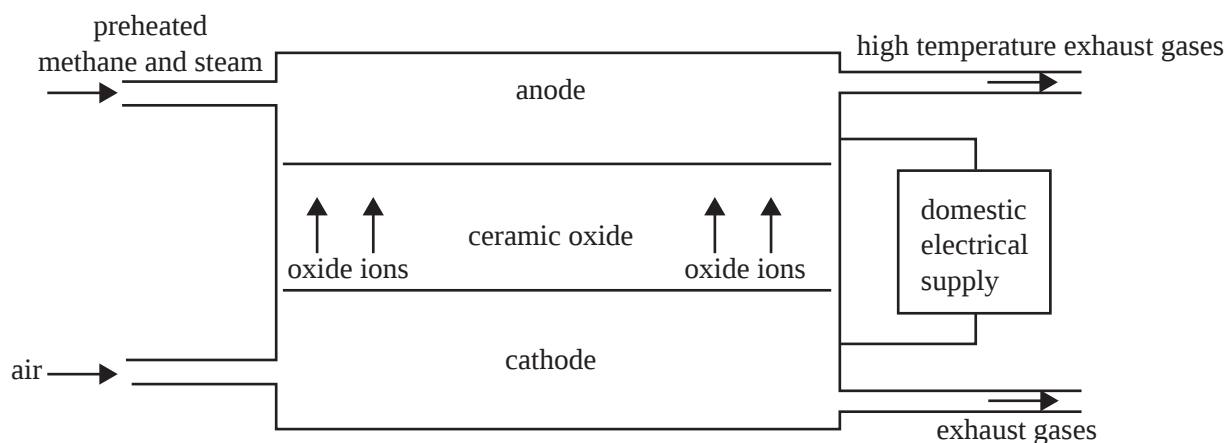
- iii. Consider the following simplified flow chart.



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.

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



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

1 + 1 + 1 = 3 marks

Total 7 marks

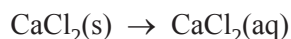
Question 3

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.

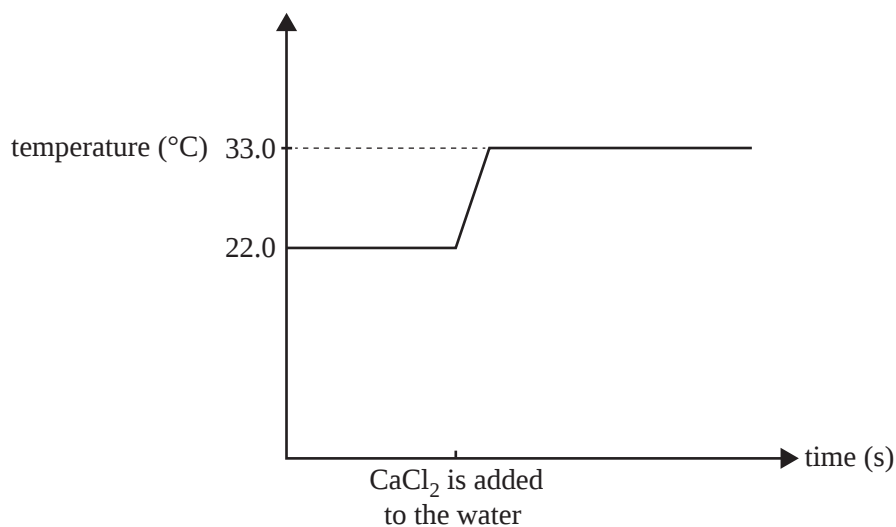
- a. Use the calibration factor to determine the electrical charge, in coulombs, that passed through the heating coil.

2 marks

This calorimeter is then used to determine the enthalpy change for the dissolution of one mol of anhydrous calcium chloride, CaCl₂, in water.



6.038 g of solid anhydrous calcium chloride, CaCl₂, 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 $\text{CaCl}_2(\text{s})$. The molar mass of $\text{CaCl}_2 = 111.1 \text{ g mol}^{-1}$.

