VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2008

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures

Words

Letter

CHEMISTRY

Written examination 1

Thursday 12 June 2008

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	8	8	58
			Total 78

- 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 26 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.

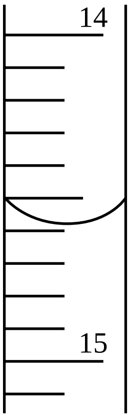
A correct answer scores 1, an incorrect answer scores 0.

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 diagram below shows a section of a 50.00 mL burette containing a colourless solution.



The reading indicated on the burette is closest to

A. 14.50

B. 14.58

C. 15.42

D. 15.50

Question 2

Serotonin ($C_{10}H_{12}N_2O$; molar mass = 176 g mol^{-1}) is a compound that conducts nerve impulses in the brain and muscles. A sample of spinal fluid from a volunteer in a study was found to contain a serotonin concentration of 1.5 ng L^{-1} (1.5 nanograms per litre).

How many molecules of serotonin are there in one millilitre of the spinal fluid?

A. 5.13×10^{9}

B. 9.03×10^{11}

C. 5.13×10^{27}

D. 9.03×10^{29}

Question 3

Xylose is a compound that has five carbon atoms in each molecule and contains 40% carbon by mass.

What is the molar mass of xylose?

A. 30

B. 67

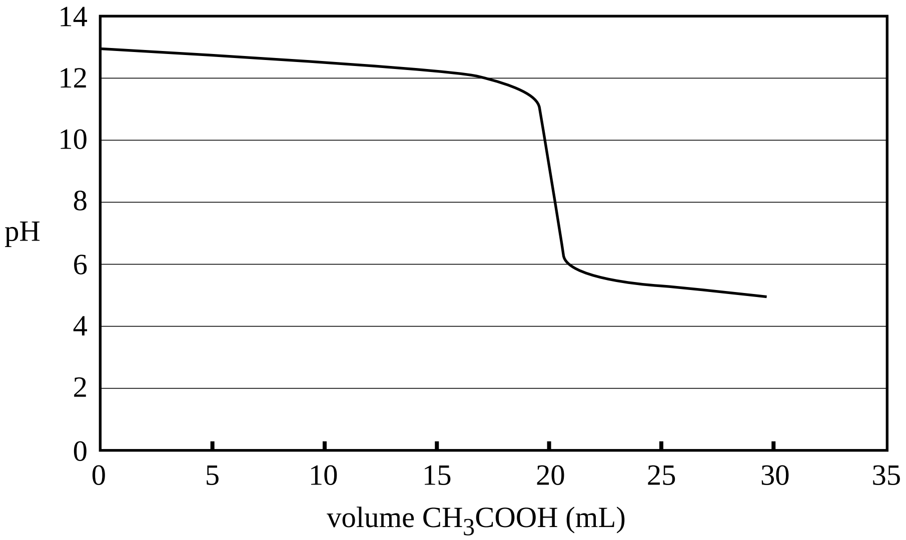
C. 150

D. It cannot be determined without further information.

Question 4

The graph below shows the change in pH of a reaction solution during a titration of 0.10 M NaOH with 0.10 M CH_3COOH.

Titration of 20.00 mL 0.10 M NaOH with 0.10 M CH_3COOH



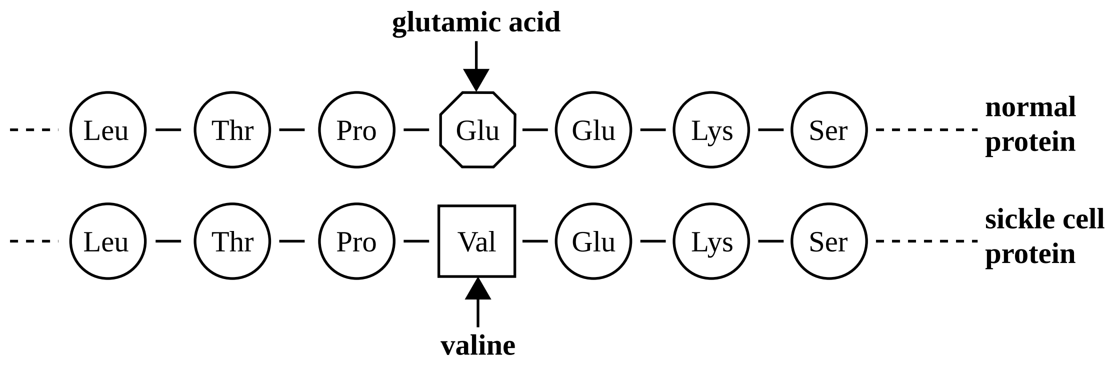
A suitable indicator for the titration and the colour change observed is

	indicator	**colour change observed**
A.	methyl red	yellow to red
B.	methyl red	red to yellow
C.	phenolphthalein	colourless to red
D.	phenolphthalein	red to colourless

Question 5

The disease *sickle cell anaemia* is marked by the presence of an abnormal protein in the blood of people with this disease. The sixth position in the normal protein chain is occupied by the amino acid, glutamic acid. The sickle cell protein chain has the amino acid, valine, in the sixth position. This is the only difference between the two protein chains.

A section of each protein chain containing glutamic acid and valine is shown below.



It is possible to determine the molecular mass of these proteins in a mass spectrometer. It is also possible to record their ^{1}H NMR spectra.

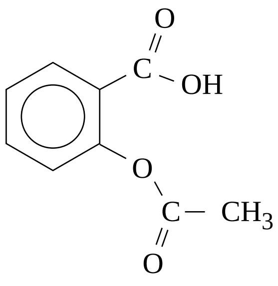
Which one of the following alternatives is correct?

	molecular mass	**^{1}H NMR spectrum**
A.	Sickle cell protein chain has the greater molecular mass.	Both protein chains have the same ^{1}H NMR spectrum.
B.	Sickle cell protein chain has the greater molecular mass.	The protein chains have different ^{1}H NMR spectra.
C.	Normal protein chain has the greater molecular mass.	Both protein chains have the same ^{1}H NMR spectrum.
D.	Normal protein chain has the greater molecular mass.	The protein chains have different ^{1}H NMR spectra.

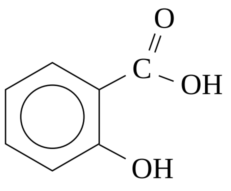
Question 6

Aspirin is a compound widely used as a painkiller and to relieve the symptoms of fever. It can be produced by means of a reaction in which salicylic acid is one of the reagents.

