VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2009

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

CHEMISTRY

Written examination 1

Wednesday 10 June 2009

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (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	10	10	53
			Total 73

- 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

The most appropriate technique to determine levels of the Pb^{2+} ion in blood is

A. mass spectrometry.

B. infrared spectroscopy.

C. atomic absorption spectroscopy.

D. high-performance liquid chromatography.

Question 2

A sample of compound M is analysed in a mass spectrometer where it forms the molecular ion M^+ according to

$$M + e^- \rightarrow M^+ + 2e^-$$

Some of the molecular ions fragment as follows.

$$M^+ \rightarrow A^+ + B \quad \text{and}$$
$$M^+ \rightarrow A + B^+$$

The mass spectrum would show peaks due to the species

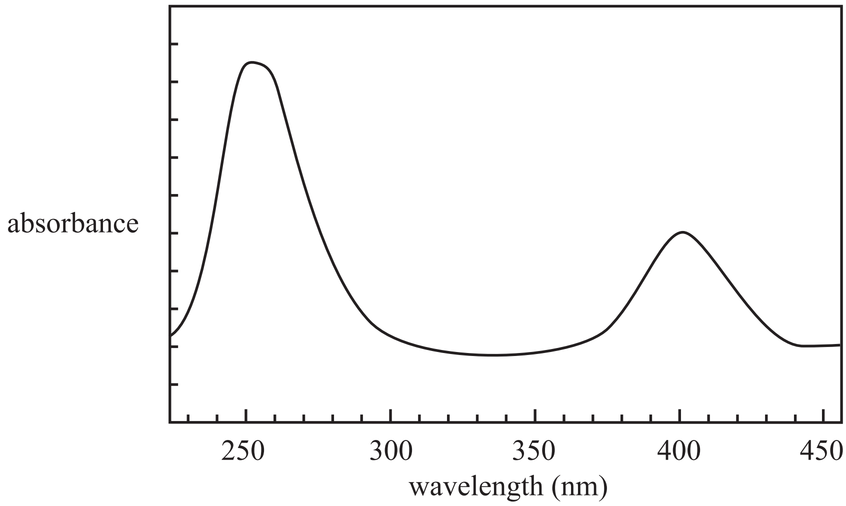
A. M^+, A, A^+, B and B^+ only.

B. M^+, A^+ and B^+ only.

C. A^+ and B^+ only.

D. A and B only.

Question 3



The UV-visible spectrum of a solution of a certain compound is shown above. Consider the following statements about this compound and its UV-visible spectrum.

I The amount of light absorbed by a solution of this compound depends on its concentration.

II The amount of light absorbed by a solution of this compound depends on the wavelength of light used.

III The spectrum is a result of electrons falling back from higher to lower electronic energy levels.

IV The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at 250 nm.

Which of the above statements are true?

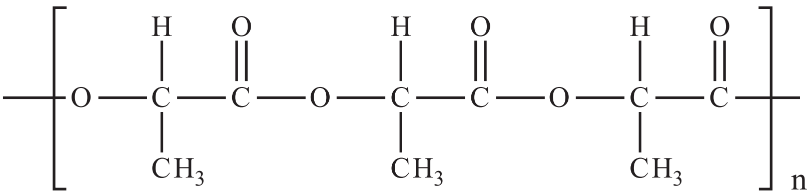
A. I and II

B. II and III

C. I, II and III

D. I, II and IV

Question 4



The polymer polylactic acid, PLA, shown above, is used to make soluble stitches which are absorbed by the body following surgery.

Other than the peak given by the TMS reference, the monomer from which PLA is formed would give

A. one set of peaks in the ^{1}H NMR

B. two sets of peaks in the ^{1}H NMR

C. three sets of peaks in the ^{1}H NMR

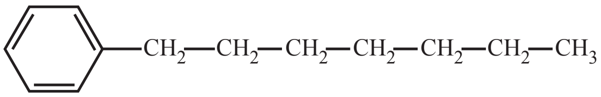
D. four sets of peaks in the ^{1}H NMR

Question 5

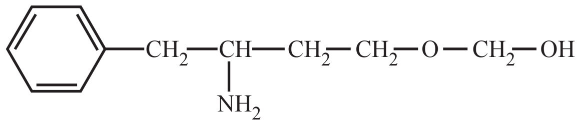
Reverse-phase high-performance liquid chromatography (HPLC) uses a non-polar stationary phase together with a polar mobile phase.

Which of the following molecules will have the greatest retention time on such a reverse phase column?

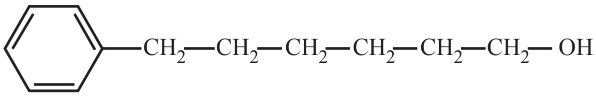
A.



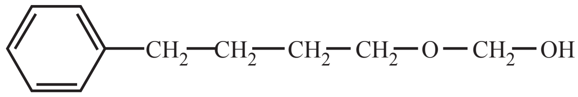
B.



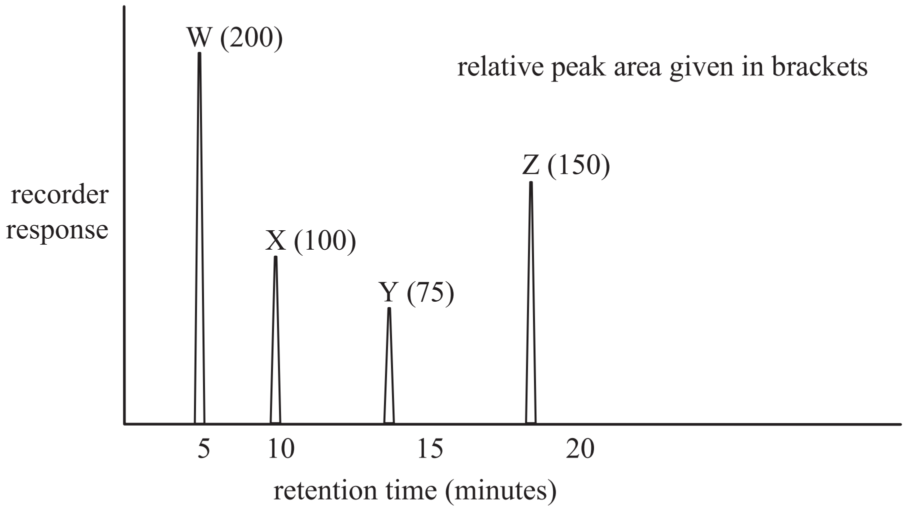
C.



D.



