VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2010

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

CHEMISTRY

Written examination 1

Wednesday 9 June 2010

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	9	9	55
			Total 75

- 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 24 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.

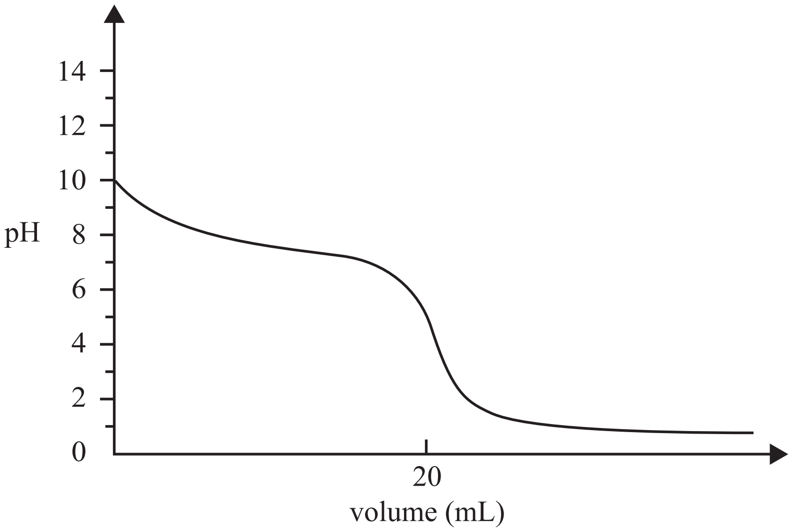
A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

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

The following information refers to Questions 1 and 2.

The following titration curve was obtained by measuring the pH in a reaction flask during an acid-base titration.



Question 1

The graph represents the change in pH in the reaction flask when

A. a weak acid is added to a strong base.

B. a weak base is added to a strong acid.

C. a strong acid is added to a weak base.

D. a strong base is added to a weak acid.

Question 2

Which one of the following is a suitable indicator for use in this titration?

A. phenol red

B. thymol blue

C. phenolphthalein

D. bromophenol blue

Question 3

A sample of the insecticide dichlorodiphenyltrichloroethane (DDT), $C_{14}H_9Cl_5$, was found to contain 0.120 g of carbon.

What mass of chlorine was present in the sample?

A. 0.127 g

B. 0.355 g

C. 0.994 g

D. 1.01 g

Question 4

When 1.0 mole of Cu_3FeS_3 and 1.0 mole of O_2 are mixed and allowed to react according to the equation

$$2Cu_3FeS_3(s) + 7O_2(g) \rightarrow 6Cu(s) + 2FeO(s) + 6SO_2(g)$$

A. no reagent is in excess.

B. 5 mole of O_2 is in excess.

C. $\frac{5}{7}$ mole of Cu_3FeS_3 is in excess.

D. $\frac{2}{7}$ mole of Cu_3FeS_3 is in excess.

Question 5

One possible reaction that occurs when trinitrotoluene (TNT), $C_7H_5N_3O_6$, explodes is

$$2C_7H_5N_3O_6(s) \rightarrow 2C(s) + 12CO(g) + 5H_2(g) + 3N_2(g)$$

When one mole of TNT explodes the total volume of the gases produced from this reaction, measured at 27 °C and 1.00×10^2 kPa, is **closest** to

A. 0.249 L

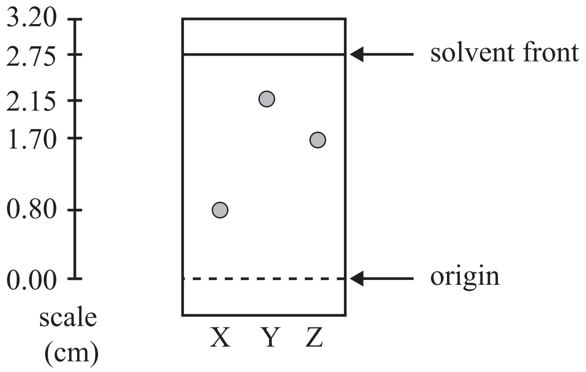
B. 22.7 L

C. 249 L

D. 274 L

Question 6

Consider the following TLC plate of compounds X, Y and Z developed using a suitable mobile phase on a polar stationary phase.



The R_f value of the most polar component in this TLC separation is

A. 0.29

B. 0.62

C. 0.78

D. 0.80

Question 7

Which of the following would be the most suitable analytical technique to determine the ratio of ^{235}U to ^{238}U in a sample of uranium metal?

A. mass spectroscopy

B. gas liquid chromatography

C. atomic absorption spectroscopy

D. nuclear magnetic resonance spectroscopy

Question 8

When a sample absorbs infrared radiation

A. covalent bonds are broken.

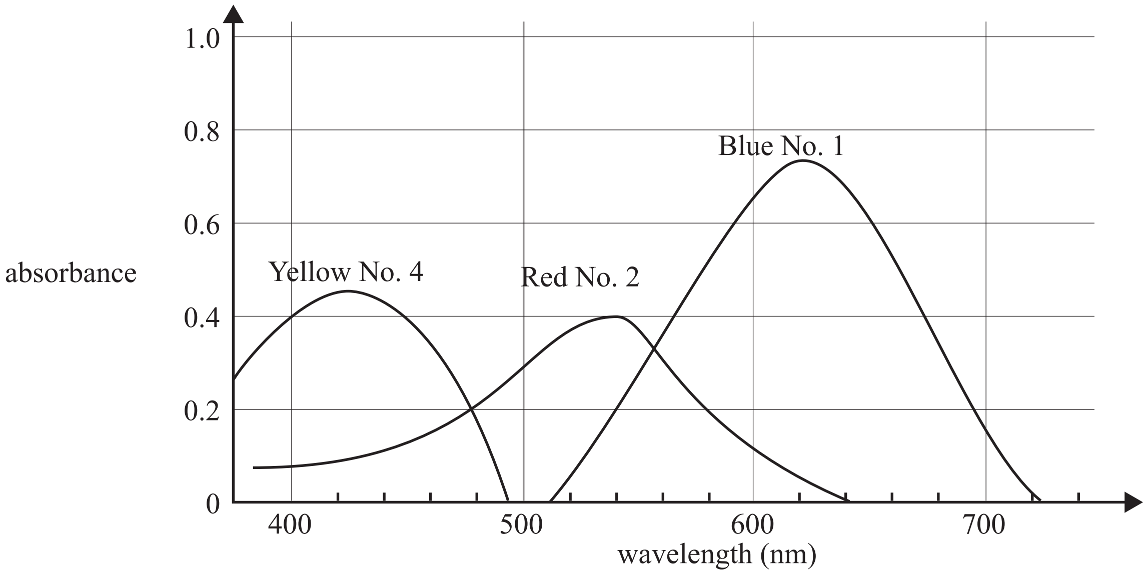
B. covalent bonds stretch and vibrate.

C. the spin alignment of certain nuclei changes.

D. electrons in atoms move to higher energy levels.

Question 9

The graph shows the absorption spectra of three food dyes: Blue No. 1, Red No. 2 and Yellow No. 4.



Which one of the following is the best wavelength to determine the concentration of Red No. 2 dye in a solution containing a mixture of all three dyes?

A. 430 nm

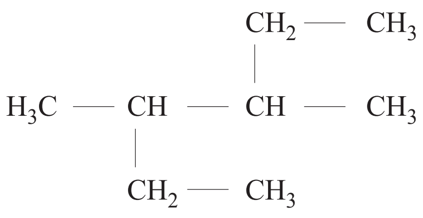
B. 500 nm

C. 540 nm

D. 620 nm

Question 10

What is the correct systematic name for the following compound?



$$\begin{array}{ccccccc} & & & & CH_2 & — & CH_3\\ & & & & | & & \\ H_3C & — & CH & — & CH & — & CH_3\\ & & | & & & & \\ & & CH_2 & — & CH_3 & & \end{array}$$

A. 2-ethyl-3-methylpentane

B. 3-methyl-4-ethylpentane

C. 3,4-dimethylhexane

D. 2,3-diethylbutane

Question 11

For which one of the following molecular formulas is there only one possible structure?