2 + 4 = 6 marks

Total 8 marks

SECTION B – continued
TURN OVER

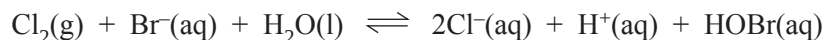
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Question 4

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

	Standard electrode potential E° in volts
$\text{HOBr(aq)} + \text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Br}^-(\text{aq}) + \text{H}_2\text{O(l)}$	+1.33
$2\text{HOBr(aq)} + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Br}_2(\text{l}) + 2\text{H}_2\text{O(l)}$	+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.



2 marks

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



Write the oxidation half-equation for this reaction.

1 mark

Total 3 marks

NO WRITING ALLOWED IN THIS AREA

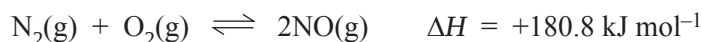
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SECTION B – continued
TURN OVER

Question 5

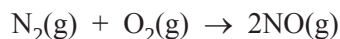
Nitrogen oxides are commonly found in the atmosphere in areas where there is serious atmospheric pollution.

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



- 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



will never be greater than the rate of the reaction



- i. while the system is reaching equilibrium

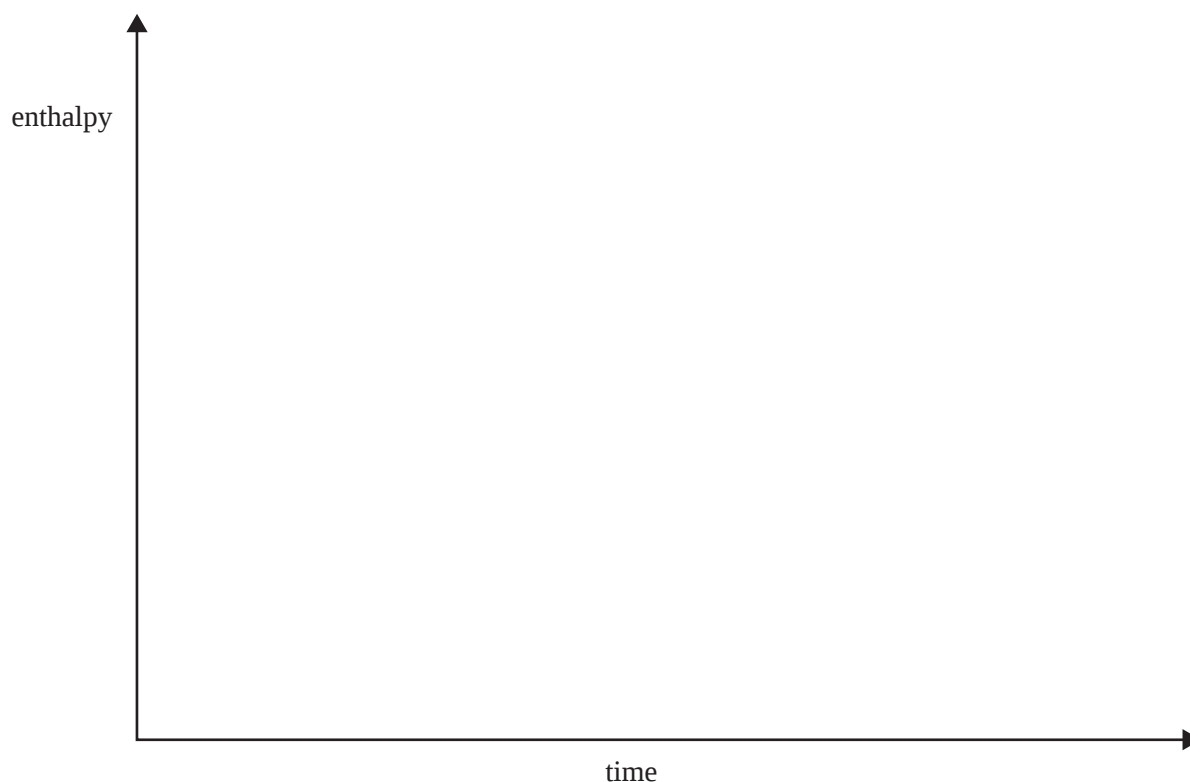
- ii. once equilibrium is established.

1 + 1 = 2 marks

NO WRITING ALLOWED IN THIS AREA

- 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 $\text{N}_2\text{(g)}$ and $\text{O}_2\text{(g)}$.
- 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

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

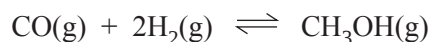
SECTION B – continued
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Question 7

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.