Question 6



The above diagram shows the gas chromatogram of a sample containing four straight chain alkanes. The following statements refer to this chromatogram.

I The boiling points of the compounds arranged from highest to lowest are Z > Y > X > W.

II The retention times will stay the same if the temperature at which the chromatogram is recorded is increased, all other conditions remaining constant.

III Hydrogen gas could have been used as a carrier gas to obtain this chromatogram.

Which of the above statements are true?

A. I only

B. I and II only

C. I and III only

D. II and III only

Question 7

When solid sodium hydride, NaH, is added to water, the hydride ion reacts according to the following equation.

$$H^-(aq) + H_2O(l) \rightarrow OH^-(aq) + H_2(g)$$

This reaction can be classified as

A. acid-base only.

B. oxidation-reduction only.

C. both acid-base and oxidation-reduction.

D. neither acid-base nor oxidation-reduction.

Questions 8 and 9 refer to the following information.

0.132 g of a pure carboxylic acid (R–COOH) was dissolved in 25.00 mL of water and titrated with 0.120 M NaOH solution. A volume of 14.80 mL was required to reach the endpoint of the titration.

Question 8

The carboxylic acid could be

A. HCOOH

B. CH_3COOH

C. C_2H_5COOH

D. C_3H_7COOH

Question 9

Which of the following best represents the pH of the solution at the equivalence point and the name of a suitable indicator for this titration?

	pH at the equivalence point	**suitable indicator**
A.	less than 7	phenolphthalein
B.	less than 7	bromophenol blue
C.	greater than 7	phenolphthalein
D.	greater than 7	bromophenol blue

Question 10

The level of carbon dioxide in the air in a spacecraft can be controlled by passing the air through canisters containing lithium hydroxide, LiOH.

In a laboratory trial, the air in a 5.00 L container at 1.10×10^2 kPa and 25.0°C was passed through a canister of LiOH. The pressure of the air in the container decreased to 1.00×10^2 kPa, measured at 25.0°C.

The mass of CO_2 absorbed from the air sample by the LiOH in the canister was

A. 0.89 g

B. 9.77 g

C. 10.6 g

D. 116 g

Question 11

Which one of the following statements about propene is **not** correct?

A. It undergoes an addition reaction with hydrogen to form propane.

B. It undergoes a polymerisation reaction expelling water in the process.

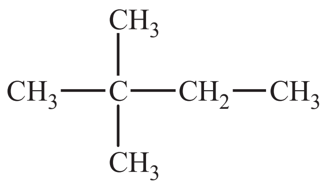
C. Weak dispersion forces act between propene molecules and consequently it is a gas at room temperature.

D. One propene molecule will react with excess oxygen to produce three molecules of water and three molecules of carbon dioxide.

Question 12

In a particular chlorination reaction, a single hydrogen atom of 2,2-dimethylbutane, C_6H_{14}, is replaced by one chlorine atom. More than one compound of formula $C_6H_{13}Cl$ will be formed.

A structure of 2,2-dimethylbutane is provided below.



The number of different compounds that could be formed in this monosubstitution reaction is

A. 2

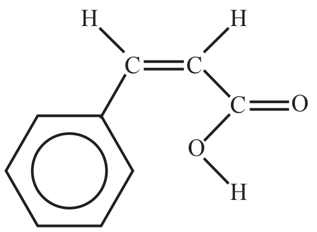
B. 3

C. 4

D. 5

Question 13

Cinnamic acid is an organic substance that partly contributes to the flavour of oil of cinnamon. A structure of cinnamic acid is given below.

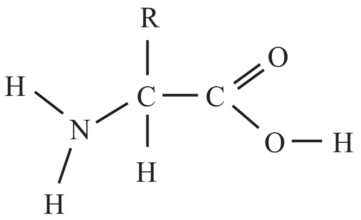


Which of the following reagents would you expect to react with cinnamic acid under the conditions given below?

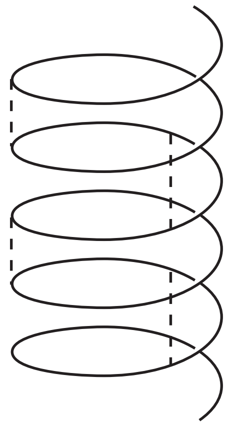
	CH_2CH_2 and catalyst	**Br_2(aq) at room temperature**	**CH_3OH and H_2SO_4 catalyst**
A.	Yes	Yes	Yes
B.	Yes	No	Yes
C.	No	Yes	Yes
D.	No	Yes	No

Question 14

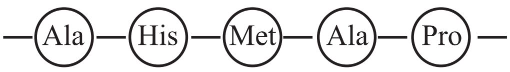
A student's study notes on protein structure included these four unlabelled sketches.



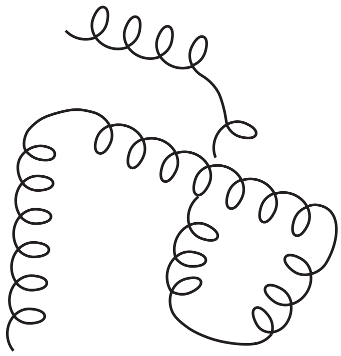
I



II



III



IV

Which sketches best represent the primary, secondary and tertiary structure of proteins?

	primary structure	**secondary structure**	**tertiary structure**
A.	I	II	IV
B.	I	IV	II
C.	III	IV	II
D.	III	II	IV

Question 15

The tertiary structure of proteins may be maintained by

A. hydrogen bonding.

B. ionic interactions.

C. covalent bonds.

D. all of the above.

Question 16

In response to a pain stimulus, the brain produces small polypeptide molecules called enkephalins. These molecules block the transmission of pain through the central nervous system.

The amino acid sequence in one such compound, methionine enkephalin, is

Tyr – Gly – Gly – Phe – Met

The number of amine, carboxylic acid and amide (peptide) functional groups in this polypeptide is

	$–NH_2$	–COOH	–CONH
A.	0	0	5
B.	1	1	4
C.	1	1	5
D.	0	2	4

Question 17

Which one of the following statements about enzymes is **not** true?