A. C_2HCl_3

B. $C_2H_4Cl_2$

C. $C_2H_2Cl_2$

D. C_4H_9OH

Question 12

An organic compound reacts with both dilute hydrochloric acid and dilute sodium hydroxide solution.

The compound could be

A. C_3H_7Cl

B. $C_3H_7NH_2$

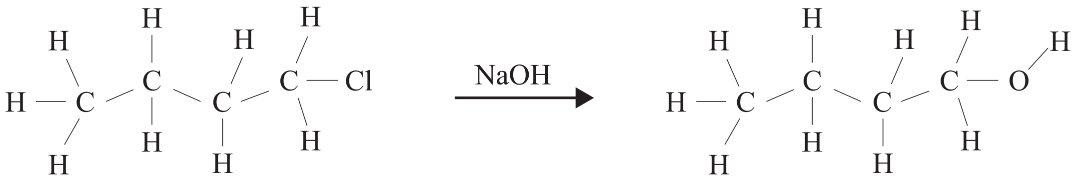
C. C_4H_9COOH

D. H_2NCH_2COOH

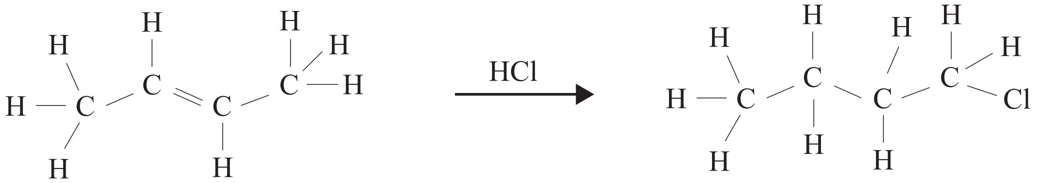
Question 13

Which one of the following organic reactions does **not** result in the product shown on the right-hand side of the reaction?

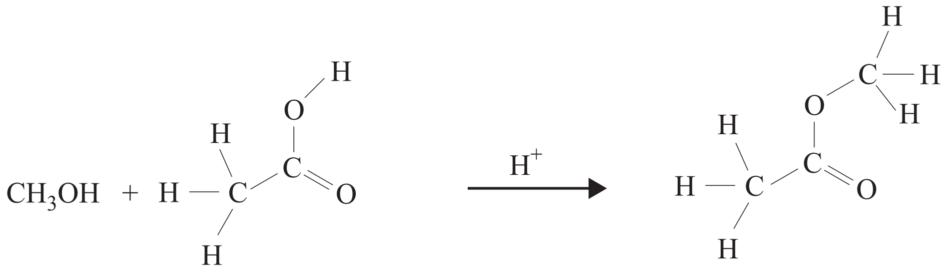
A.



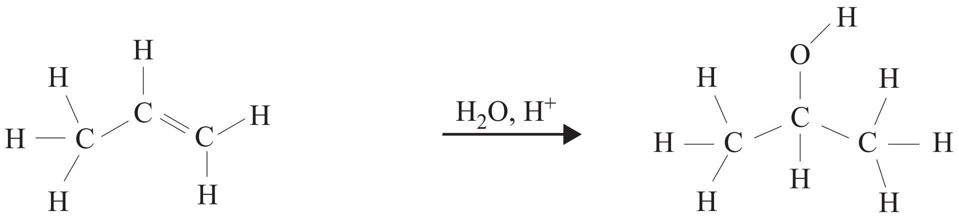
B.



C.

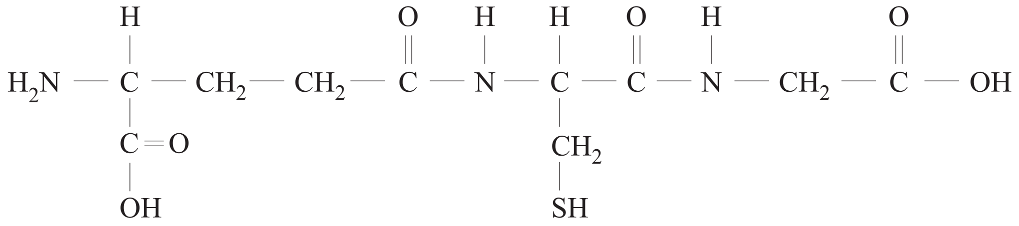


D.



Question 14

The side chains of some amino acids are able to form amide (peptide) bonds. Glutathione is a tripeptide that protects cells in humans by acting as an antioxidant. The structure of glutathione is



$H_2N-CH(COOH)-CH_2-CH_2-C(=O)-NH-CH(CH_2SH)-C(=O)-NH-CH_2-C(=O)-OH$

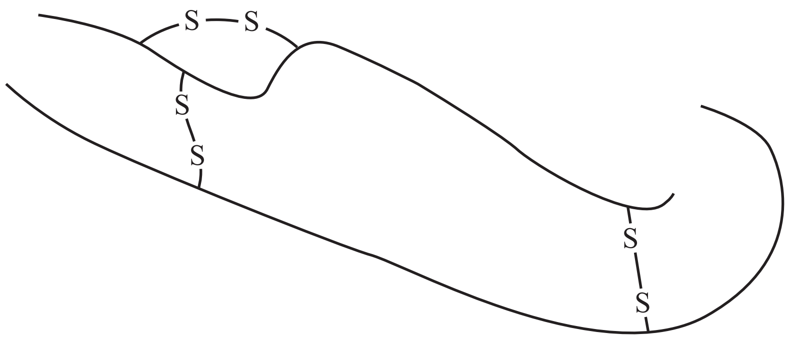
The molecule of glutathione contains residues from the amino acids cysteine and glycine.

The name of the third amino acid found in glutathione is

A. asparagine.
B. aspartic acid.
C. glutamine.
D. glutamic acid.

Questions 15 and 16 refer to the following information.

The following diagram is a simplified illustration of the protein insulin. Insulin consists of 51 amino acids arranged in two individual chains linked by disulfide bridges.



Question 15

How many peptide links are present in one molecule of insulin?

A. 48
B. 49
C. 50
D. 51

Question 16

Disulfide bridges are formed when the side chains of two amino acid residues react.

The pair of amino acids that form the disulfide bridges could be

A. cysteine and serine.
B. cysteine and glycine.
C. cysteine and cysteine.
D. cysteine and glutamic acid.

Question 17

The following are **incomplete** and **unbalanced** equations representing three types of chemical reactions that involve glucose. In reactions 1 and 3, product A is the same compound. In reactions 2 and 3, product B is the same compound.

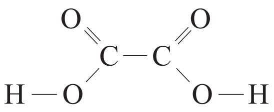
reaction 1 $C_6H_{12}O_6(aq) \rightarrow C_2H_5OH(aq)$ + product A
reaction 2 $C_6H_{12}O_6(aq) \rightarrow C_{12}H_{22}O_{11}(aq)$ + product B
reaction 3 $C_6H_{12}O_6(aq) \rightarrow$ product A + product B

Which one of the following correctly names reaction 3 and identifies product A and product B?

	Reaction 3	**Product A**	**Product B**
A.	fermentation	water	carbon dioxide
B.	fermentation	carbon dioxide	water
C.	combustion	water	carbon dioxide
D.	combustion	carbon dioxide	water

Question 18

The structure of oxalic acid is shown below.