The structures of aspirin and salicylic acid are shown below.



aspirin



salicylic acid

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

A. Aspirin may be prepared by reaction between salicylic acid and CH_3OH.

B. Aspirin contains both an ester and a carboxylic acid functional group.

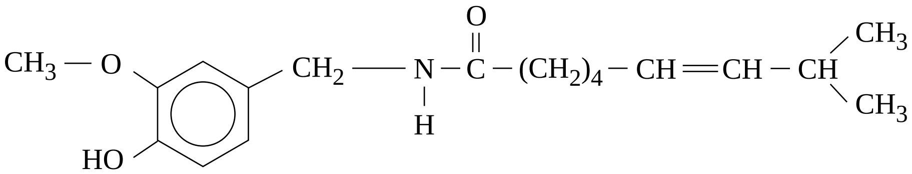
C. Aspirin can undergo an acid-base reaction with $NaHCO_3$.

D. Aspirin may be prepared by reaction between salicylic acid and CH_3COOH.

Question 7

Capsaicin is an important component of some pain relief ointments. It is also the major compound responsible for the burning sensation of chilli peppers.

A structure for capsaicin is given below.



A molecule of capsaicin contains

A. an ester functional group and an amide functional group.

B. an ester functional group and an alcohol functional group.

C. an alkene functional group and an amide functional group.

D. a carboxylic acid functional group and an alcohol functional group.

Question 8

A biomolecule is chemically analysed and found to contain only the elements carbon, hydrogen, oxygen, nitrogen and phosphorus.

The biomolecule is most likely to be

A. DNA.

B. a protein.

C. a polysaccharide.

D. a fat formed by condensation of glycerol with stearic acid.

Question 9

A piece of double-stranded DNA, which is 200 **base pairs** in length, contains 50 thymine bases.

The number of guanine bases in the piece of DNA is

A. 50

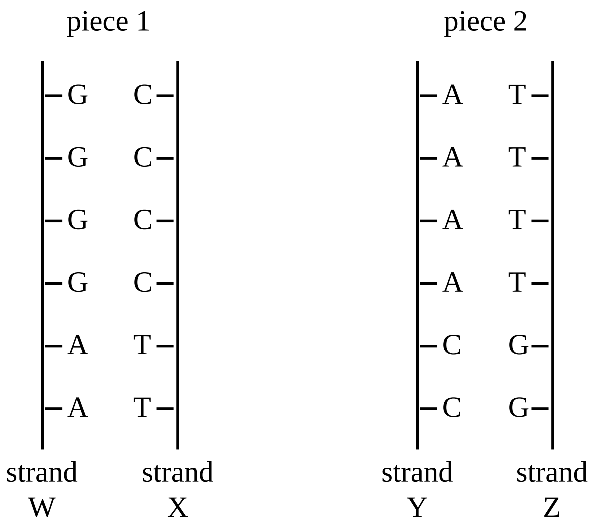
B. 100

C. 125

D. 150

Question 10

In the pieces of double-stranded DNA shown below, the letters A, C, G and T represent the bases adenine, cytosine, guanine and thymine respectively. Each vertical line represents a sugar-phosphate backbone.

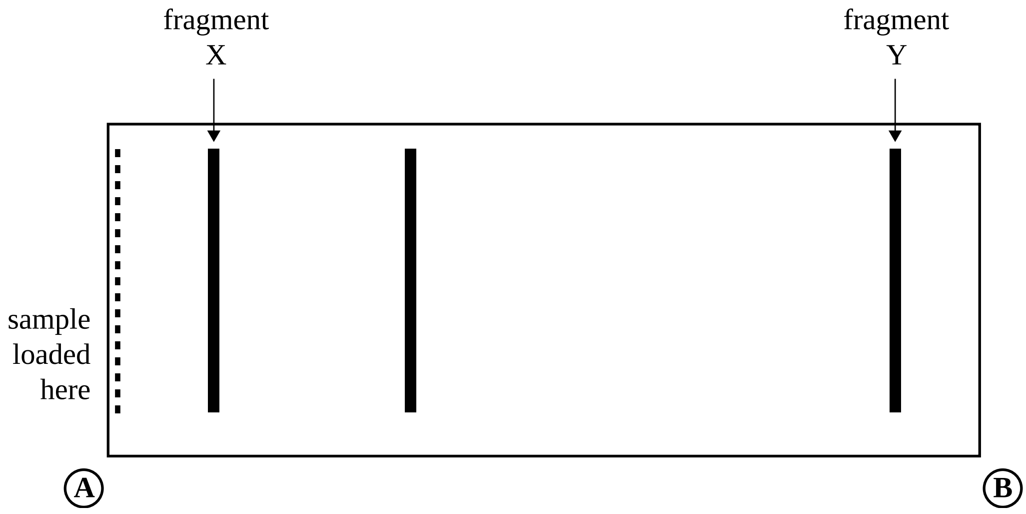


Which one of the following alternatives correctly identifies the DNA piece that is most readily separated by heating and the strand of highest molecular mass?

	piece most readily separated by heating	**strand of highest molecular mass**
A.	1	X
B.	2	W
C.	2	X
D.	1	W

Question 11

Gel electrophoresis is a technique that can be used to separate DNA fragments in forensic chemistry. The gel resulting from such a separation experiment carried out at pH 7 is shown below.



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

A. Fragment X has a higher molecular mass than fragment Y.

B. Fragment Y moves through the gel at a faster rate than fragment X.

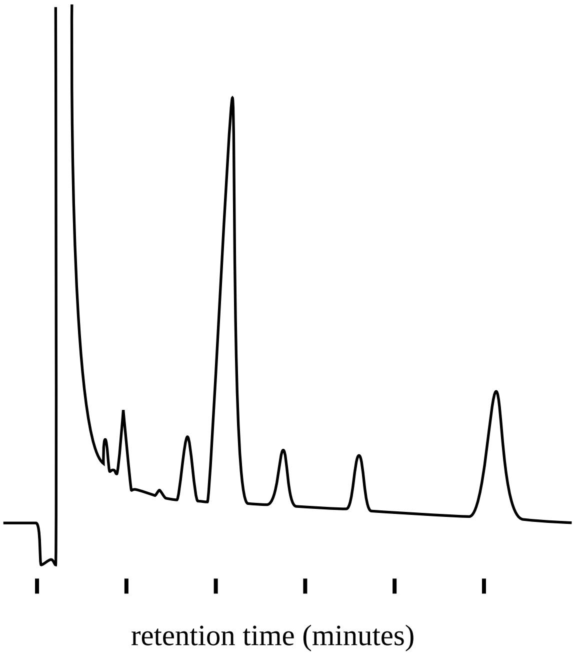
C. The negative terminal of the power supply is connected to end A of the gel.

D. Under the conditions of this experiment, the DNA fragments are positively charged.

Questions 12 and 13 refer to the following information.