A. Enzymes can only be denatured by an increase in temperature.

B. Enzymes may form temporary ion-dipole bonds with substrate molecules.

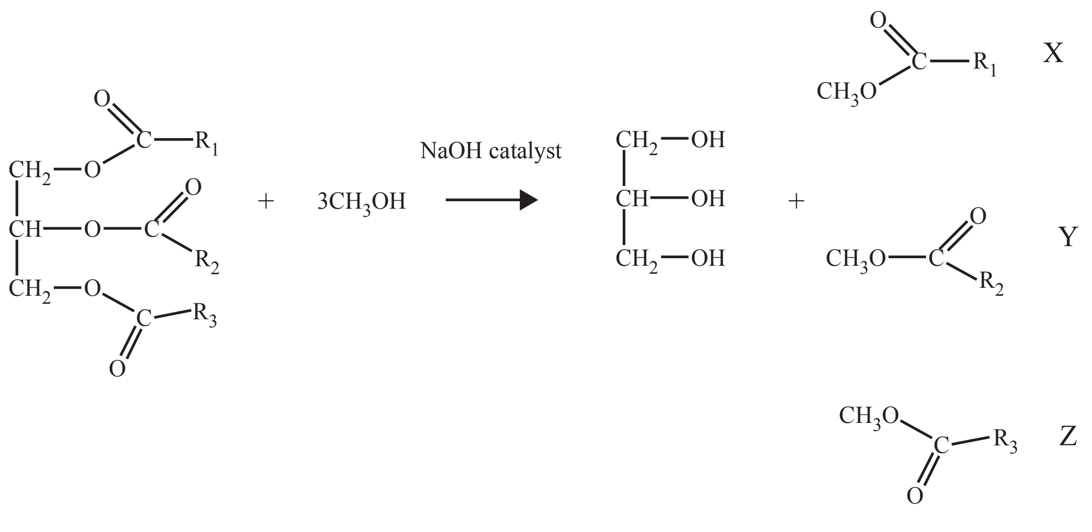
C. Enzymes speed up reactions by holding substrate molecules in positions necessary for reaction.

D. The tertiary structure of an enzyme may be altered if one amino acid in its primary structure is substituted for another, different amino acid.

Question 18

A product derived from palm tree oil is used as an alternative fuel in diesel engines.

Palm oil is converted to biodiesel by the following reaction.



Glycerol is separated from the reaction mixture. The mixture of the compounds labelled X, Y and Z is used as palm oil biodiesel.

The term that best describes the mixture of compounds in palm oil biodiesel is

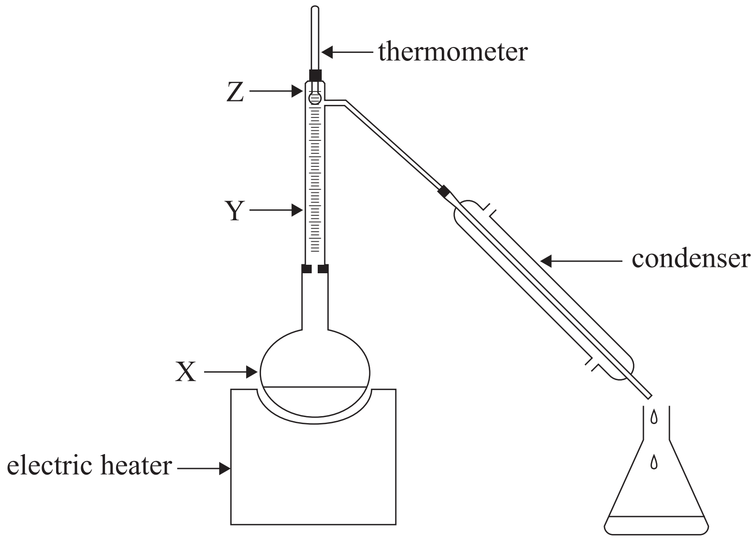
A. methyl esters.

B. carbohydrates.

C. carboxylic acids.

D. monoglycerides.

Question 19



A liquid mixture of 50% ethanol and 50% water was distilled in the apparatus shown above. The boiling point of ethanol is 78°C and that of water is 100°C.

As the mixture was heated the temperature shown by the thermometer initially rose but then remained constant at 78°C for some time.

Which one of the following statements about percentage of ethanol in the vapours shown at points X, Y and Z, when the temperature is at a constant 78°C, is true?

A. The percentage of ethanol in the vapours at X is equal to 50%.

B. The percentages of ethanol in the vapours increase in order at positions X, Y and Z.

C. The percentages of ethanol in the vapours at Y and Z are equal but greater than at X.

D. The percentages of ethanol in the vapours at X, Y and Z are equal but greater than 50%.

Question 20

The separation and identification of proteins that can be used as disease markers is an exciting area of research. Researchers must separate and identify proteins that could be used as disease markers from the many thousands of proteins that exist in our bodies.

Which of the following sequence of techniques could be used to

i. separate these molecules, then

ii. accurately determine their molecular mass, and then

iii. determine their molecular structure.

A. NMR spectroscopy, followed by mass spectrometry, followed by high-performance liquid chromatography

B. high-performance liquid chromatography, followed by mass spectrometry, followed by NMR spectroscopy

C. high-performance liquid chromatography, followed by infrared spectroscopy, followed by mass spectrometry

D. mass spectrometry, followed by high-performance liquid chromatography, followed by infrared spectroscopy

END OF SECTION A
TURN OVER

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

2-chloro-3-methylpentane and 2-chloro-3-methylhexane were dissolved together and the mixture was analysed using gas chromatography. The chromatogram of this mixture produced the following peak areas.

compound	**peak area**
1.06×10^{-3} mol of 2-chloro-3-methylpentane	922 units
1.53×10^{-3} mol of 2-chloro-3-methylhexane	1570 units

a. Draw a structural formula of **either** 2-chloro-3-methylpentane or 2-chloro-3-methylhexane, clearly showing all bonds.

1 mark

b. Which molecule would you expect to have the shortest retention time in the chromatography column? Explain your answer.

1 mark

c. In another experiment, 0.57×10^{-3} mol of 2-chloro-3-methylpentane was analysed in a different mixture under the same conditions.

What would be the expected peak area on the chromatogram associated with this amount of 2-chloro-3-methylpentane?

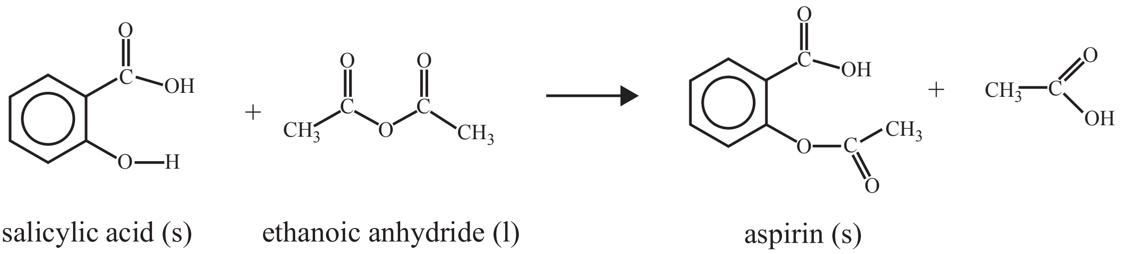
1 mark

Total 3 marks

Question 2

A sample of aspirin was prepared by reacting 2.20 g of salicylic acid with 4.20 mL of ethanoic anhydride in a conical flask. After heating for 20 minutes the reaction mixture was cooled and white crystals precipitated. The crystals were then collected, dried to constant mass and weighed.