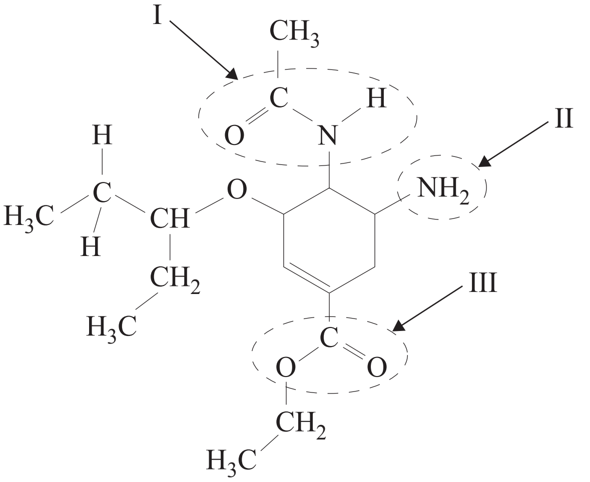
A 25.0 mL solution of oxalic acid reacts completely with 15.0 mL of 2.50 M NaOH.

The concentration of the oxalic acid solution is

A. 0.667 M
B. 0.750 M
C. 1.33 M
D. 1.50 M

Question 19

The structure of Tamiflu®, an antiflu drug, is shown below.



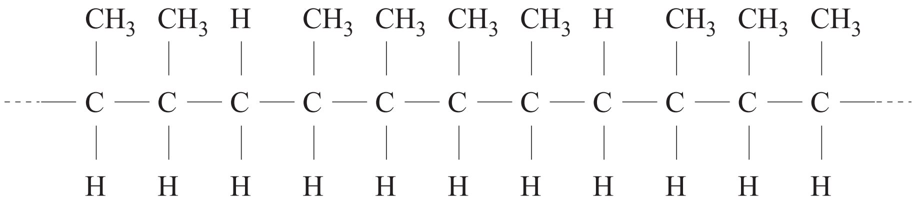
The names of the functional groups labelled I, II and III are

	I	II	III
A.	amide	amino	carboxylic acid
B.	amino	amide	ester
C.	amide	amino	ester
D.	amino	amide	carboxylic acid

Question 20

Copolymers are obtained when two or more different monomers are allowed to polymerise together.

Part of a copolymer chain is shown below.



$$\begin{array}{ccccccccccccc} & CH_3 & CH_3 & H & CH_3 & CH_3 & CH_3 & CH_3 & H & CH_3 & CH_3 & CH_3 & \\ & | & | & | & | & | & | & | & | & | & | & | & \\ \cdots - & C - & C - & C - & C - & C - & C - & C - & C - & C - & C - & C & - \cdots \\ & | & | & | & | & | & | & | & | & | & | & | & \\ & H & H & H & H & H & H & H & H & H & H & H & \end{array}$$

The **two** alkenes that could react together to form this polymer are

A. propene and but-1-ene.

B. propene and but-2-ene.

C. but-1-ene and but-2-ene.

D. pent-2-ene and but-2-ene.

END OF SECTION A
TURN OVER

SECTION B – Short answer questions

Instructions for Section B

Answer **all** questions in the spaces provided in blue or black pen or pencil.

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

The amount of iron in a newly developed, heat-resistant aluminium alloy is to be determined.

An 80.50 g sample of alloy is dissolved in concentrated hydrochloric acid and the iron atoms are converted to $Fe^{2+}(aq)$ ions.

This solution is accurately transferred to a 250.0 mL volumetric flask and made up to the mark.

20.00 mL aliquots of this solution are then titrated against a standard 0.0400 M potassium permanganate solution.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

Four titrations were carried out and the volumes of potassium permanganate solution used were recorded in the table below.

Titration number	1	2	3	4
Volume of $KMnO_4$ (mL)	22.03	20.25	21.97	21.99

a. Write a balanced half-equation, including states, for the conversion of MnO_4^- ions, in an acidic solution, to Mn^{2+} ions.

2 marks

b. Calculate the average volume, in mL, of the concordant titres of the potassium permanganate solution.

1 mark

c. Use your answer to **part b.** to calculate the amount, in mol, of MnO_4^-(aq) ions used in this titration.

1 mark

d. Calculate the amount, in mol, of Fe^{2+}(aq) ions present in the 250.0 mL volumetric flask.

2 marks

e. Calculate the percentage, by mass, of iron in the 80.50 g sample of alloy. Express your answer to the correct number of significant figures.

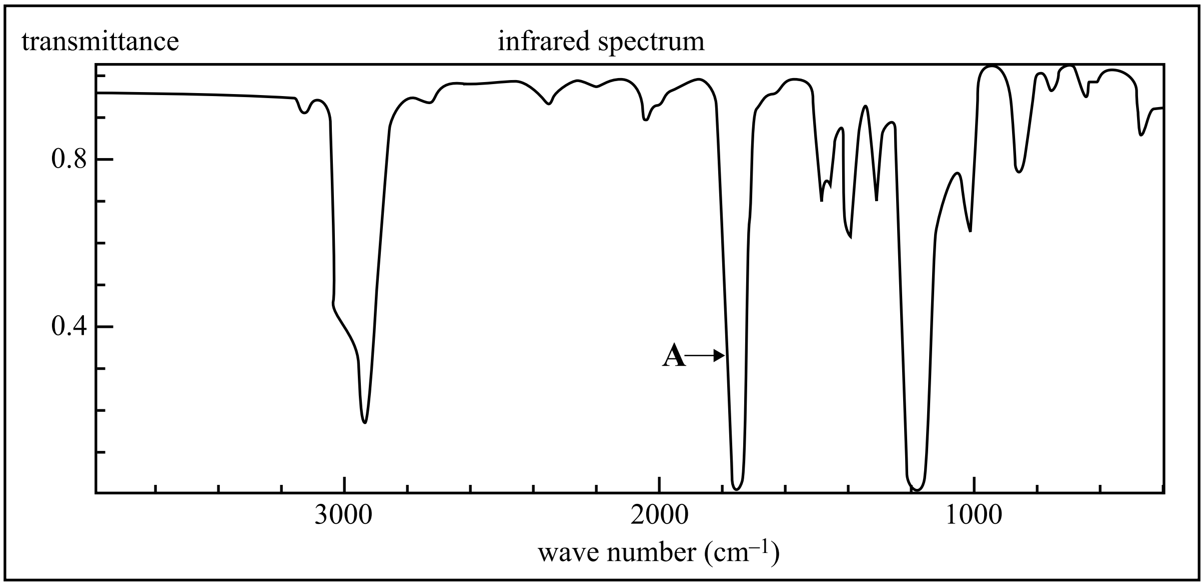
3 marks

Total 9 marks

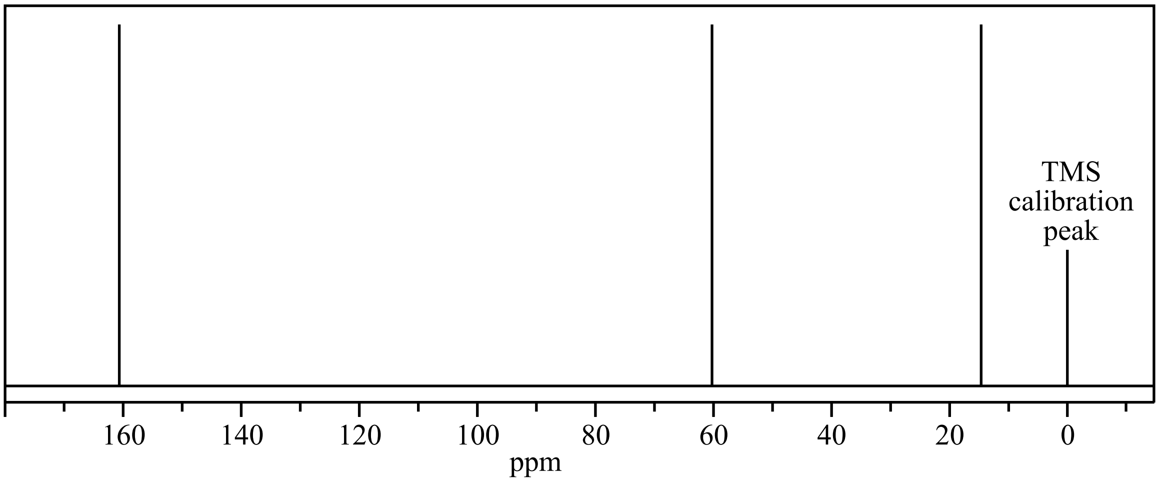
Question 2

The molecular formula of an unknown compound, X, is $C_3H_6O_2$.