Deadly diseases such as tetanus, botulism and gangrene are caused by related groups of bacteria (*clostridium* genus) found in the soil. Each group of bacteria produces specific volatile fatty acids. These fatty acids can be identified using gas chromatography by comparison with a control chromatogram of known standards.

The following gas chromatogram is of the fatty acids produced by one such group of bacteria.



Question 12

The identity of the fatty acids can be determined by measuring

A. their retention times.

B. the temperature of the column.

C. the flow rate of the carrier gas.

D. the area under each of the peaks.

Question 13

The relative amount of each of the fatty acids can be determined by measuring

A. their retention times.

B. the temperature of the column.

C. the flow rate of the carrier gas.

D. the area under each of the peaks.

Question 14

Pyrethrins belong to a naturally occurring group of insecticides produced by the chrysanthemum daisy. The formula of one such compound, pyrethrin I, is $C_{21}H_{28}O_3$.

The analytical technique that would **not** provide information that is useful in determining the structure of pyrethrin I is

A. mass spectroscopy.

B. infrared spectroscopy.

C. atomic absorption spectroscopy.

D. nuclear magnetic resonance spectroscopy.

Question 15

A sample of a hydrocarbon for analysis is placed in a strong magnetic field and irradiated with electromagnetic radiation of radio wave frequency.

This is most likely to result in

A. ionisation and fragmentation of molecules.

B. an increase in bond vibrations of molecules.

C. the promotion of electrons to higher energy levels.

D. a change in the energy of the nuclei of the hydrogen atoms.

Question 16

How many structural isomers, each containing a double bond, have the molecular formula C_5H_{10}?

A. 3

B. 4

C. 5

D. 6

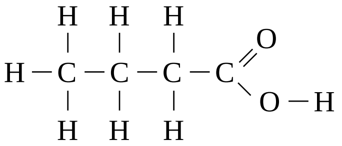
Question 17

A student was given the task of identifying a liquid organic compound that contains only carbon, hydrogen and oxygen. The following tests were carried out

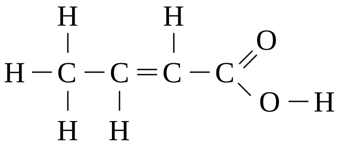
	Procedure	**Result**
Test 1	Some brown $Br_2(aq)$ was added to a sample of the compound.	A reaction occurred and a colourless product formed.
Test 2	Some $Na_2CO_3(s)$ was added to a sample of the compound.	A reaction occurred and a colourless gas was evolved.

Based on the above test results, the compound could be

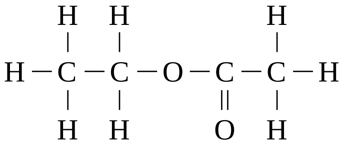
A.



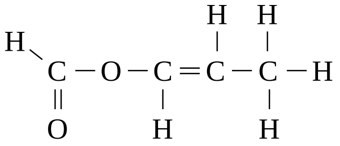
B.



C.



D.



Question 18

Starch consists mainly of amylose, which is a polymer made from glucose, $C_6H_{12}O_6$. A particular form of amylose has a molar mass 3.62×10^5 g mol^{-1}.

A molecule of this amylose can be described as

A. an addition polymer of 2235 glucose molecules.

B. an addition polymer of 2011 glucose molecules.

C. a condensation polymer of 2235 glucose molecules.

D. a condensation polymer of 2011 glucose molecules.

Question 19

When molecular iodine, I_2, reacts with an unsaturated compound, one molecule of iodine adds across each double bond. Unsaturated fatty acids react in this way with iodine.

0.150 mol of a particular fatty acid reacts with exactly 0.300 mol of I_2.

The fatty acid could be

A. lauric.

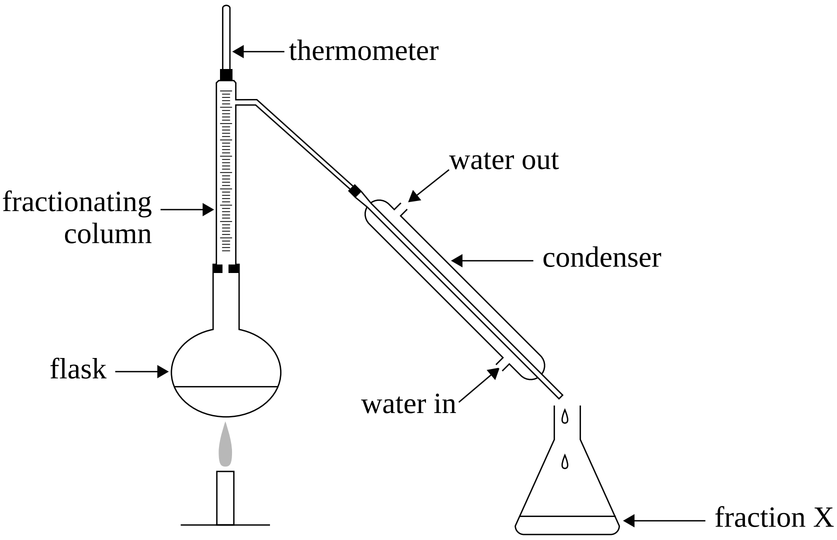
B. linoleic.

C. palmitoleic.

D. arachidonic.

Question 20

In a laboratory experiment, a mixture of alkanes was separated into components by fractional distillation using the following apparatus.



The first fraction collected is fraction X, then fraction Y then fraction Z.

From this information we can deduce that

A. fraction Y is more volatile than Z.

B. fraction Y has a higher molar mass than Z.

C. fraction X has a higher boiling point than Y and Z.

D. fraction Z has stronger covalent bonds in its molecules than X and Y.

END OF SECTION A

SECTION B – Short answer questions

Instructions for Section B

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

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; $NaCl(s)$

Question 1

The percentage purity of powdered, impure magnesium sulfate, $MgSO_4$, can be determined by gravimetric analysis. Shown below is the method used in one such analysis.

Method

- 32.50 g of the impure magnesium sulfate is dissolved in water and the solution is made up to 500.0 mL in a volumetric flask.
- Different volumes of 0.100 M $BaCl_2(aq)$ are added to six separate 20.00 mL samples of this solution. This precipitates the sulfate ions as barium sulfate. The equation for the reaction is

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

- The precipitate from each sample is filtered, rinsed with de-ionised water and then dried to constant mass.

The results of this analysis are shown on the next page.