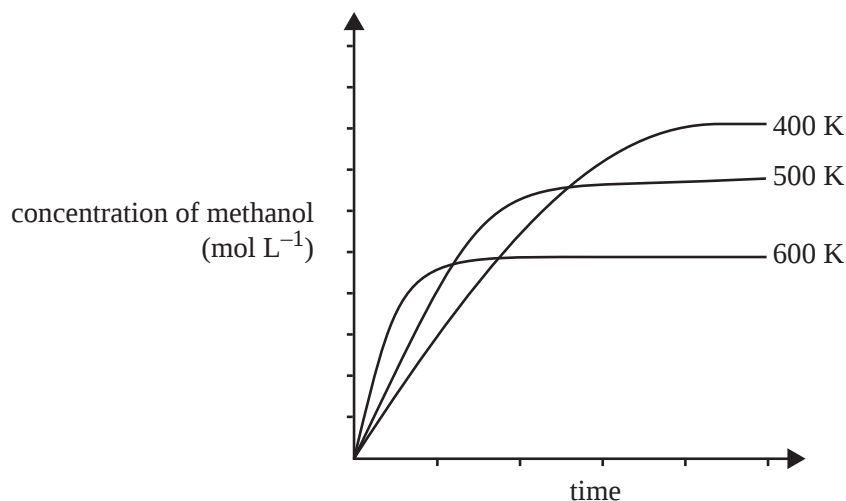
The reaction that occurs in the methanol converter is



- 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.

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

- 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

SECTION B – continued
TURN OVER

NO WRITING ALLOWED IN THIS AREA

Question 8

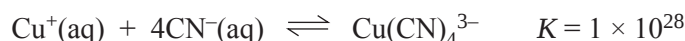
A chemical engineer designs a pilot plant to determine the conditions that will give the best results for copper plating different objects.

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

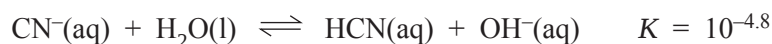
The quality of the copper coating depends on maintaining a low, constant concentration of copper(I) ions in the electrolyte. This is achieved by making use of the following reaction which takes place in the electrolyte bath. In this reaction, copper(I) ions, Cu^+ , react with the cyanide ions, CN^- ,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



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

1 mark

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



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



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.

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1. Periodic table of the elements

1 H 1.0 Hydrogen	79 Au 197.0 Gold atomic number symbol of element relative atomic mass name of element										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
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
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
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 (271) Unb

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
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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
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TURN OVER

2. The electrochemical series

	E° in volt
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$	+2.87
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{Au}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.68
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	+1.09
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightleftharpoons 4\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{S}(\text{s}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0.14
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.23
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.03
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.67
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.34
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.02

3. Physical constants

Avogadro's constant (N_A) = $6.02 \times 10^{23} \text{ mol}^{-1}$

Charge on one electron = $-1.60 \times 10^{-19} \text{ C}$

Faraday constant (F) = $96\,500 \text{ C mol}^{-1}$

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

Ionic product for water (K_w) = $1.00 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}$ 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 = $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

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

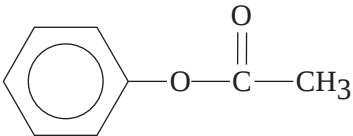
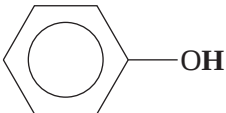
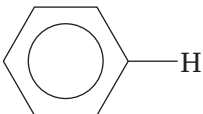
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^1H 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-CH ₃	1.7
R ₃ -CH	2.0
$\text{CH}_3-\text{C} \begin{array}{l} \text{O} \\ \parallel \\ \text{OR} \end{array}$ or $\text{CH}_3-\text{C} \begin{array}{l} \text{O} \\ \parallel \\ \text{NHR} \end{array}$	2.0