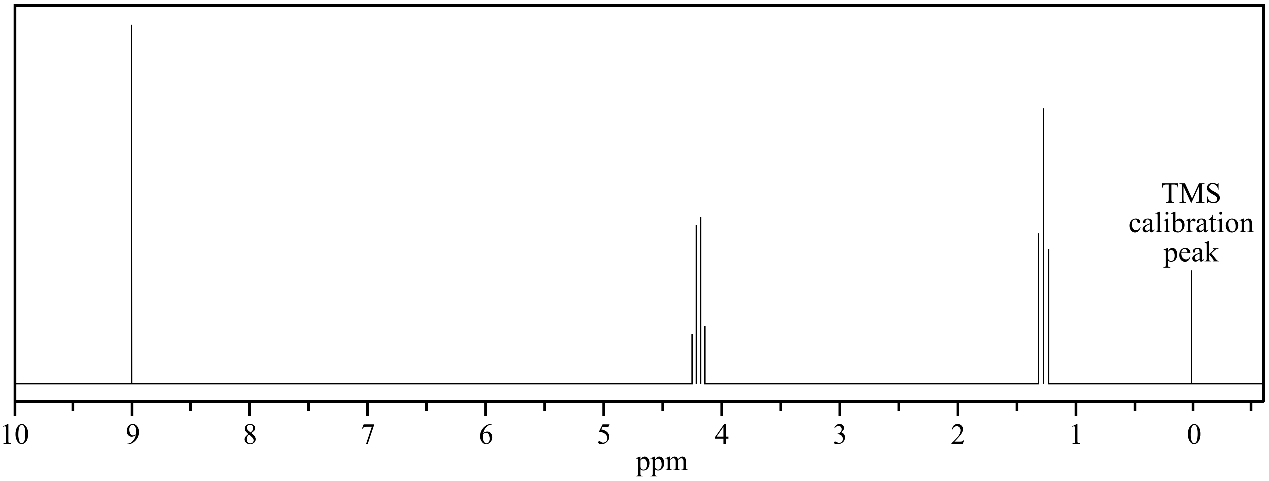
The infrared ^{13}C NMR and ^{1}H NMR spectra of this compound are shown below.



^{13}C NMR



^{1}H NMR



The ^1H NMR spectrum data is summarised in the following table.

Chemical shift (ppm)	**Relative peak area**	**Peak splitting**
1.3	3	triplet (3)
4.2	2	quartet (4)
9.0	1	singlet (1)

a. Using the **Infrared absorption data** on page 7 of the Data Book, identify the atoms and the bonds between them that are associated with the absorption labelled A on the infrared spectrum.

1 mark

b. How many different carbon environments are present in compound X?

1 mark

c. How many different hydrogen environments are present in compound X?

1 mark

d. **i.** The signal at 1.3 ppm is split into a triplet. What is the number of equivalent protons bonded to the adjacent carbon atom?

ii. Draw the grouping of atoms that would give rise to the triplet and quartet splitting patterns.

1 + 1 = 2 marks

e. A chemical test showed that compound X does **not** react with a base.

Propose a structure for compound X that is consistent with all the evidence provided.

2 marks

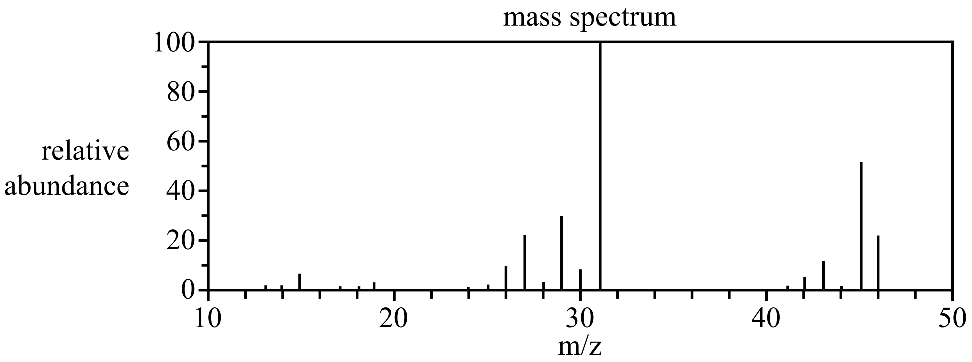
Total 7 marks

Question 3

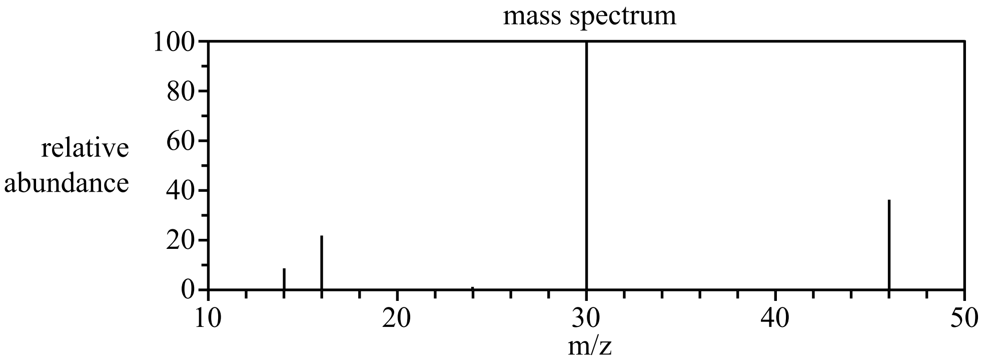
The molecules ethanol and nitrogen dioxide have the same molar mass (M = 46 g mol^{-1}). They can be easily distinguished by mass spectrometry.

The mass spectra of the two molecules are shown below.

Spectrum A



Spectrum B



a. Write an equation showing how **either** an ethanol molecule **or** a nitrogen dioxide molecule becomes ionised in the mass spectrometer.

1 mark

b. Which mass spectrum **cannot** be that of nitrogen dioxide? What evidence does the mass spectrum provide to support your answer?

2 marks

c. What is the formula of the species that produces the peak seen at m/z 30 in spectrum B?

1 mark

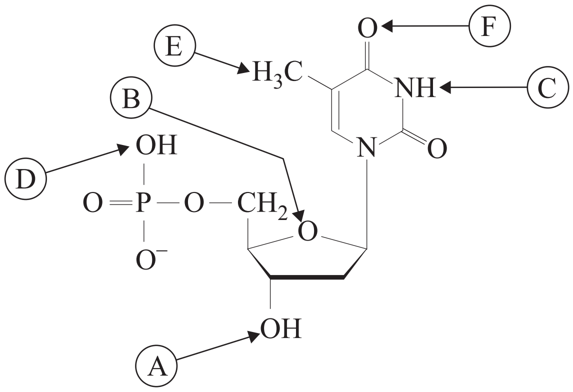
Total 4 marks

Question 4

A single strand of DNA consists of a long chain of monomers called nucleotides. The structure of one of these nucleotides of DNA is shown below.

Each nucleotide will polymerise with other nucleotides to form a single strand of DNA.

Part of this nucleotide will also form bonds with a complementary nucleotide on a parallel strand of DNA forming the double helix structure.



a. Circle only the letters which represent the sites where this nucleotide can form bonds with other nucleotides to form a single strand of DNA.