The equation for the reaction is



The following results were obtained.

mass of salicylic acid	2.20 g
volume ethanoic anhydride	4.20 mL
mass product	2.25 g

Use the following data to answer the questions below.

	molar mass ($g\ mol^{-1}$)	**density ($g\ mL^{-1}$)**
aspirin	180	
ethanoic anhydride	102	1.08
salicylic acid	138	

a. **i.** Calculate the initial amount, in moles, of salicylic acid used in this preparation.

ii. What initial amount, in moles, of ethanoic anhydride was used?

iii. What is the maximum mass of aspirin that can theoretically be produced from these reagents?

iv. Determine the percentage yield in this preparation.

4 marks

b. Describe how the purity of the product could be **qualitatively** determined using thin layer chromatography. Both salicylic acid and aspirin can be detected using ultraviolet light. Ethyl ethanoate can be used as a suitable solvent.

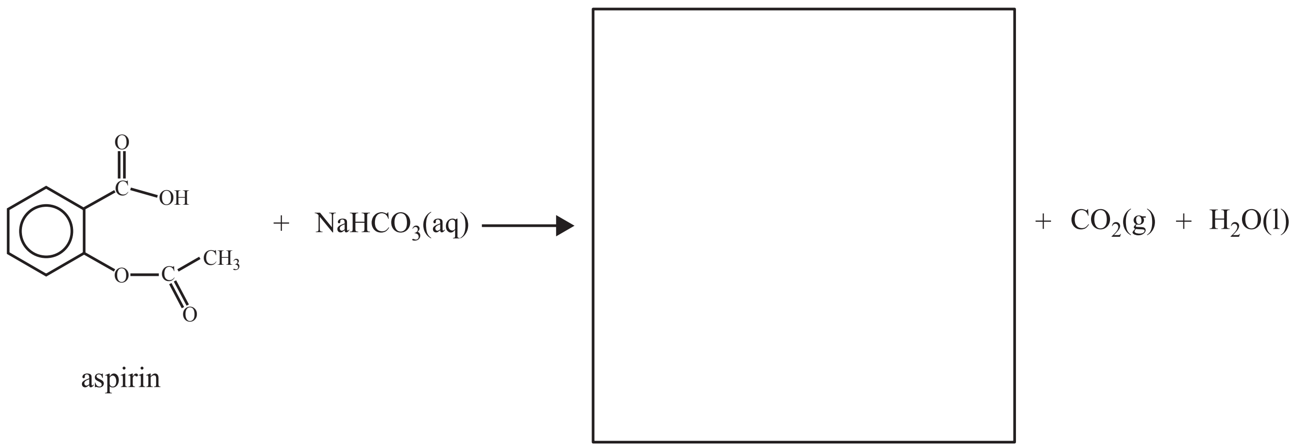
2 marks

Salicylic acid reacts with aqueous $FeCl_3$ to form a purple compound. Aspirin does not react with aqueous $FeCl_3$.

c. Describe how the purity of the product could be **quantitatively** determined using UV-visible spectroscopy.

3 marks

d. The sodium salt of aspirin is more soluble than aspirin itself. This salt may be synthesised by reaction between aspirin and sodium hydrogen carbonate as follows.



aspirin

i. In the box provided, give the complete structure for the sodium salt of aspirin.

ii. Explain why the sodium salt of aspirin is more water-soluble than aspirin.

2 marks

Total 11 marks

SECTION B – continued

TURN OVER

Question 3

A student is to accurately determine the concentration of a solution of sodium hydrogencarbonate in a titration against a standard solution of hydrochloric acid, HC1.

The first step in this experiment is to accurately dilute 100.0 mL of a 1.00 M HCl stock solution to a 0.100 M solution using a 1.00 L volumetric flask.

However, instead of using distilled water in the dilution, the student mistakenly adds 900.0 mL of 0.0222 M sodium hydroxide, NaOH, solution.

a. Write an equation for the reaction that occurs in the 1.00 L volumetric flask.

1 mark

b. Calculate the concentration of the hydrochloric acid in the 1.00 L volumetric flask after the student added the sodium hydroxide solution. Give your answer to correct significant figures.

2 marks

The student then uses this contaminated hydrochloric acid solution to determine the accurate concentration of the unknown sodium hydrogencarbonate solution.

c. Will the calculated concentration of sodium hydrogencarbonate solution be greater or smaller than the true value? Justify your answer.

1 mark

Total 4 marks

Question 4

Myrcene is a naturally occurring compound found in the leaves of bay trees. It is known to be a polyunsaturated hydrocarbon. It can react with hydrogen to produce a saturated hydrocarbon.

In a laboratory investigation, a 1.00 g sample of pure myrcene fully reacted with exactly 510 mL of hydrogen gas measured at 20.0°C and 105.0 kPa. In this reaction, myrcene was converted to a saturated alkane with a molecular formula $C_{10}H_{22}$.

a. What type of reaction has occurred between the myrcene and hydrogen?

1 mark

b. Calculate the amount, in moles, of hydrogen reacting.

1 mark

c. Calculate the mass of $C_{10}H_{22}$ produced in the reaction.

2 marks

d. Determine the number of double bonds in each molecule of myrcene.