Results

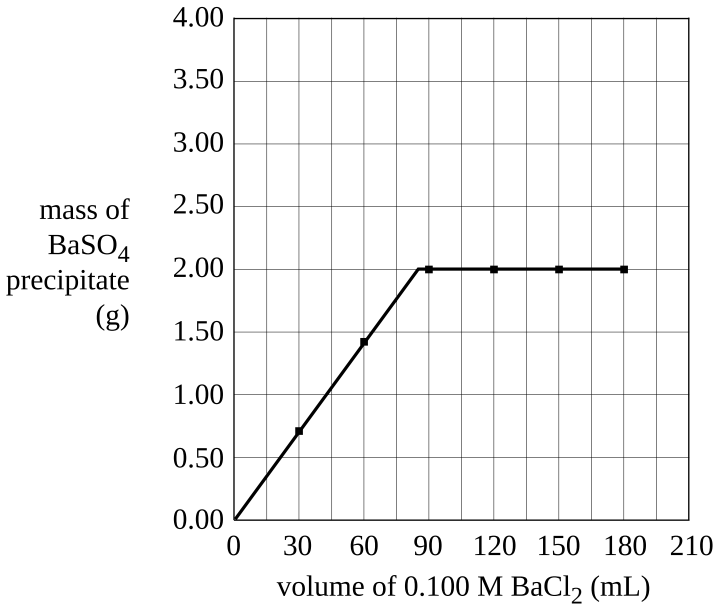
Mass of impure magnesium sulfate = 32.50 g

Volume of volumetric flask = 500.0 mL

Volume of magnesium sulfate solution in each sample = 20.00 mL

Sample	**1**	**2**	**3**	**4**	**5**	**6**
volume of $BaCl_2$(aq) added (mL)	30.0	60.0	90.0	120	150	180
mass of $BaSO_4$(s) precipitated (g)	0.704	1.41	2.00	2.00	2.00	2.00

These results are shown on the graph below.



a. Why is it necessary to rinse the precipitate with de-ionised water before drying?

1 mark

b. Explain why the amount of $BaSO_4$(s) precipitated remains constant for the last four samples tested even though more $BaCl_2$(aq) is being added.

1 mark

c. Calculate

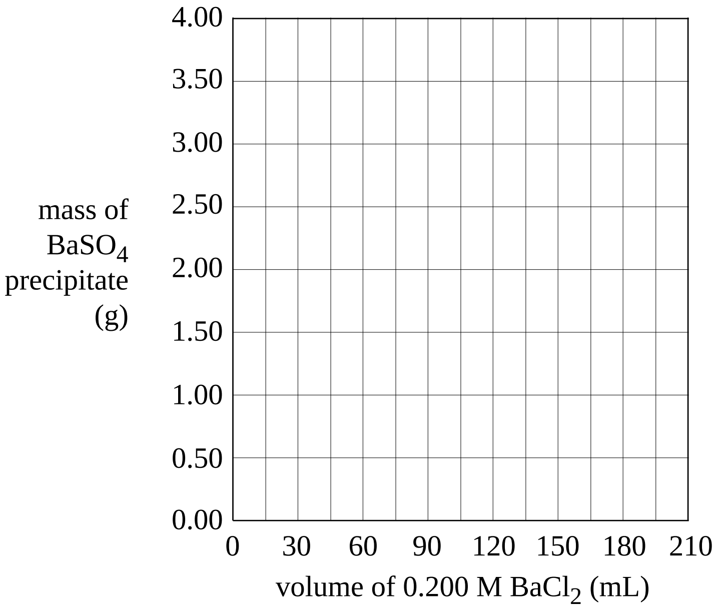
i. the amount, in mole, of $SO_4^{2-}(aq)$ in the 500.0 mL volumetric flask.

ii. the percentage, by mass, of magnesium sulfate in the powder.

2 + 2 = 4 marks

Six further 20.00 mL samples of the magnesium sulfate solution are analysed. However, the concentration of the barium chloride added to those six samples is 0.200 M and not 0.100 M.

d. On the axes below, draw the graph you would expect to obtain when plotting the mass of $BaSO_4(s)$ precipitate against volume of 0.200 M $BaCl_2(aq)$ used.



2 marks

Total 8 marks

Question 2

One method of analysing the manganese content of steel is to dissolve the steel in nitric acid; producing a solution of manganese(II) ions, $Mn^{2+}(aq)$.

The $Mn^{2+}(aq)$ ions are then treated with an excess of acidified solution of periodate ions, $IO_4^-(aq)$. The products of this reaction are iodate ions, $IO_3^-(aq)$, and the deeply purple-coloured permanganate ions, $MnO_4^-(aq)$.

The concentration of $MnO_4^-(aq)$ is then determined by UV-visible spectroscopy.

a. **i.** Calculate the oxidation number of iodine in the $IO_4^-(aq)$ ion.

ii. Give a half equation for the conversion of $IO_4^-(aq)$ into $IO_3^-(aq)$ in acid solution.

iii. Is the $IO_4^-(aq)$ ion acting as an oxidant or reductant? Explain your choice.

1 + 1 + 1 = 3 marks

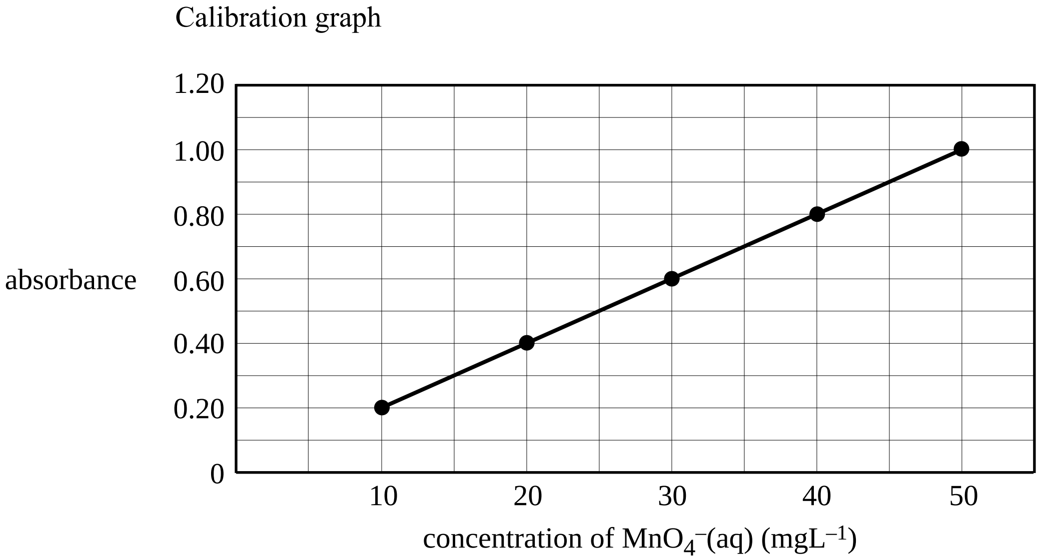
An experiment was carried out to determine the percentage of manganese in a particular sample of steel by the above method.