A B C D E F

2 marks

b. **i.** Name the type of bonding that holds the two strands in human DNA together.

____

ii. Circle only the letters that represent the locations where these bonds between the two strands of DNA are formed.

A B C D E F

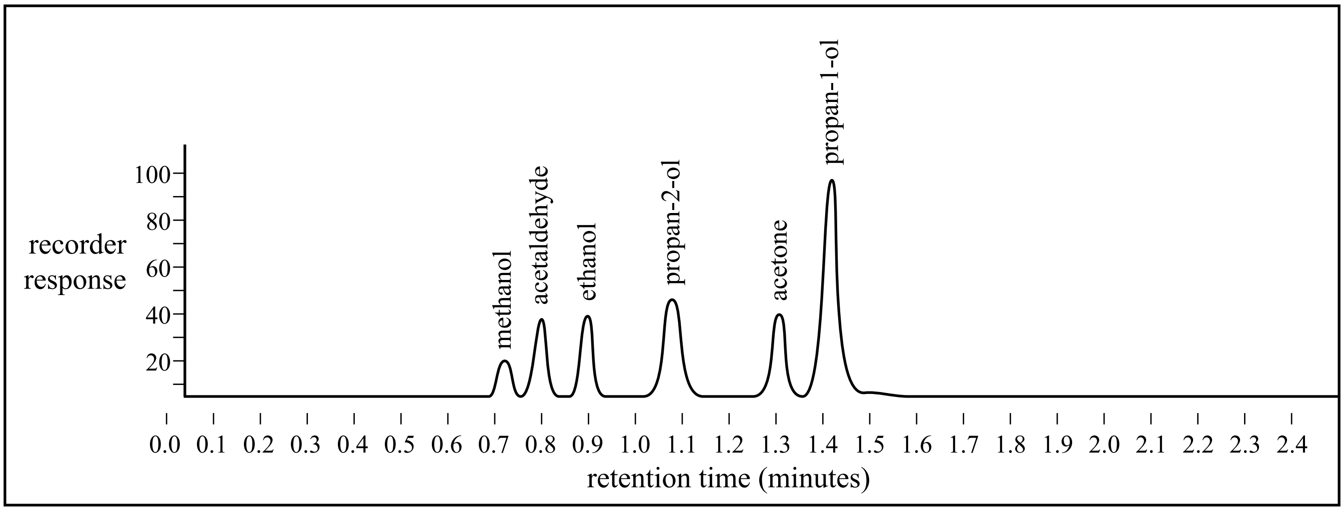
1 + 2 = 3 marks

Total 5 marks

Question 5

A forensic chemist wants to test the accuracy of a gas chromatograph that is to be used for the analysis of blood alcohol content.

A blood sample may contain a number of volatile chemicals that can interfere with the identification and measurement of ethanol in the blood. A sample containing a mixture of ethanol and several other volatile chemicals was injected into the gas chromatograph. The following chromatogram was obtained.



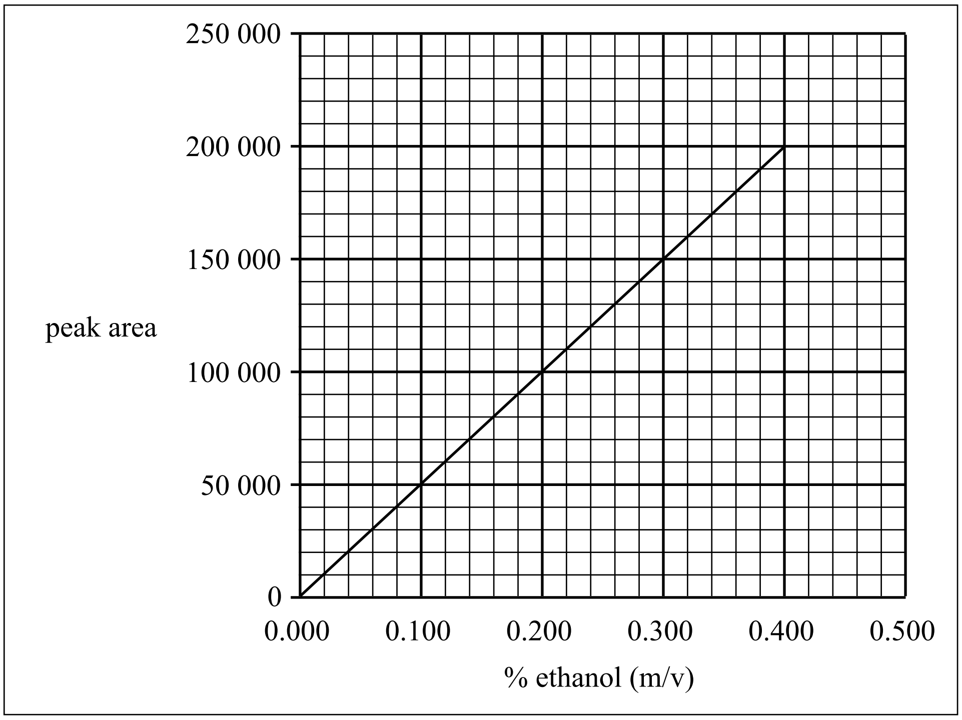
a. The forensic chemist claims that the presence of these volatile chemicals would not affect the qualitative analysis of ethanol.

i. What evidence is presented in the chromatogram to support this claim?

ii. To determine the percentage of alcohol in a blood sample only the peak at a retention time of 0.9 minutes is measured. Explain why.

1 + 1 = 2 marks

The following calibration graph was constructed using simulated standard blood alcohol samples ranging in concentration from 0.000% to 0.400% m/v ethanol. Each standard was run through the chromatography column and the area under the peak produced at a retention time of 0.9 minutes was measured.



The blood alcohol content of a car driver was determined using this chromatographic technique.

b. Determine the percentage (m/v) of alcohol in the driver's blood if the peak area at a retention time of 0.9 minutes was found to be 110 000.

1 mark

Total 3 marks

Question 6

Enzymes are complex protein structures that function as biological catalysts.

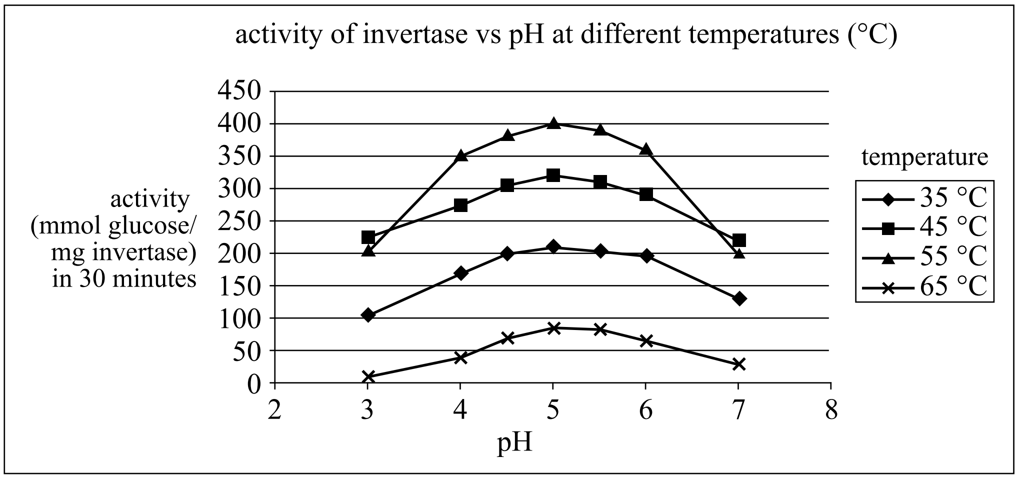
a. Why does a particular enzyme generally only catalyse a specific reaction?