2 marks

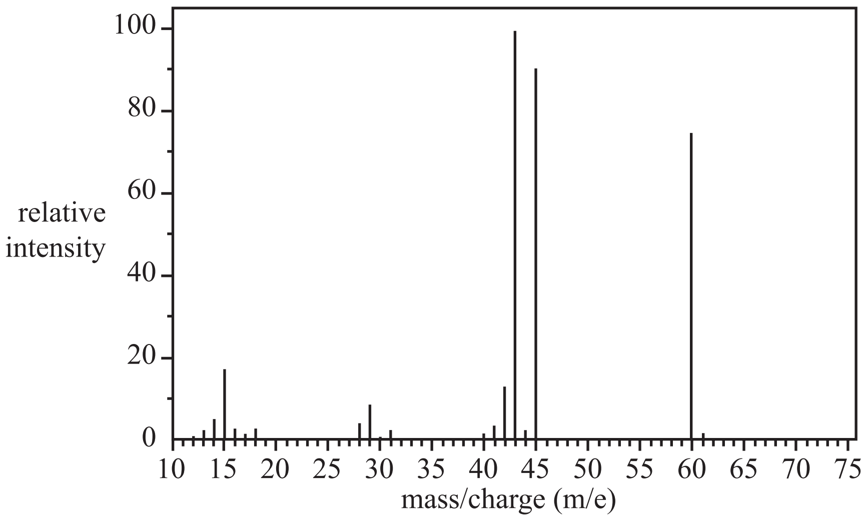
Total 6 marks

Question 5

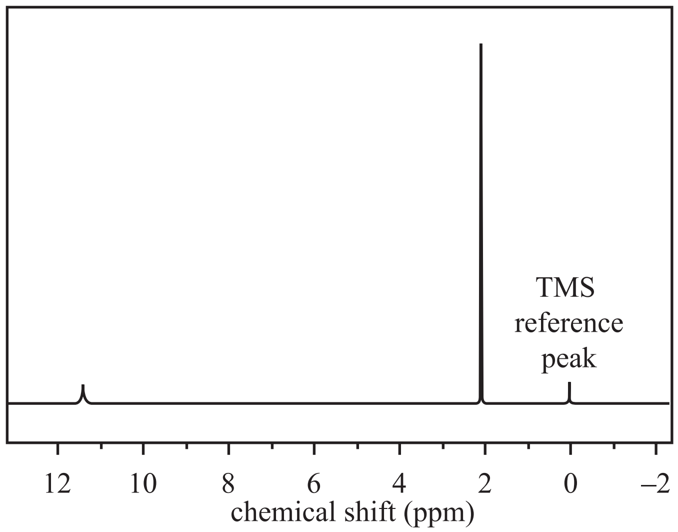
The structure of an organic molecule, with empirical formula CH_2O, is determined using spectroscopic techniques.

The mass spectrum, infrared spectrum and ^1H NMR spectrum for this molecule are given below.

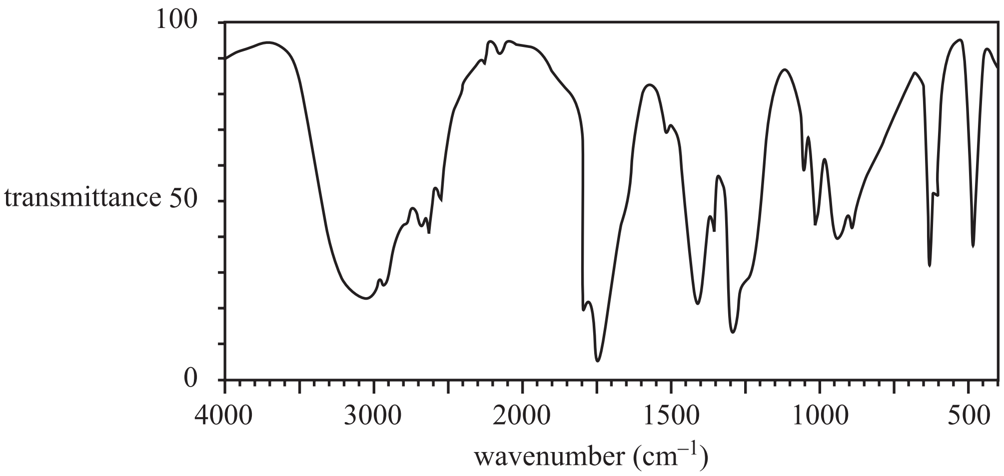
mass spectrum



^1H NMR spectrum



infrared spectrum



Use the information provided by these spectra to answer the following questions.

a. What is the molecular formula of this molecule?

1 mark

b. How many different proton environments are there in this molecule?

1 mark

c. Draw the structure of the unknown molecule, clearly showing all bonds.

1 mark

d. Explain how the structure of the compound you have drawn in **part c.** is consistent with its IR spectrum.

1 mark

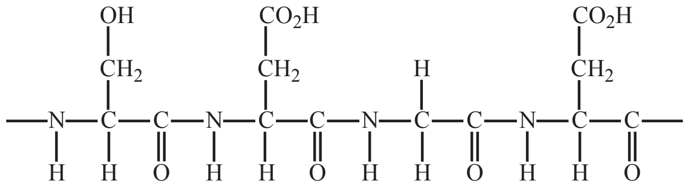
e. Name the compound you have drawn in **part c.**

1 mark

Total 5 marks

Question 6

a. The following structure shows part of a polypeptide.



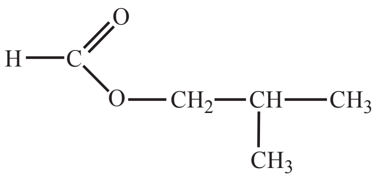
i. Name the amino acids that make up this section of the polypeptide.

At a particular pH, an amino acid in solution can exist as ions that have both a negative and positive charge. These ions are called zwitterions.

ii. Choose **one** of the amino acids in this section of polypeptide and draw the structure of its zwitterion clearly showing all bonds.

2 marks

b. Many esters are used as flavouring agents in food. The structure of the ester used in raspberry flavouring is provided below.



Give the names of **two** carbon compounds that can be used to synthesise this ester.

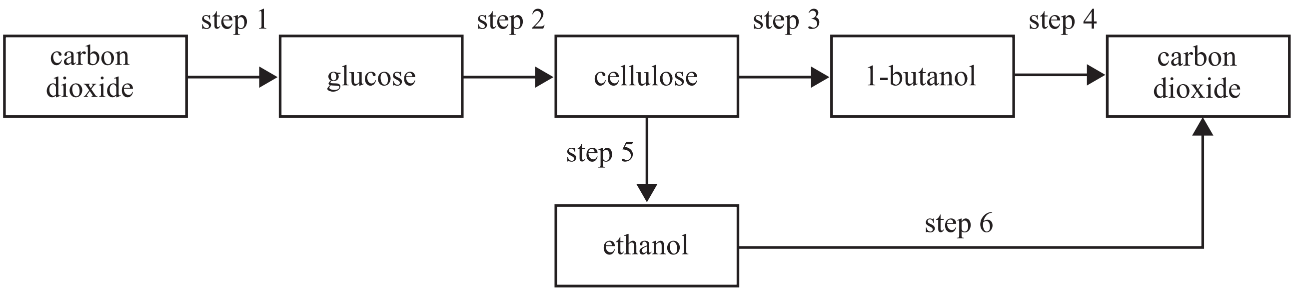
2 marks

Total 4 marks

Question 7

Research is being conducted into the development of new biofuels. It is known that a type of bacteria, *clostridium acetobutylcium,* converts cellulose to butanol.