Type of proton	Chemical shift (ppm)
$\begin{array}{c} \text{R} \quad \text{CH}_3 \\ \diagdown \quad / \\ \text{C} \\ \\ \text{O} \end{array}$	2.1
R-CH ₂ -X (X = F, Cl, Br or I)	3–4
R-CH ₂ -OH	3.6
$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C} \\ \\ \text{NHCH}_2\text{R} \end{array}$	3.2
R-O-CH ₃ or R-O-CH ₂ R	3.3
	2.3
$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C} \\ \\ \text{OCH}_2\text{R} \end{array}$	4.1
R-O-H	1–6 (varies considerably under different conditions)
R-NH ₂	1–5
RHC=CH ₂	4.6–6.0
	7.0
	7.3
$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C} \\ \\ \text{NHCH}_2\text{R} \end{array}$	8.1
$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C} \\ \\ \text{H} \end{array}$	9–10
$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C} \\ \\ \text{O}-\text{H} \end{array}$	11.5

6. ^{13}C NMR data

Type of carbon	Chemical shift (ppm)
$\text{R}-\text{CH}_3$	8–25
$\text{R}-\text{CH}_2-\text{R}$	20–45
R_3-CH	40–60
R_4-C	36–45
$\text{R}-\text{CH}_2-\text{X}$	15–80
$\text{R}_3\text{C}-\text{NH}_2$	35–70
$\text{R}-\text{CH}_2-\text{OH}$	50–90
$\text{RC}\equiv\text{CR}$	75–95
$\text{R}_2\text{C}=\text{CR}_2$	110–150
RCOOH	160–185

7. Infrared absorption data

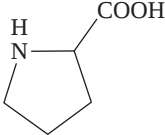
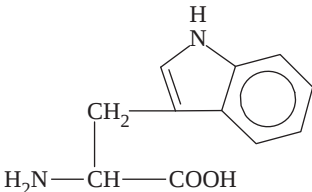
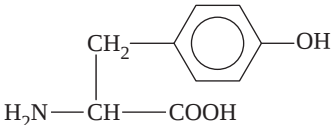
Characteristic range for infrared absorption

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

TURN OVER

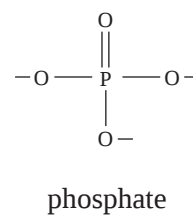
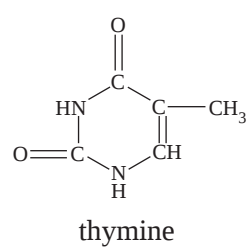
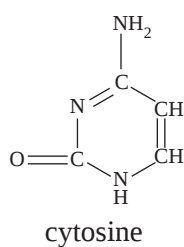
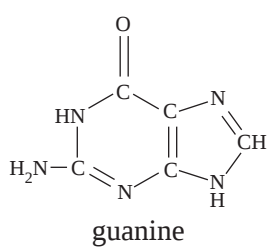
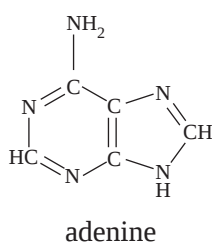
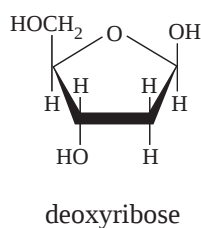
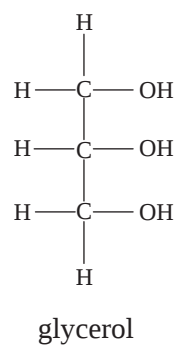
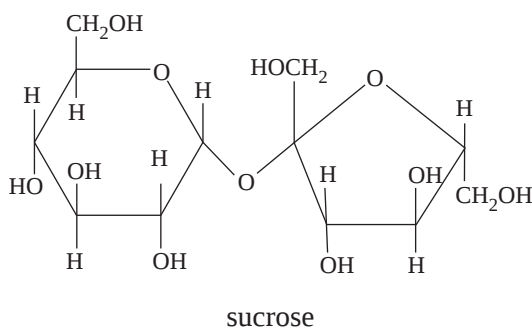
8. 2-amino acids (α -amino acids)

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

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

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

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	$\text{C}_6\text{H}_5\text{COOH}$	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	$\text{HC}_3\text{H}_5\text{O}_3$	1.4×10^{-4}
Methanoic	HCOOH	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	$\text{C}_2\text{H}_5\text{COOH}$	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	$\Delta H_c (\text{kJ mol}^{-1})$
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	$\text{C}_2\text{H}_5\text{OH}$	l	–1364
1-propanol	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	l	–2016
2-propanol	$\text{CH}_3\text{CHOHCH}_3$	l	–2003
glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	s	–2816