A 13.936 g sample of steel was dissolved in acid and the manganese was converted to $MnO_4^-(aq)$ ions.

The solution containing the $MnO_4^-(aq)$ ions was filtered and made up to a volume of 1.00 L.

25.00 mL of this solution was then further diluted to 100.0 mL in a volumetric flask. The absorbance, at 525 nm, of this solution was 0.70.

Next, the absorbance, at 525 nm, of a series of solutions of $MnO_4^-(aq)$ ions of known concentration was measured and a calibration graph drawn.



b. **i.** What is the concentration, in mg L^{-1}, of $MnO_4^-(aq)$ in the diluted solution in the 100 mL volumetric flask?

ii. Calculate the mass, in mg, of **manganese** in the steel sample.

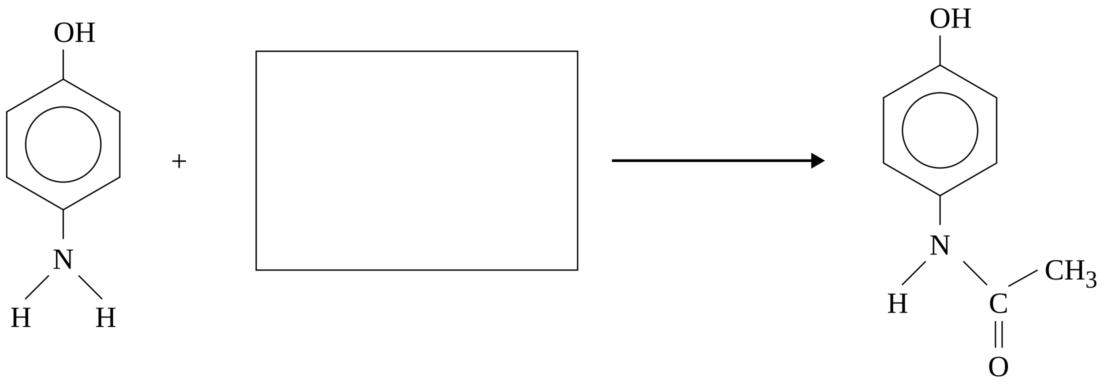
iii. Calculate the percentage, by mass, of **manganese** in the steel sample.

1 + 2 + 1 = 4 marks

Total 7 marks

Question 3

Paracetamol is a commonly used painkiller. The equation below shows one method of preparing paracetamol.



4-aminophenol

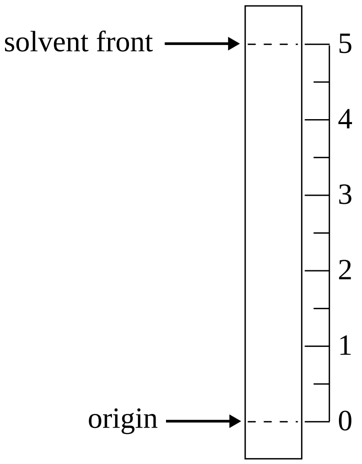
paracetamol

a. In the box provided in the equation above, give the formula of a possible reagent that can be used in this synthesis.

1 mark

b. A student uses thin layer chromatography (TLC) to analyse the products of this preparation of paracetamol. For the stationary and mobile phases used for this analysis, the R_f of paracetamol is 0.4.

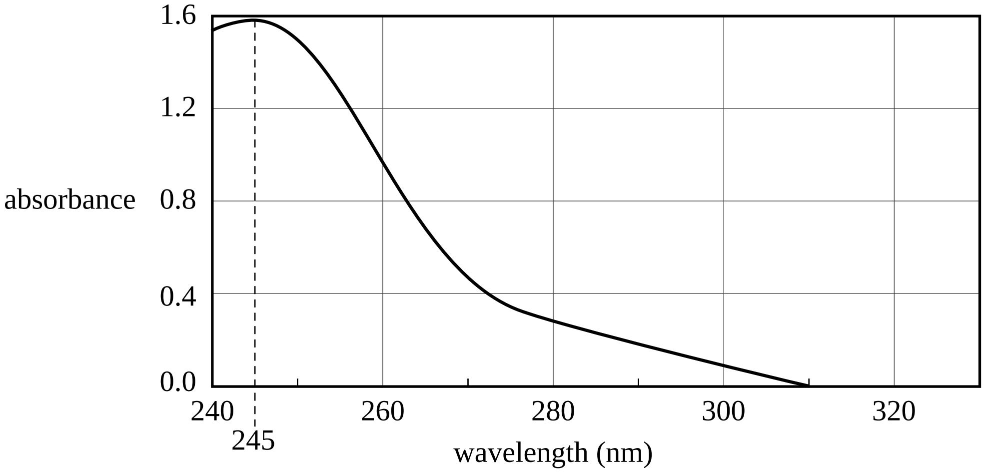
i. On the diagram of a TLC plate below, use a horizontal line to mark the spot where paracetamol would appear in such an analysis.



ii. 4-aminophenol adsorbs less strongly than paracetamol onto the stationary phase of this TLC plate. Predict whether the R_f value of 4-aminophenol in this analysis is greater or smaller than that of paracetamol, giving a reason for your choice.

1 + 1 = 2 marks

The UV-visible absorption spectrum of a solution of paracetamol is shown below. The concentration of paracetamol in the solution is 15.1 μg mL^{-1}.



The absorbance of another solution of paracetamol is measured under the same conditions and, at 245 nm, the absorbance is 0.96.

c. What is the concentration, in μg mL^{-1}, of the paracetamol in this other solution?

1 mark

Total 4 marks

Question 4

A mixture contains several different organic liquids all of which boil at temperatures greater than 50°C.

The compounds present in the mixture are separated. Three of the compounds, compounds X, Y and Z, are analysed as follows.

Compound X is vaporised. At a temperature of 120°C and a pressure of 115 kPa, a 0.376 g sample of the vapour occupies 124 mL.

a. Calculate the molar mass, in g mol^{-1}, of compound X.

2 marks

Compound Y is an alkanol of molecular formula of $C_4H_{10}O$.

b. **i.** In the boxes below, draw the structural formulas, showing **all** bonds, of the four possible alkanols with a molecular formula of $C_4H_{10}O$.

Alkanol I	Alkanol II
Alkanol III	Alkanol IV

Compound Y shows 3 lines in the ^{13}C NMR spectrum and undergoes reaction with $Cr_2O_7^{2-}(aq)$ in acid to produce a carboxylic acid.

ii. What evidence about the structure of Y can be gained from this information?