The following diagram represents a series of steps (which may involve multiple reactions) for the formation and combustion of the biofuels, ethanol and 1-butanol.



a. Identify **one** step that represents an overall reduction reaction.

1 mark

b. Write a balanced equation for step 4 where, in a single reaction, 1-butanol reacts to form carbon dioxide as one of the products.

1 mark

Glucose can combine with fructose to form the disaccharide, sucrose.

Sucrose (molar mass 342 g mol^{-1}) is highly soluble in water. However, 1-butanol, a much smaller molecule (molar mass 74 g mol^{-1}), is much less soluble in water.

c. Explain, in terms of the structure of these two molecules, why this is the case.

1 mark

Consider the following two observations about sucrose.

I Dry sucrose can be mixed with the enzyme sucrase and no significant change will occur.

II Sucrose rapidly breaks down into its monosaccharides when a small amount of sucrase is added to a solution of sucrose at room temperature.

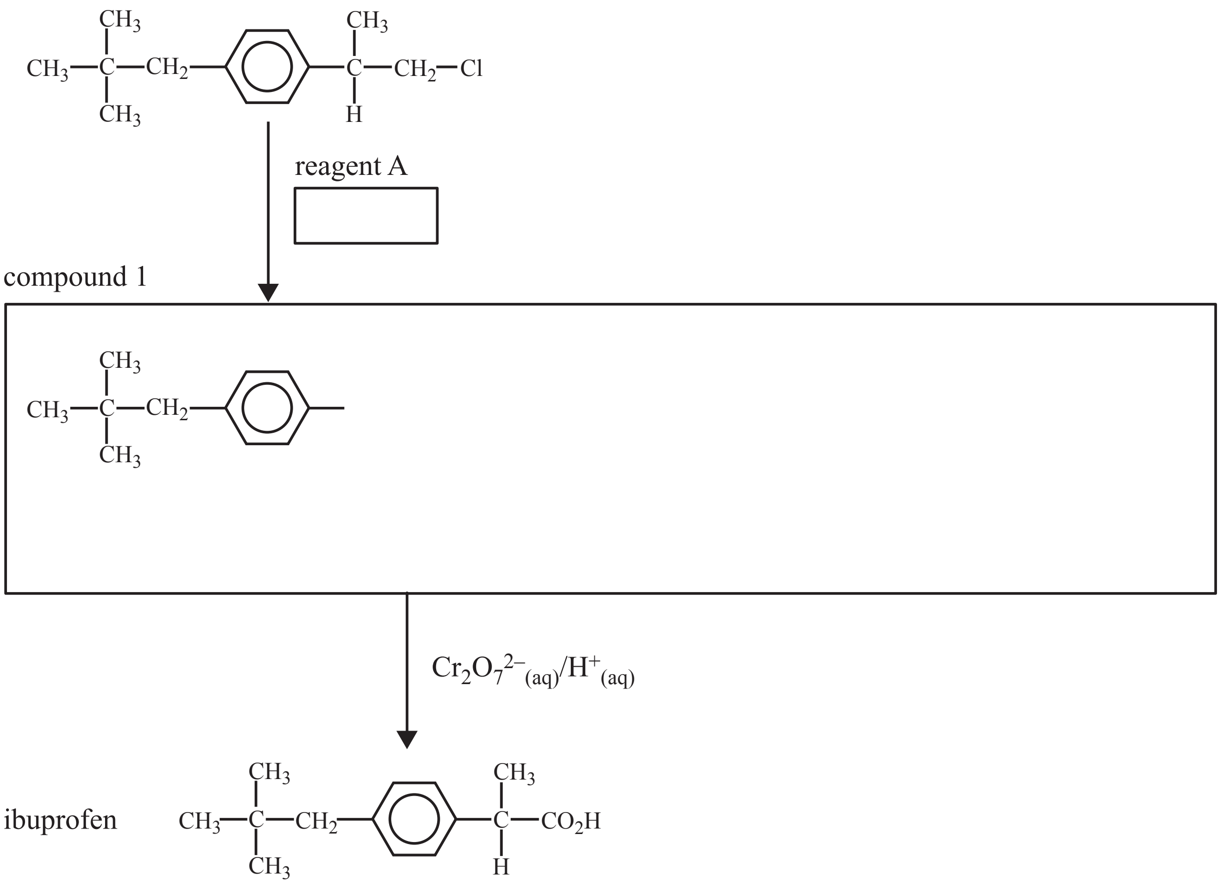
d. Why does the breakdown of sucrose require the presence of both water and sucrase?

1 mark

Total 4 marks

Question 8

a. A partially completed reaction pathway for the synthesis of the painkiller ibuprofen is given below.



i. In the appropriate box, write the formula for reagent A.

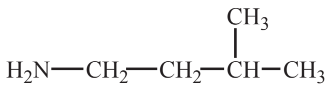
ii. In the appropriate box, complete the structure for compound 1.

iii. Write a balanced half-equation for the reduction of dichromate ions to Cr^{3+} ions in an aqueous acid solution.

---

3 marks

b. Ibuprofen reacts with compound 2 which has the semi-structural formula shown below.

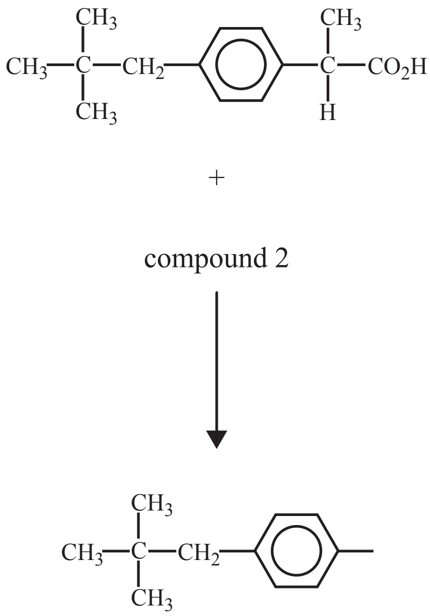


compound 2

i. Give the systematic name of compound 2.

---

ii. Complete the following structure of the compound formed between ibuprofen and compound 2.