___

___

1 mark

Invertase is an enzyme which catalyses the conversion of sucrose to glucose and fructose. Invertase has a maximum activity temperature different from many other enzymes. The graph below shows the results of a study into the effects of both pH and temperature on the activity of invertase in sucrose solution.



b. At what temperature and pH does the enzyme in the study have maximum activity?

Temperature ___________ pH ___________

2 marks

c. Why does changing the pH from the optimum value cause a decrease in the activity of the enzyme?

___

1 mark

d. In this study the activity of the enzyme was measured as the number of millimole of glucose produced per milligram of enzyme (mmol glucose/mg invertase) in 30 minutes.

Assuming excess sucrose, calculate the mass of glucose ($M_r = 180$) produced in 30 minutes from a sucrose solution containing 1.00×10^{-4} g of invertase if the measured activity is 300 mmol glucose/mg invertase.

2 marks

Total 6 marks

Question 7

a. Biodiesel is an alternative to standard diesel fuel. Biodiesel is made from biological ingredients instead of petroleum. Biodiesel is usually made from plant oils or animal fats through a series of chemical reactions.

In one process a common **triglyceride** in palm oil, known as POP, is reacted with methanol in the presence of potassium hydroxide as a catalyst. The result is a mixture of methyl esters of the fatty acids (biodiesel).

i. The value of the stoichiometric ratio $\frac{\text{number of moles of methanol}}{\text{number of moles of POP}}$ is

ii. Calculate the volume, in litres, of methanol (density = 0.79 g mL^{-1}) required to react completely with 10.0 kg of the triglyceride POP (M_r = 833) to produce glycerol and the mixture of methyl esters.

1 + 3 = 4 marks

b. Cervonic acid is a polyunsaturated fatty acid found in fish oil. The number of carbon-carbon double bonds in a molecule of cervonic acid can be determined by titration with iodine, I_2, solution. An addition reaction takes place between the double bonds in cervonic acid and iodine.

20.00 mL of 0.300 M I_2 solution reacted exactly with 0.328 g of cervonic acid. The molar mass of cervonic acid is 328.0 g mol^{-1}.

i. Calculate the number of double bonds in a molecule of cervonic acid.

There are 22 carbon atoms in a molecule of cervonic acid.

ii. What is the formula of cervonic acid?

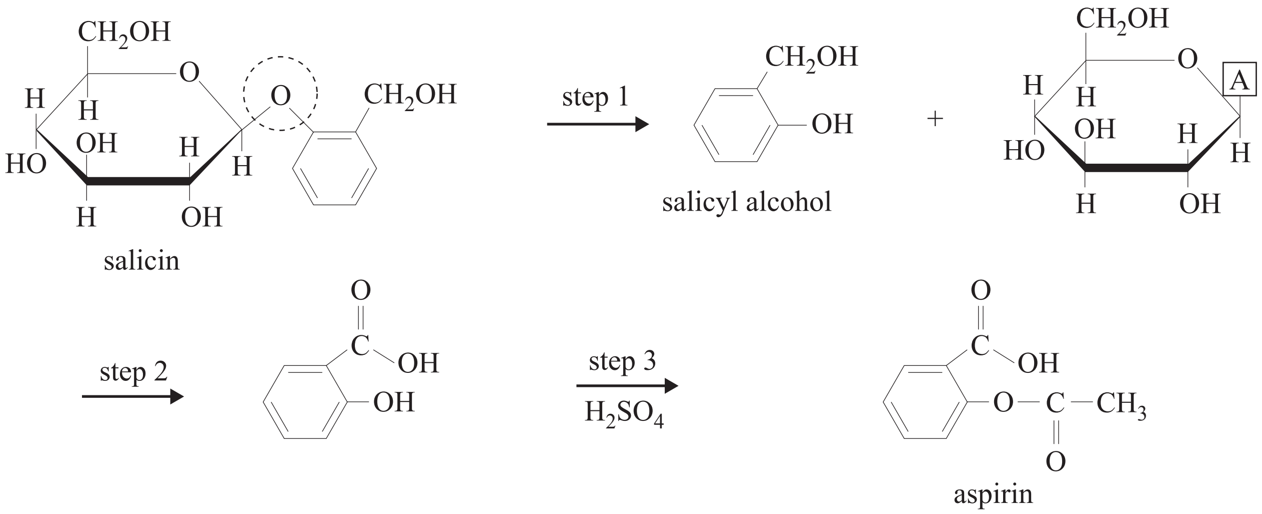
3 + 1 = 4 marks

Total 8 marks

Question 8

Since ancient times, the bark of willow trees has been used for pain relief. In the 19th century, chemists isolated the active compound, *salicin*, from the bark. This was eventually converted into aspirin, which is now a widely used drug.

The reaction scheme below shows the steps used to carry out the conversion.



a. What type of linkage is circled in the structure of salicin?

1 mark

b. In step 1, salicyl alcohol and another compound is produced.

i. What group of biomolecules does this other compound belong to?

ii. The structure of this other compound is not complete. Write the formula of the atom or group of atoms represented by A in the reaction scheme above.

1 + 1 = 2 marks

c. Step 2 involves the conversion of salicyl alcohol into salicylic acid.

i. What type of reaction is step 2?

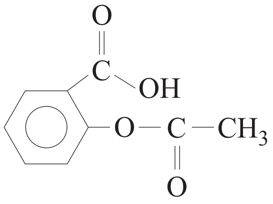
ii. Suggest a suitable reagent to carry out the reaction.

1 + 1 = 2 marks

d. Step 3 requires sulfuric acid catalyst and another reagent. Name this reagent.

1 mark

e. Aspirin reacts with a strong base according to the equation



$+ OH^-(aq) \rightarrow H_2O(l) + \text{product B}$

Draw the structure of product B.

1 mark

Total 7 marks

Question 9

The boiling points of several alkanols are provided in the following table.

Alkanol	methanol	ethanol	propan-1-ol	butan-1-ol	pentan-1-ol
Boiling point (°C)	64.5	78.3	97.2	117.2	138.0

A mixture of two of these alkanols is to be separated in an experiment using fractional distillation. The mixture is placed into the distillation apparatus at room temperature and then gently heated. The first fraction is collected at 97.2 °C.

a. **i.** Identify one alkanol that could **not** be present in this mixture.

ii. By specifically referring to this experiment, explain why the alkanol identified in **part i.** could not be present.

1 + 1 = 2 marks

b. Provide one reason why the distillation flask should **not** be heated using a bunsen burner.

1 mark

c. Butane and propan-1-ol have similar molar masses. The boiling point of butane is –138.4 °C and that of propan-1-ol is 97.2 °C. Explain, in terms of intermolecular forces, the difference between the boiling points of these two compounds.

3 marks

Total 6 marks

END OF QUESTION AND ANSWER BOOK

Victoria
The Place To Be

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2010

CHEMISTRY
Written examination

Wednesday 9 June 2010

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

		page
1.	Periodic table of the elements	3
2.	The electrochemical series	4
3.	Physical constants	5
4.	SI prefixes, their symbols and values	5
5.	^{1}H NMR data	5–6
6.	^{13}C NMR data	7
7.	Infrared absorption data	7
8.	2-amino acids (α-amino acids)	8–9
9.	Formulas of some fatty acids	10
10.	Structural formulas of some important biomolecules	10
11.	Acid-base indicators	11
12.	Acidity constants, K_a, of some weak acids	11
13.	Values of molar enthalpy of combustion of some common fuels at 298 K and 101.3 kPa	11