Evidence from ^{13}C NMR spectrum

Evidence from reaction with $Cr_2O_7^{2-}(aq)$ in acid solution

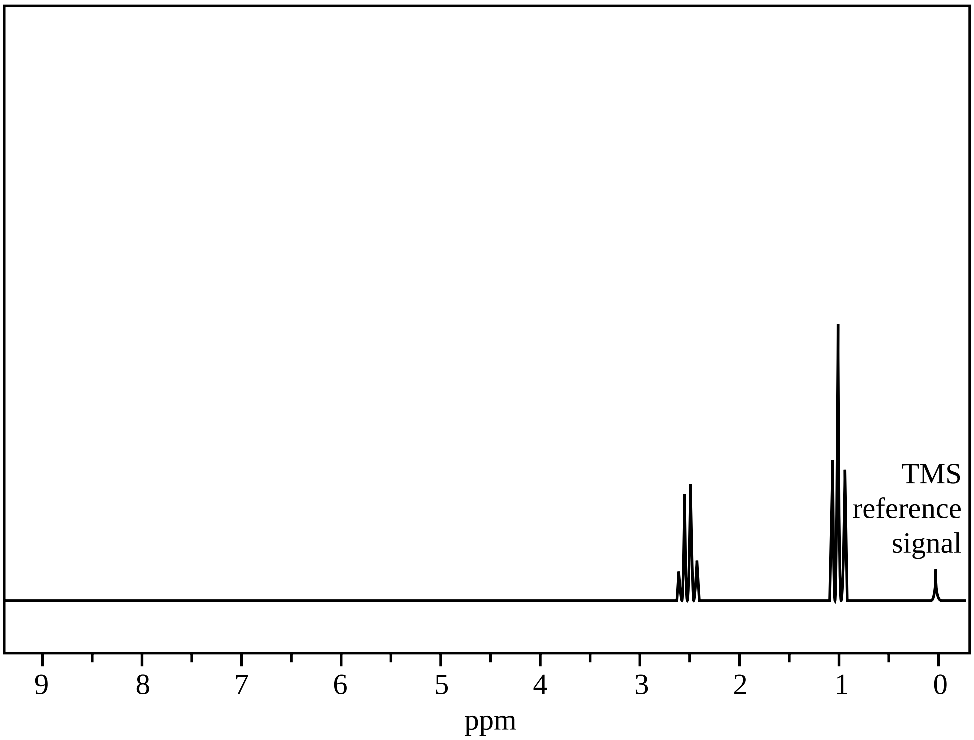
iii. Based on the above evidence, identify compound Y by

- circling the structural formula in **part i.** that corresponds to compound Y
- writing below the systematic name of compound Y.

4 + 2 + 2 = 8 marks

CONTINUED OVER PAGE

Compound Z has the molecular formula $C_5H_{10}O$ and shows a strong band in the infrared spectrum at about 1700 cm^{-1}. The ^1H NMR spectrum of compound Z is given below.



c. **i.** What information about the structure of Z can be deduced from the above spectral data?

From IR data

From ^1H NMR

ii. Draw a structure for compound Z that is consistent with the spectral data.

2 + 1 = 3 marks

Total 13 marks

Question 5

a. **i.** Draw the structure, showing **all** bonds, of the amino acid serine as it would exist in solution at pH 2.

ii. Name the functional group on the side chain of serine.

___

1 + 1 = 2 marks

b. Write the molecular formula of the amino acid phenylalanine.

___

1 mark

Two different dipeptides can form between phenylalanine and serine.

c. **i.** Draw the structure of **one** of these dipeptides.

ii. Circle the peptide (amide) functional group in the dipeptide you have drawn in **part i.** above.

1 + 1 = 2 marks

The tertiary structure of a protein is maintained by interactions between the side chains of amino acid residues. One such interaction is between cysteine residues.

d. In the space below, sketch a covalent link that can form between the side chains of two cysteine residues. Only the relevant atoms that form the link need to be shown.

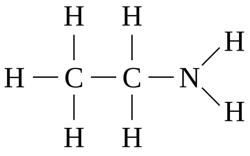
1 mark

Total 6 marks

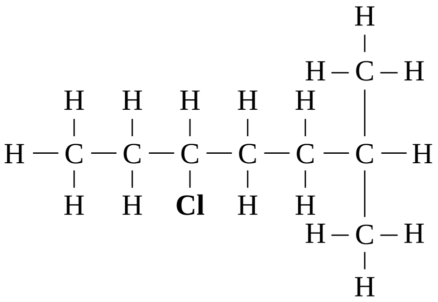
Question 6

a. Give a systematic name for each of the following compounds.

i.



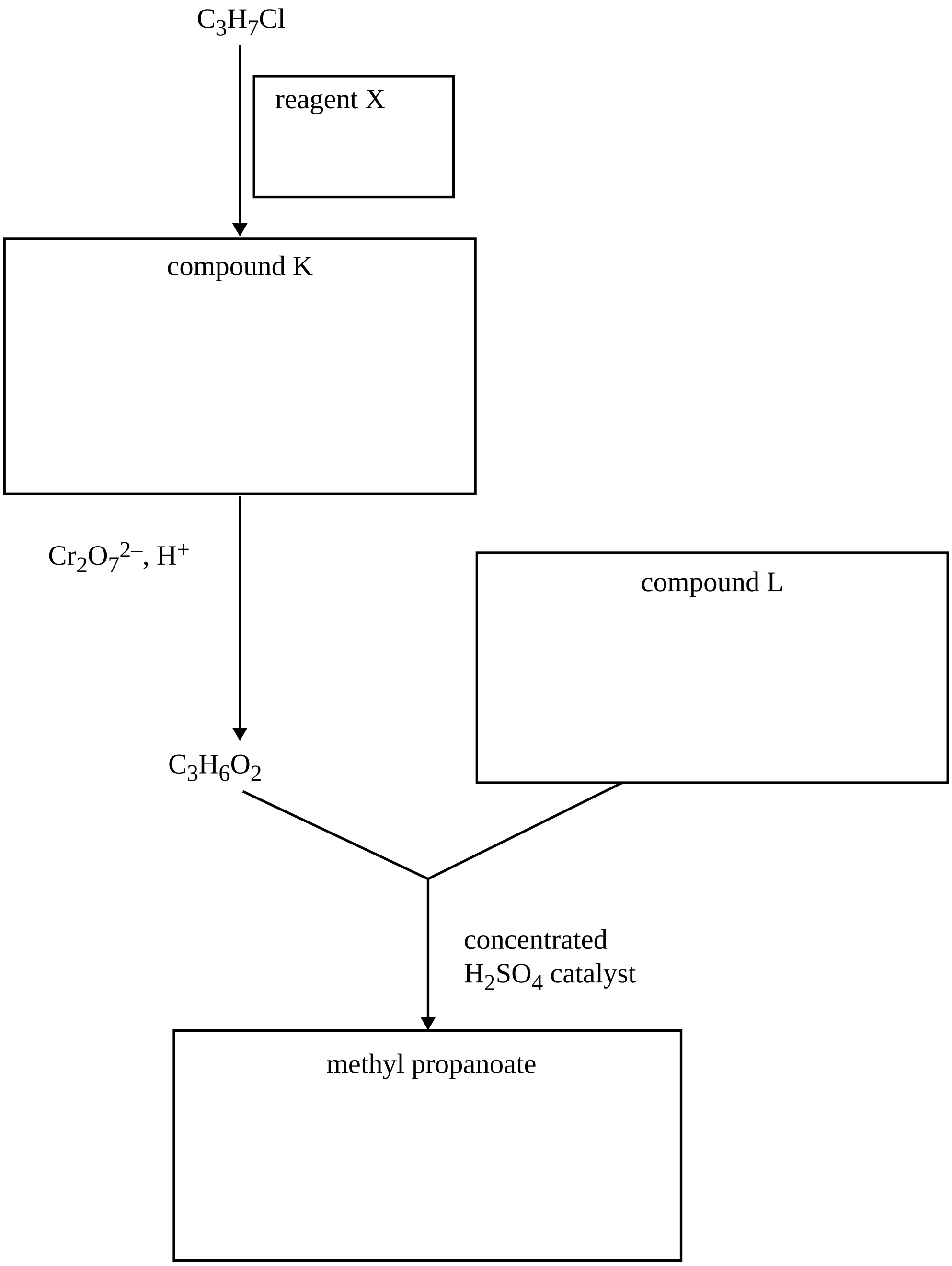
ii.