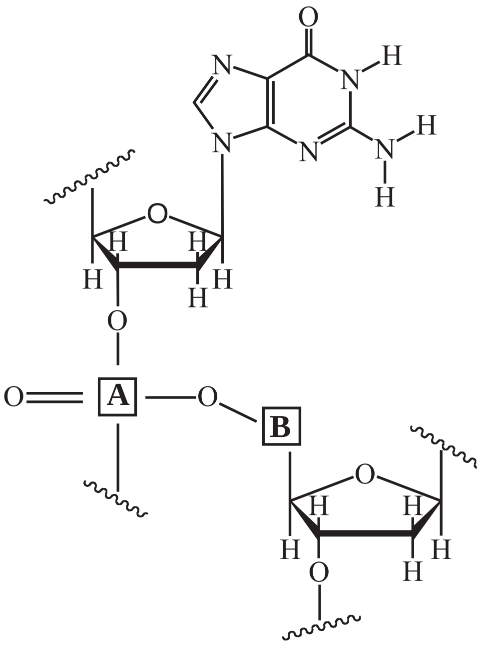


2 marks

Total 5 marks

Question 9

a. The diagram below represents part of the DNA double helix.



i. Write down the formula of the atom or groups of atoms represented by A and B.

A ________________________________

B ________________________________

ii. Name the base that is complementary to the base shown.

____

2 marks

The temperature at which 50% of a piece of double-stranded DNA separates into single strands is known as the melting temperature. A certain human viral DNA contains a greater percentage of adenine than a monkey viral DNA. The lengths of the human and monkey viral DNA molecules are equal.

b. Explain why the human viral DNA has a lower melting temperature than the monkey viral DNA.

____

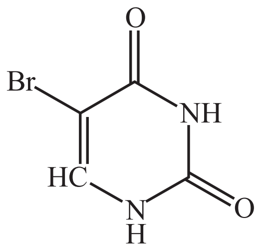
____

____

____

1 mark

Under certain circumstances the compound 5-bromouracil (shown below) is incorporated into the DNA structure in place of one of the normal DNA bases.



c. Which DNA base is likely to be replaced by 5-bromouracil?

1 mark

Total 4 marks

Question 10

Elemental sulfur can be used to control outbreaks of powdery mildew on grapes. However, sulfur remaining on the grapes after harvest can be converted to a number of undesirable compounds during fermentation in wine production.

A wine chemist uses atomic absorption spectroscopy to determine the amount of sulfur remaining on grapes.

In a particular analysis, 100.0 g of grapes are treated with 100.0 mL of surfactant solution to remove the sulfur remaining on the grapes when they were harvested.

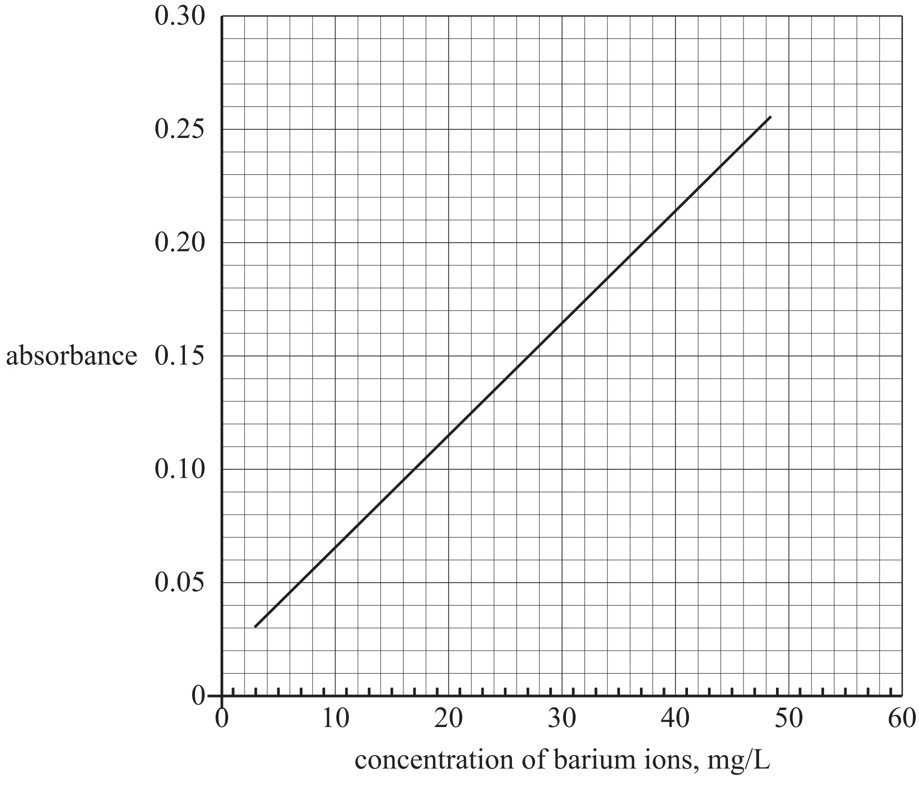
25.00 mL of this surfactant solution is treated to convert all of the sulfur to sulfate ions and then dried to produce an ash containing the sulfate ions.

This ash is transferred to a 10.00 mL volumetric flask containing 2.00 mL of 200 mg/L solution of barium Ba^{2+} ions.

The volume of solution in the volumetric flask is then made up to the calibration line. A precipitate of $BaSO_4$ forms and settles to the bottom of the volumetric flask.

A small amount of the solution containing the unreacted Ba^{2+} ions is removed from the volumetric flask and analysed using atomic absorption spectroscopy. This solution gave an absorbance of 0.11.

A calibration curve was prepared using standard solutions of 10, 20, 30 and 40 mg/L Ba^{2+} (aq).



a. Determine the concentration of barium ions remaining in the 10.00 mL sample solution. Hence determine the mass of barium ions, in mg, remaining in the 10.00 mL sample solution.

2 marks

b. Determine the amount of barium ions, in moles, that reacted to produce the barium sulfate precipitate.

2 marks

c. Determine the mass of sulfur, in mg, remaining on the 100 g of harvested grapes.

2 marks

The amount of sulfur remaining on the grapes can also be determined using gravimetric analysis.

d. Give **one** reason why atomic absorption spectroscopy is a better way to determine the residual sulfur on the grapes compared to gravimetric analysis.

1 mark

Total 7 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2009

CHEMISTRY

Written examination

Wednesday 10 June 2009

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

DATA BOOK

Directions to students

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

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

Table of contents

1. Periodic table of the elements

atomic number / 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

2. The electrochemical series

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

3. Physical constants

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

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

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

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

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

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

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

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

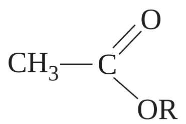
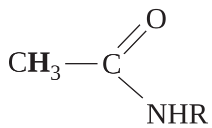
4. SI prefixes, their symbols and values

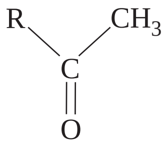
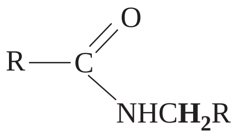
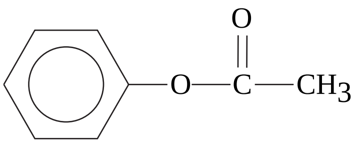
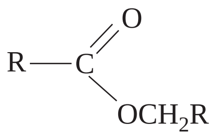
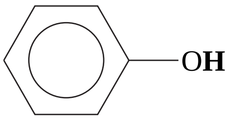
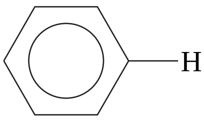
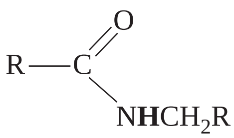
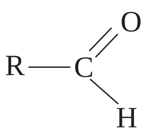
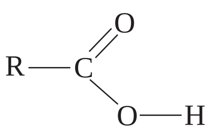
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

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

Type of proton	Chemical shift (ppm)
$R{-}CH_3$	0.9
$R{-}CH_2{-}R$	1.3
$RCH = CH{-}C\mathbf{H_3}$	1.7
$R_3{-}CH$	2.0
 or 	2.0

Type of proton	Chemical shift (ppm)
	2.1
R–CH_2–X (X = F, Cl, Br or I)	3–4
R–C**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

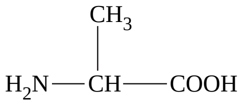
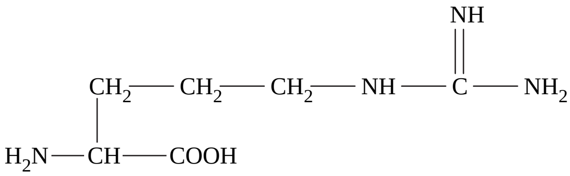
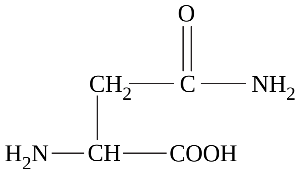
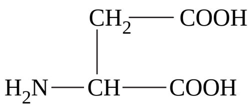
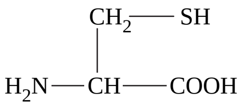
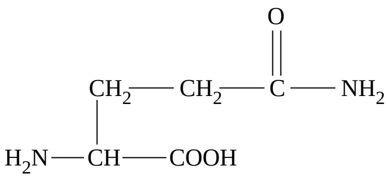
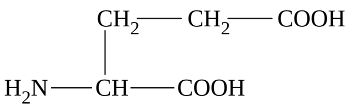
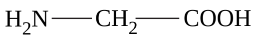
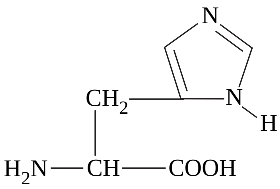
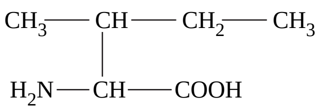
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
$RC{\equiv}CR$	75–95
$R_2C{=}CR_2$	110–150
RCOOH	160–185

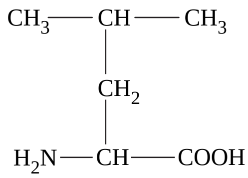
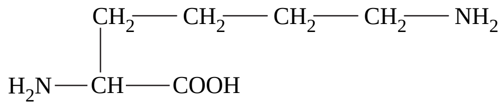
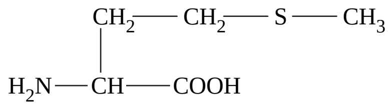
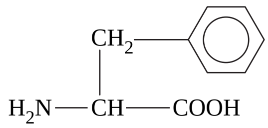
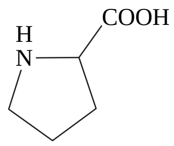
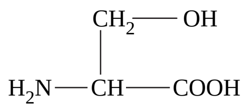
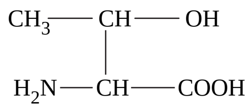
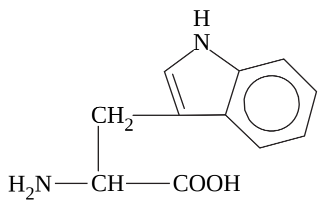
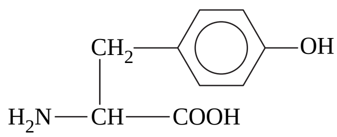
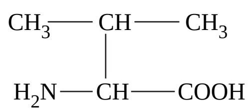
7. Infrared absorption data

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)

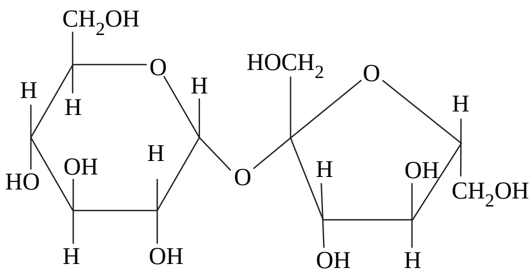
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

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

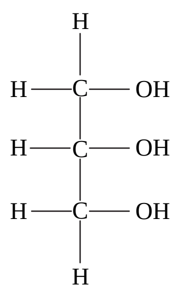
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

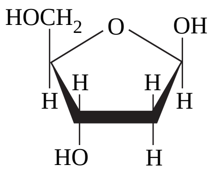
10. Structural formulas of some important biomolecules



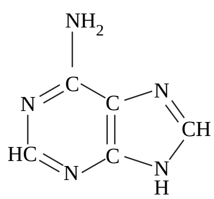
sucrose



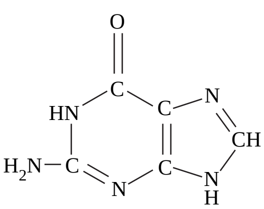
glycerol



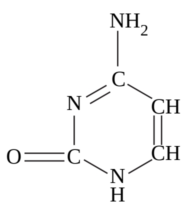
deoxyribose



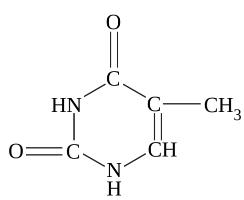
adenine



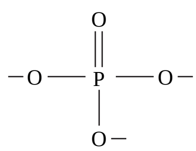
guanine



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. 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}	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