1. Periodic table of the elements

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

1 **H** 1.0 Hydrogen																	**2** **He** 4.0 Helium
3 **Li** 6.9 Lithium	**4** **Be** 9.0 Beryllium											**5** **B** 10.8 Boron	**6** **C** 12.0 Carbon	**7** **N** 14.0 Nitrogen	**8** **O** 16.0 Oxygen	**9** **F** 19.0 Fluorine	**10** **Ne** 20.1 Neon
11 **Na** 23.0 Sodium	**12** **Mg** 24.3 Magnesium											**13** **Al** 27.0 Aluminium	**14** **Si** 28.1 Silicon	**15** **P** 31.0 Phosphorus	**16** **S** 32.1 Sulfur	**17** **Cl** 35.5 Chlorine	**18** **Ar** 39.9 Argon
19 **K** 39.1 Potassium	**20** **Ca** 40.1 Calcium	**21** **Sc** 44.9 Scandium	**22** **Ti** 47.9 Titanium	**23** **V** 50.9 Vanadium	**24** **Cr** 52.0 Chromium	**25** **Mn** 54.9 Manganese	**26** **Fe** 55.9 Iron	**27** **Co** 58.9 Cobalt	**28** **Ni** 58.7 Nickel	**29** **Cu** 63.6 Copper	**30** **Zn** 65.4 Zinc	**31** **Ga** 69.7 Gallium	**32** **Ge** 72.6 Germanium	**33** **As** 74.9 Arsenic	**34** **Se** 79.0 Selenium	**35** **Br** 79.9 Bromine	**36** **Kr** 83.8 Krypton
37 **Rb** 85.5 Rubidium	**38** **Sr** 87.6 Strontium	**39** **Y** 88.9 Yttrium	**40** **Zr** 91.2 Zirconium	**41** **Nb** 92.9 Niobium	**42** **Mo** 95.9 Molybdenum	**43** **Tc** 98.1 Technetium	**44** **Ru** 101.1 Ruthenium	**45** **Rh** 102.9 Rhodium	**46** **Pd** 106.4 Palladium	**47** **Ag** 107.9 Silver	**48** **Cd** 112.4 Cadmium	**49** **In** 114.8 Indium	**50** **Sn** 118.7 Tin	**51** **Sb** 121.8 Antimony	**52** **Te** 127.6 Tellurium	**53** **I** 126.9 Iodine	**54** **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	**56** **Ba** 137.3 Barium	**57** **La** 138.9 Lanthanum	**72** **Hf** 178.5 Hafnium	**73** **Ta** 180.9 Tantalum	**74** **W** 183.8 Tungsten	**75** **Re** 186.2 Rhenium	**76** **Os** 190.2 Osmium	**77** **Ir** 192.2 Iridium	**78** **Pt** 195.1 Platinum	**79** **Au** 197.0 Gold	**80** **Hg** 200.6 Mercury	**81** **Tl** 204.4 Thallium	**82** **Pb** 207.2 Lead	**83** **Bi** 209.0 Bismuth	**84** **Po** (209) Polonium	**85** **At** (210) Astatine	**86** **Rn** (222) Radon
87 **Fr** (223) Francium	**88** **Ra** (226) Radium	**89** **Ac** (227) Actinium	**104** **Rf** (261) Rutherfordium	**105** **Db** (262) Dubnium	**106** **Sg** (266) Seaborgium	**107** **Bh** (264) Bohrium	**108** **Hs** (277) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Uub**		**114** **Uuq**		**116** **Uuh**		**118** **Uuo**

58 **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.3 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.2 Gadolinium	**65** **Tb** 158.9 Terbium	**66** **Dy** 162.5 Dysprosium	**67** **Ho** 164.9 Holmium	**68** **Er** 167.3 Erbium	**69** **Tm** 168.9 Thulium	**70** **Yb** 173.0 Ytterbium	**71** **Lu** 175.0 Lutetium

90 **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237.1) Neptunium	**94** **Pu** (244) Plutonium	**95** **Am** (243) Americium	**96** **Cm** (247) Curium	**97** **Bk** (247) Berkelium	**98** **Cf** (251) Californium	**99** **Es** (252) Einsteinium	**100** **Fm** (257) Fermium	**101** **Md** (258) Mendelevium	**102** **No** (259) Nobelium	**103** **Lr** (262) Lawrencium

2. The electrochemical series

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

3. Physical constants

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

Charge on one electron = -1.60×10^{-19} C

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

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

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

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

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

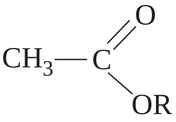
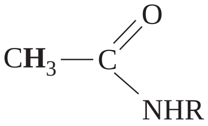
1 atm = 101.3 kPa = 760 mm Hg
0°C = 273 K

4. SI prefixes, their symbols and values

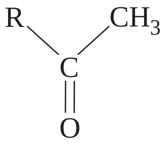
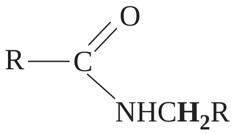
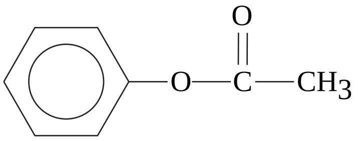
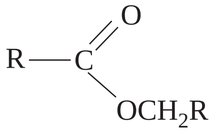
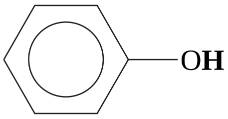
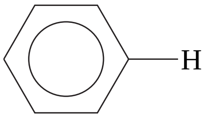
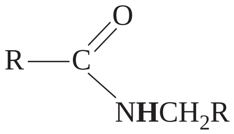
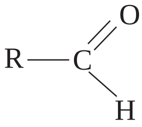
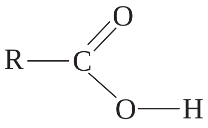
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0
These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

Type of proton	Chemical shift (ppm)
R–CH_3	0.9
R–CH_2–R	1.3
RCH = CH–$\mathbf{CH_3}$	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
$R{-}C\mathbf{H}_{\mathbf{2}}{-}OH$	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
$RHC{=}\mathbf{CH}_2$	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	11.5

6. ^{13}C NMR data

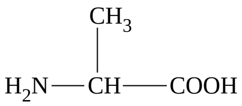
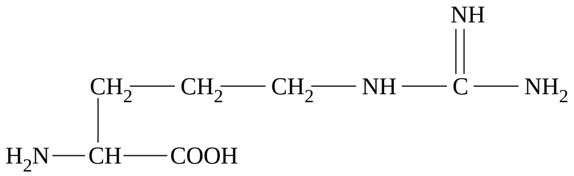
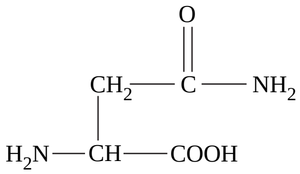
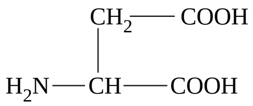
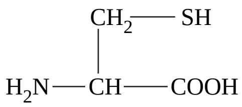
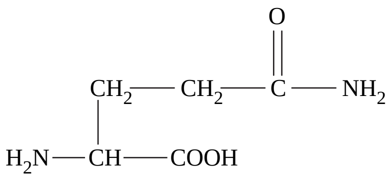
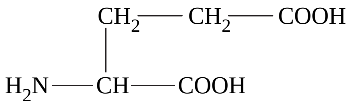
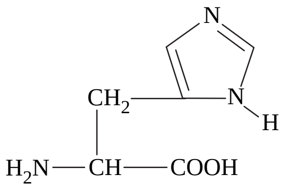
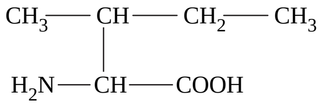
Type of carbon	**Chemical shift (ppm)**
R–CH_3	8–25
R–CH_2–R	20–45
R_3–CH	40–60
R_4–C	36–45
R–CH_2–X	15–80
R_3C–NH_2	35–70
R–CH_2–OH	50–90
RC≡CR	75–95
R_2C=CR_2	110–150
RCOOH	160–185

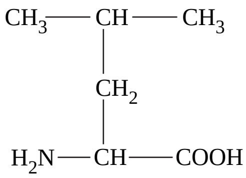
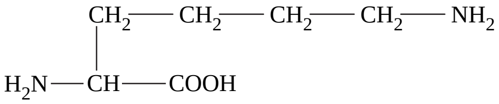
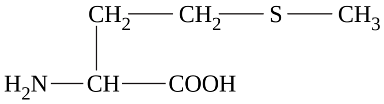
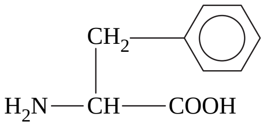
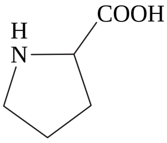
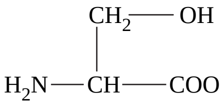
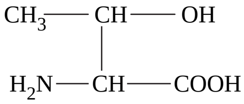
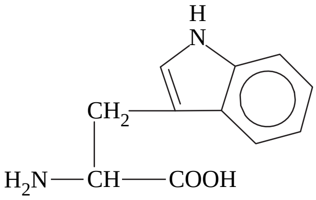
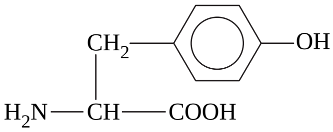
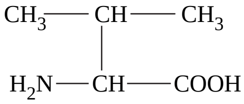
7. Infrared absorption data

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	 $\begin{array}{lll} & CH_3 & \\ & \vert & \\ H_2N- & CH- & COOH\end{array}$
arginine	Arg	 $\begin{array}{llllll} & & & & NH & \\ & & & & \Vert & \\ & CH_2- & CH_2- & CH_2-NH- & C- & NH_2 \\ & \vert & & & & \\ H_2N- & CH- & COOH & & & \end{array}$
asparagine	Asn	 $\begin{array}{llll} & & O & \\ & & \Vert & \\ & CH_2- & C- & NH_2 \\ & \vert & & \\ H_2N- & CH- & COOH & \end{array}$
aspartic acid	Asp	 $\begin{array}{lll} & CH_2- & COOH \\ & \vert & \\ H_2N- & CH- & COOH\end{array}$
cysteine	Cys	 $\begin{array}{lll} & CH_2- & SH \\ & \vert & \\ H_2N- & CH- & COOH\end{array}$
glutamine	Gln	 $\begin{array}{lllll} & & & O & \\ & & & \Vert & \\ & CH_2- & CH_2- & C- & NH_2 \\ & \vert & & & \\ H_2N- & CH- & COOH & & \end{array}$
glutamic acid	Glu	 $\begin{array}{llll} & CH_2- & CH_2- & COOH \\ & \vert & & \\ H_2N- & CH- & COOH & \end{array}$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	 $\begin{array}{llll} CH_3- & CH- & CH_2- & CH_3 \\ & \vert & & \\ H_2N- & CH- & COOH & \end{array}$

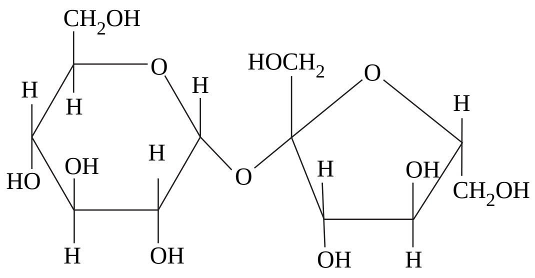
Name	**Symbol**	**Structure**
leucine	Leu	 $\begin{array}{l} CH_3-CH-CH_3 \\ \quad\quad\ \vert \\ \quad\quad CH_2 \\ \quad\quad\ \vert \\ H_2N-CH-COOH \end{array}$
lysine	Lys	 $\begin{array}{l} \quad\quad\ \ CH_2-CH_2-CH_2-CH_2-NH_2 \\ \quad\quad\quad \vert \\ H_2N-CH-COOH \end{array}$
methionine	Met	 $\begin{array}{l} \quad\quad\ \ CH_2-CH_2-S-CH_3 \\ \quad\quad\quad \vert \\ H_2N-CH-COOH \end{array}$
phenylalanine	Phe	
proline	Pro	
serine	Ser	 $\begin{array}{l} \quad\quad\ \ CH_2-OH \\ \quad\quad\quad \vert \\ H_2N-CH-COOH \end{array}$
threonine	Thr	 $\begin{array}{l} CH_3-CH-OH \\ \quad\quad\ \vert \\ H_2N-CH-COOH \end{array}$
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	 $\begin{array}{l} CH_3-CH-CH_3 \\ \quad\quad\ \vert \\ H_2N-CH-COOH \end{array}$

TURN OVER

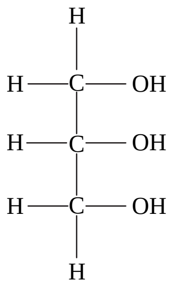
9. Formulas of some fatty acids

Name	Formula
Lauric	$C_{11}H_{23}COOH$
Myristic	$C_{13}H_{27}COOH$
Palmitic	$C_{15}H_{31}COOH$
Palmitoleic	$C_{15}H_{29}COOH$
Stearic	$C_{17}H_{35}COOH$
Oleic	$C_{17}H_{33}COOH$
Linoleic	$C_{17}H_{31}COOH$
Linolenic	$C_{17}H_{29}COOH$
Arachidic	$C_{19}H_{39}COOH$
Arachidonic	$C_{19}H_{31}COOH$

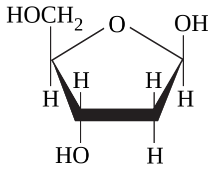
10. Structural formulas of some important biomolecules



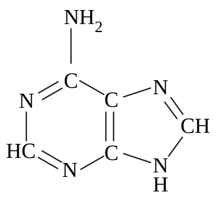
sucrose



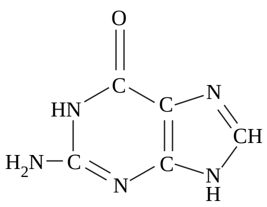
glycerol



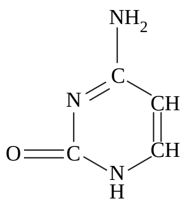
deoxyribose



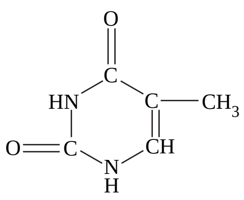
adenine



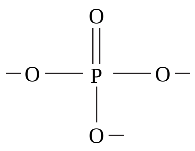
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
Thymol blue	1.2–2.8	red	yellow	2×10^{-2}
Methyl orange	3.1–4.4	red	yellow	2×10^{-4}
Bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
Methyl red	4.2–6.3	red	yellow	8×10^{-6}
Bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
Phenol red	6.8–8.4	yellow	red	1×10^{-8}
Phenolphthalein	8.3–10.0	colourless	red	5×10^{-10}

12. Acidity constants, K_a, of some weak acids

Name	Formula	K_a
Ammonium ion	NH_4^+	5.6×10^{-10}
Benzoic	C_6H_5COOH	6.4×10^{-5}
Boric	H_3BO_3	5.8×10^{-10}
Ethanoic	CH_3COOH	1.7×10^{-5}
Hydrocyanic	HCN	6.3×10^{-10}
Hydrofluoric	HF	7.6×10^{-4}
Hypobromous	$HOBr$	2.4×10^{-9}
Hypochlorous	$HOCl$	2.9×10^{-8}
Lactic	$HC_3H_5O_3$	1.4×10^{-4}
Methanoic	$HCOOH$	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	C_2H_5COOH	1.3×10^{-5}

13. Values of molar enthalpy of combustion of some common fuels at 298 K and 101.3 kPa

Substance	Formula	State	ΔH_c (kJ mol^{-1})
hydrogen	H_2	g	–286
carbon (graphite)	C	s	–394
methane	CH_4	g	–889
ethane	C_2H_6	g	–1557
propane	C_3H_8	g	–2217
butane	C_4H_{10}	g	–2874
pentane	C_5H_{12}	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