2 + 2 = 4 marks

The ester methyl propanoate has a characteristic fruity odour and has been isolated from many fruits including pineapple. A sample of this ester is to be prepared in the laboratory.

A partly completed reaction pathway for this preparation is shown below.



b. **i.** In the appropriate box, write a structural formula, showing **all** bonds, for methyl propanoate.

ii. In the appropriate boxes, write structural formulas, showing **all** bonds, for compounds K and L.

iii. In the appropriate box, write the formula of reagent X.

1 + 2 + 1 = 4 marks

Total 8 marks

Question 7

In many countries, ethanol is present in petrol as a renewable fuel additive to reduce dependence on fossil fuels.

a. Write a chemical equation for the combustion of ethanol in excess oxygen.

2 marks

Ethanol is fully miscible with water. It is also fully miscible with petrol (a mixture of hydrocarbons).

b. Give chemical reasons why ethanol can mix with both water and petrol.

2 marks

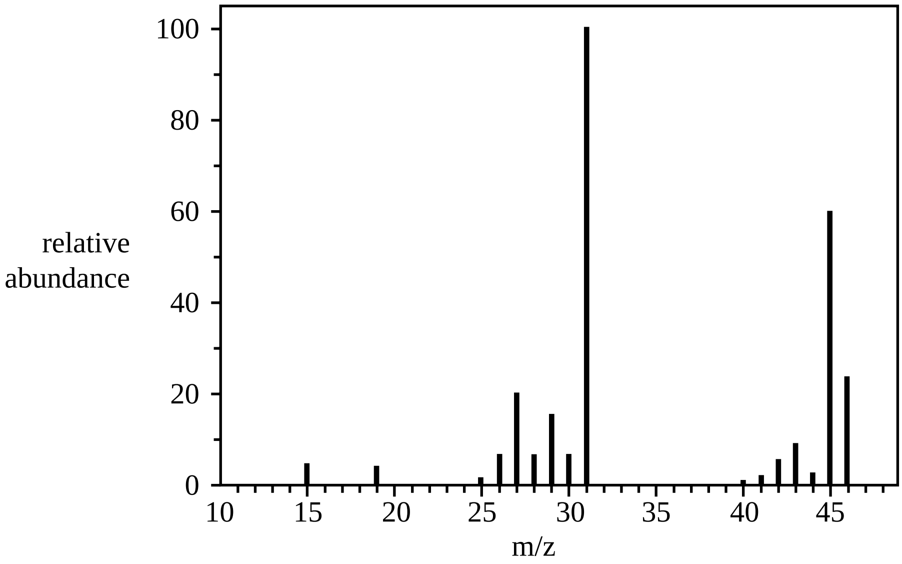
Ethanol can be produced by fermentation of glucose.

c. **i.** Write a chemical equation for the fermentation of glucose to produce ethanol.

ii. Explain why ethanol produced by fermentation is referred to as a 'biochemical fuel'.

1 + 1 = 2 marks

The mass spectrum of ethanol is given below.



d. What fragment must have been lost from the molecular ion to account for the high peak at m/z 45?

1 mark

Total 7 marks

Question 8

0.415 g of a pure acid, $H_2X(s)$, is added to exactly 100 mL of 0.105 M NaOH(aq).

A reaction occurs according to the equation

$$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$$

The NaOH is in excess. This excess NaOH requires 25.21 mL of 0.197 M HCl(aq) for neutralisation.

Calculate

i. the amount, in mol, of NaOH that is added to the acid H_2X initially.

ii. the amount, in mol, of NaOH that reacts with the acid H_2X.

iii. the molar mass, in g mol^{-1}, of the acid H_2X.

1 + 2 + 2 = 5 marks

Total 5 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2008

CHEMISTRY

Written examination

Thursday 12 June 2008

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 — **79**
relative atomic mass — 197.0
Au — symbol of element
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

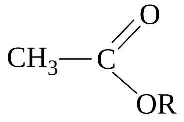
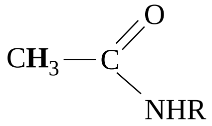
4. SI prefixes, their symbols and values

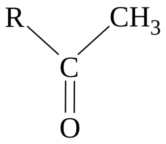
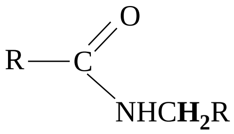
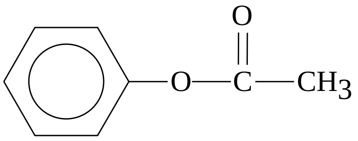
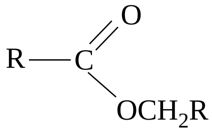
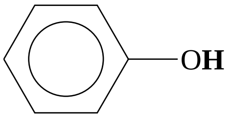
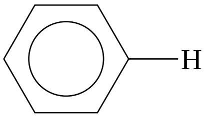
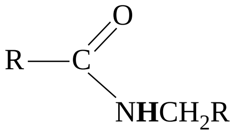
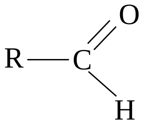
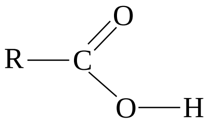
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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
 $CH_3{-}C({=}O){-}OR$ or  $CH_3{-}C({=}O){-}NHR$	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$_2$R	3.3
	2.3
	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
	8.1
	9–10
	11.5

6. ^{13}C NMR data

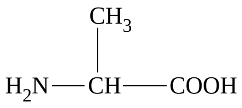
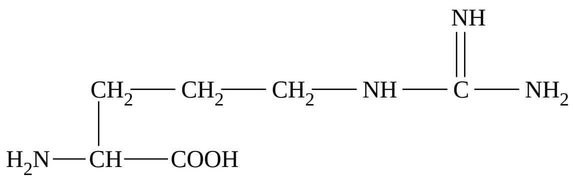
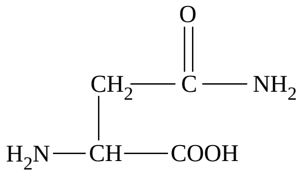
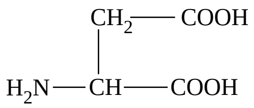
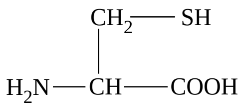
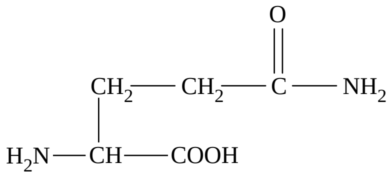
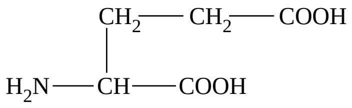
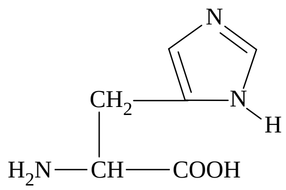
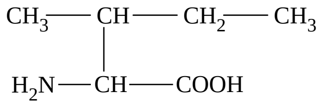
Type of carbon	**Chemical shift (ppm)**
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
$RC{\equiv}CR$	75–95
$R_2C{=}CR_2$	110–150
RCOOH	160–185

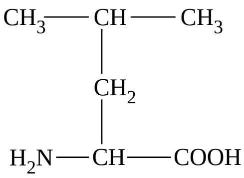
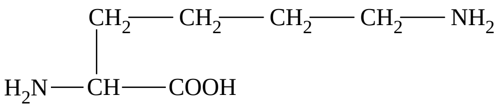
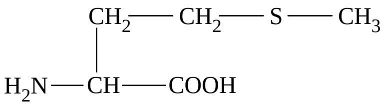
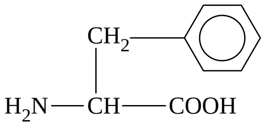
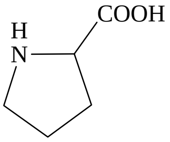
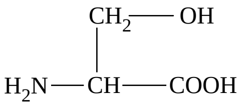
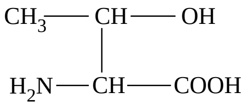
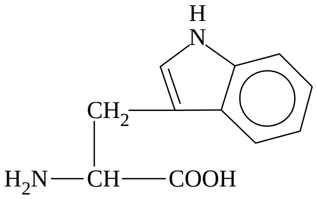
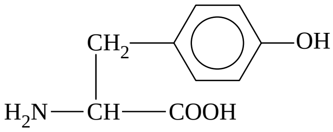
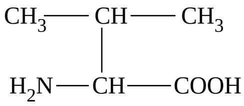
7. Infrared absorption data

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)

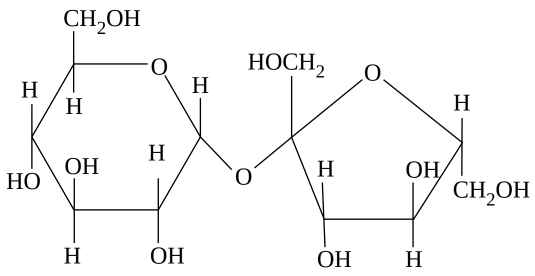
Name	Symbol	Structure
alanine	Ala	 $H_2N-CH(CH_3)-COOH$
arginine	Arg	 $H_2N-CH(CH_2-CH_2-CH_2-NH-C(=NH)-NH_2)-COOH$
asparagine	Asn	 $H_2N-CH(CH_2-C(=O)-NH_2)-COOH$
aspartic acid	Asp	 $H_2N-CH(CH_2-COOH)-COOH$
cysteine	Cys	 $H_2N-CH(CH_2-SH)-COOH$
glutamine	Gln	 $H_2N-CH(CH_2-CH_2-C(=O)-NH_2)-COOH$
glutamic acid	Glu	 $H_2N-CH(CH_2-CH_2-COOH)-COOH$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	 $H_2N-CH(CH(CH_3)-CH_2-CH_3)-COOH$

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

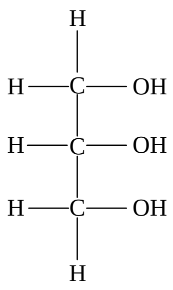
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

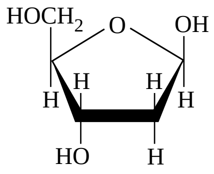
10. Structural formulas of some important biomolecules



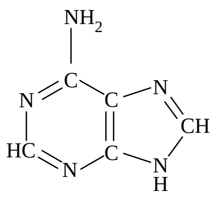
sucrose



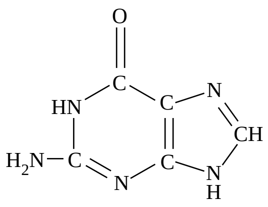
glycerol



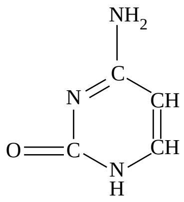
deoxyribose



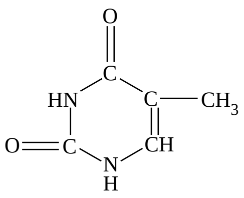
adenine



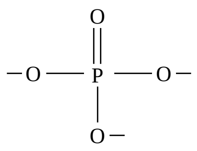
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

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

12. Acidity constants, K_a, of some weak acids

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

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

Substance	**Formula**	**State**	ΔH_c **(kJ mol^{-1})**
hydrogen	H_2	g	–286
carbon(graphite)	C	s	–394
methane	CH_4	g	–889
ethane	C_2H_6	g	–1557
propane	C_3H_8	g	–2217
butane	C_4H_{10}	g	–2874
pentane	C_5H_{12}	1	–3509
hexane	C_6H_{14}	1	–4158
octane	C_8H_{18}	1	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	1	–725
ethanol	C_2H_5OH	1	–1364
1-propanol	$CH_3CH_2CH_2OH$	1	–2016
2-propanol	$CH_3CHOHCH_3$	1	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK