VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2012

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures									Letter
Words									

CHEMISTRY

Written examination 1

Wednesday 13 June 2012

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	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 27 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.

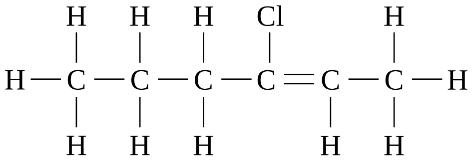
Choose the response that is **correct** or that **best answers** the question.

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 correct systematic name for the compound shown above is

A. 2-chlorohex-2-ene

B. 3-chlorohex-2-ene

C. 3-chlorohex-3-ene

D. 4-chlorohex-5-ene

Question 2

The number of structural isomers of C_4H_9Cl is

A. 2

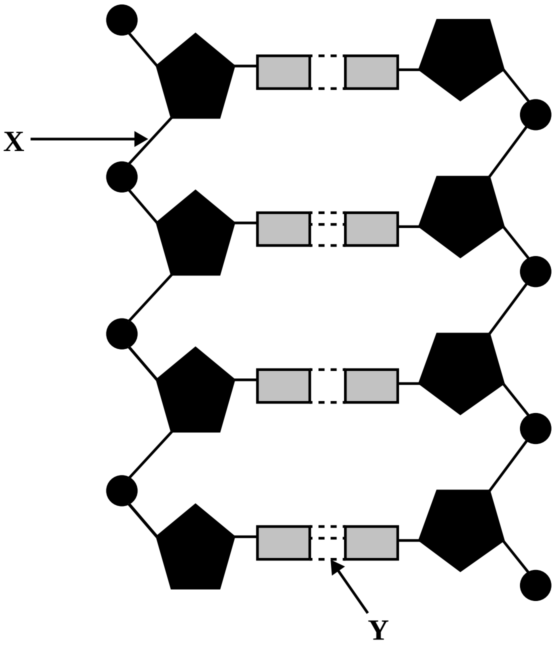
B. 3

C. 4

D. 5

Question 3

The following diagram is a simplified representation of a section of DNA.



The main types of bonds at X and Y are

	X	Y
A.	ionic bonds	hydrogen bonds
B.	covalent bonds	dispersion forces
C.	dispersion forces	ionic bonds
D.	covalent bonds	hydrogen bonds

Question 4

In a double-stranded DNA sample, adenine constitutes 16% of the total number of bases.

The percentage of guanine content in the double strand is

A. 16%

B. 34%

C. 42%

D. 68%

Question 5

Consider the following statements about the structure of proteins.

I The primary structure of a protein is determined by the sequence of amino acid residues.
II The secondary structure of a protein is the result of hydrogen bonding between –NH and –CO groups.
III The tertiary structure of a protein involves bonding between the side chains on the amino acid residues.

Of these statements

A. only I and III are true.
B. only I and II are true.
C. only II and III are true.
D. I, II and III are all true.

Question 6

Which one of the following amino acids is likely to be most polar in an aqueous solution at pH 7?

A. glutamic acid
B. glycine
C. leucine
D. valine

Question 7

Enzymes play an important role in biochemical reactions. Consider the following statements relating to enzyme-catalysed reactions.

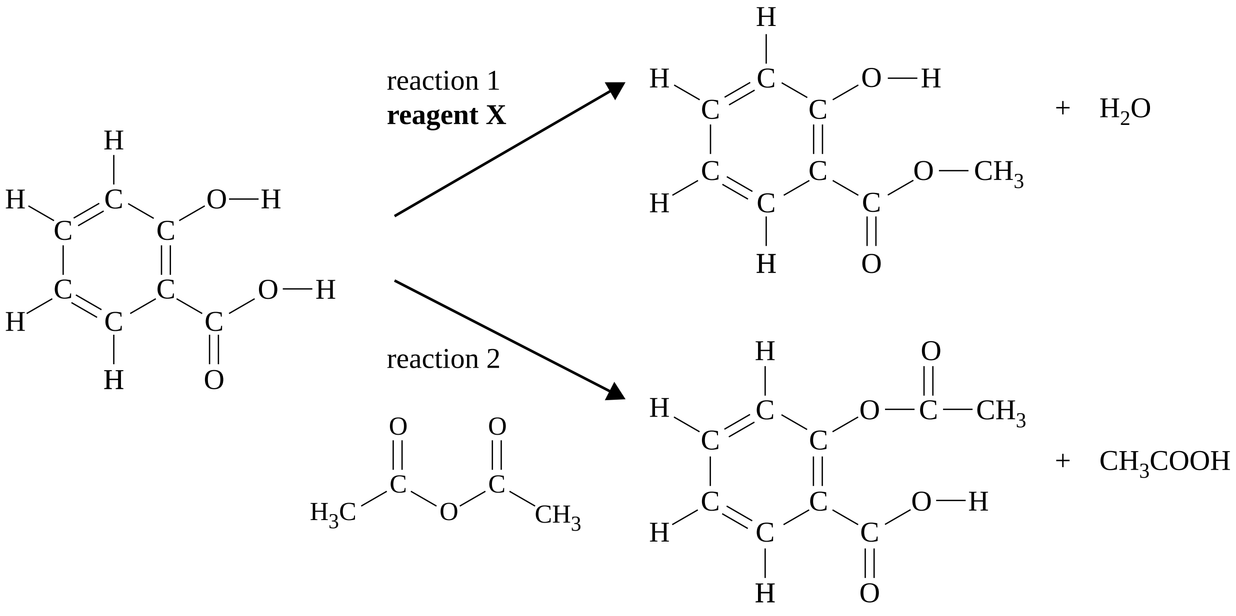
I The shapes of the substrate and the active site of the enzyme are complementary.
II When enzymes are denatured, the shape and structure of the active sites are **not** altered.
III The substrate forms bonds with the active site of the enzyme.

Of these statements

A. only I is true.
B. only III is true.
C. only I and III are true.
D. I, II and III are all true.

Question 8

In the laboratory, salicylic acid can be used to produce two different compounds as shown in the diagram below. These compounds are key components of pharmaceutical products.

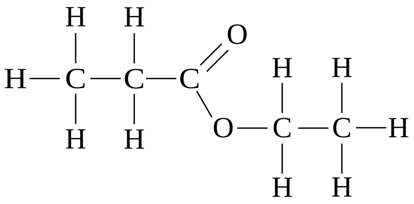


compound Y

Which one of the following correctly identifies reagent X and compound Y?

	reagent X	compound Y
A.	methanol	methyl salicylate
B.	methanoic acid	methyl salicylate
C.	methanoic acid	acetylsalicylic acid (aspirin)
D.	methanol	acetylsalicylic acid (aspirin)

Use the following information to answer Questions 9–11.



Question 9

Which one of the following is the correct systematic name of this compound?

A. ethyl propanoate

B. ethyl ethanoate

C. propyl ethanoate

D. propyl pentanoate

Question 10

The species that produces the molecular ion peak in the mass spectrum of this compound is

A. $[CH_3CH_2COOCH_2CH_3]^+$

B. $[CH_3CH_2COOCH_2CH_3]^{2+}$

C. $[CH_3CH_2COOCH_2CH_3]^-$

D. $CH_3CH_2COOCH_2CH_3$

Question 11

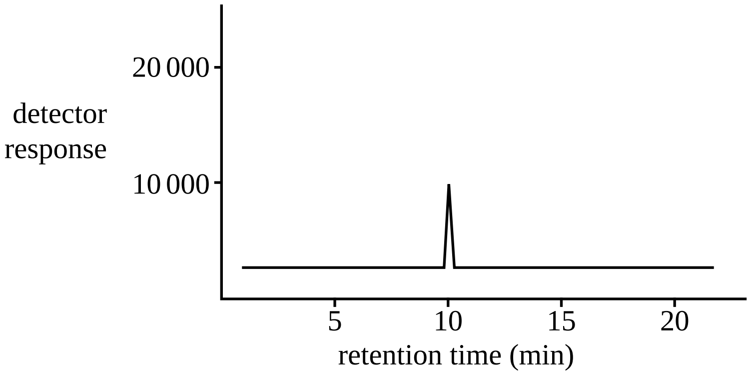
Which one of the following infrared (IR) spectra is consistent with the structure of this compound?

Due to copyright restriction,
this material is not supplied.

Source: Spectral Database for Organic Compounds SDBS

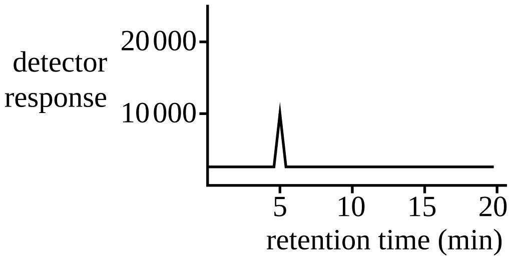
Question 12

The following chromatogram was produced when 0.1 μg of decane was passed through a gas chromatography column.

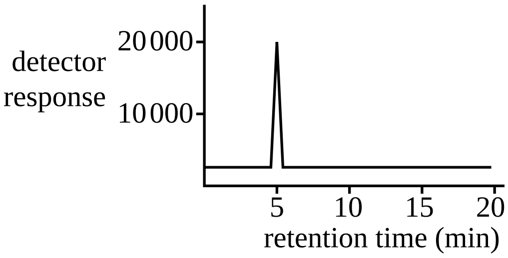


The chromatogram produced when 0.2 μg of decane is passed through the same column under identical conditions is best represented by

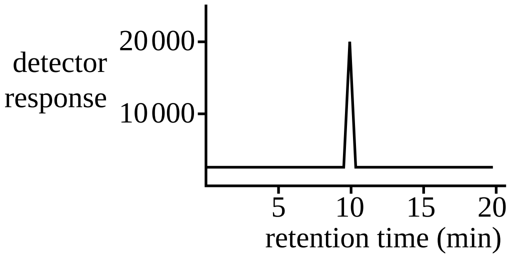
A.



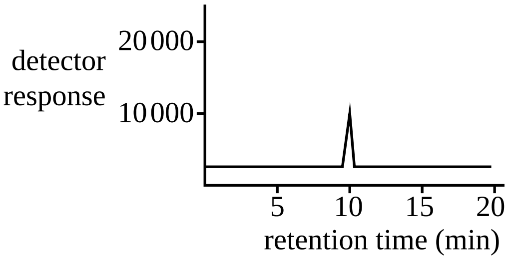
B.



C.



D.



Question 13

15.0 mL of 10.0 M HCl is added to 60.0 mL of deionised water.

The concentration of the diluted acid is

A. 3.33 M

B. 2.50 M

C. 2.00 M

D. 0.500 M

Question 14

A desalination plant produces 200 gigalitres (GL) of fresh water each year. The maximum level of boron permitted in desalinated water is 0.5 ppm (0.5 mg L^{-1}). The maximum mass, in kilograms, of boron that is permitted in one year's production of desalinated water is

A. 9.26×10^{3}

B. 1.0×10^{5}

C. 1.08×10^{6}

D. 1.0×10^{8}

Question 15

A sample of the anticancer drug Taxol®, $C_{47}H_{51}NO_{14}$, contains 0.157 g of carbon.

The mass, in grams, of oxygen in the sample is

A. 0.0468

B. 0.0624

C. 0.209

D. 0.703

Question 16

A helium balloon is inflated to a volume of 5.65 L and a pressure of 10.2 atm at a temperature of 25 °C.

The amount of helium, in moles, in the balloon is

A. 0.023

B. 0.276

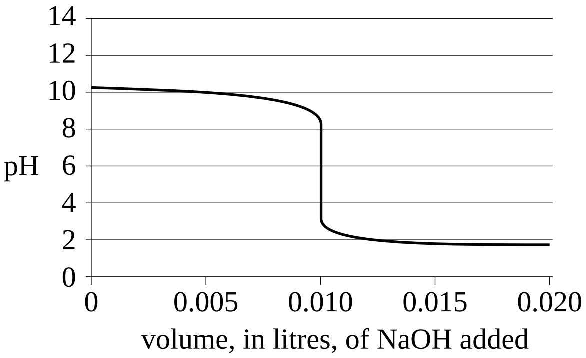
C. 2.36

D. 27.95

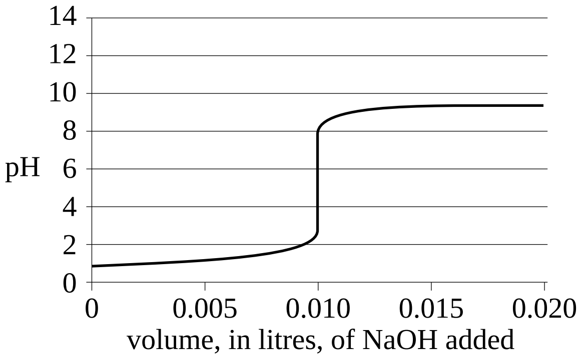
Question 17

Which titration curve best represents the change in pH as 0.100 M NaOH solution is added to a 10.0 mL aliquot of 0.100 M HCl solution?

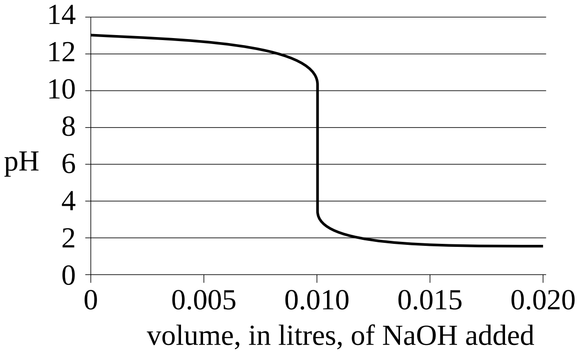
A.



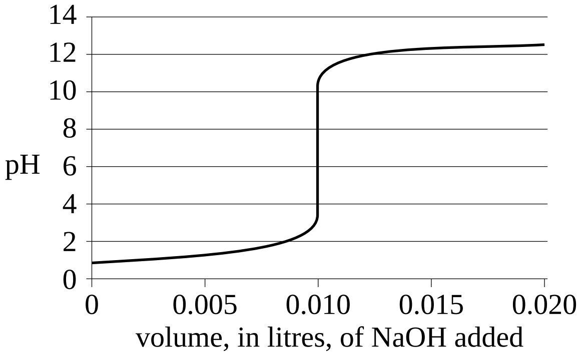
B.



C.



D.



Question 18

2.1 g of an alkene that contains only one double bond per molecule reacted completely with 8.0 g of bromine, Br_2. The molar mass of bromine, Br_2, is 160 g mol^{-1}.

Which one of the following is the molecular formula of the alkene?

A. C_5H_{10}

B. C_4H_8

C. C_3H_6

D. C_2H_4

Question 19

The oxidation state of phosphorus in the pyrophosphate ion $P_2O_7^{4-}$ is

A. +3.5

B. +5

C. +7

D. +10

Question 20

Consider the following reaction.

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(s) + 3H_2O(l)$$

The correct half equation for the reduction reaction is

A. $2I^-(aq) \rightarrow I_2(s) + 2e^-$

B. $2H^+(aq) + 2e^- \rightarrow H_2O(l)$

C. $IO_3^-(aq) + I^-(aq) \rightarrow I_2(s) + 3O^{2-}(aq) + 4e^-$

D. $2IO_3^-(aq) + 12H^+(aq) + 10e^- \rightarrow I_2(s) + 6H_2O(l)$

END OF SECTION A
TURN OVER

SECTION B – Short answer questions

Instructions for Section B

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

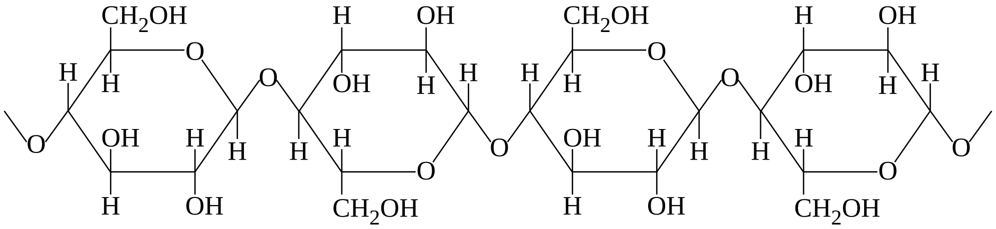
To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No 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

a. The cellulose that is present in plant matter cannot be directly fermented to produce bioethanol. The cellulose polymer must first be broken down into its constituent monomers.

A section of cellulose polymer is shown below.



i. What is the name of the monomer from which cellulose is formed?

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ii. Complete the following chemical equation to show the formation of ethanol by fermentation of the cellulose monomer.

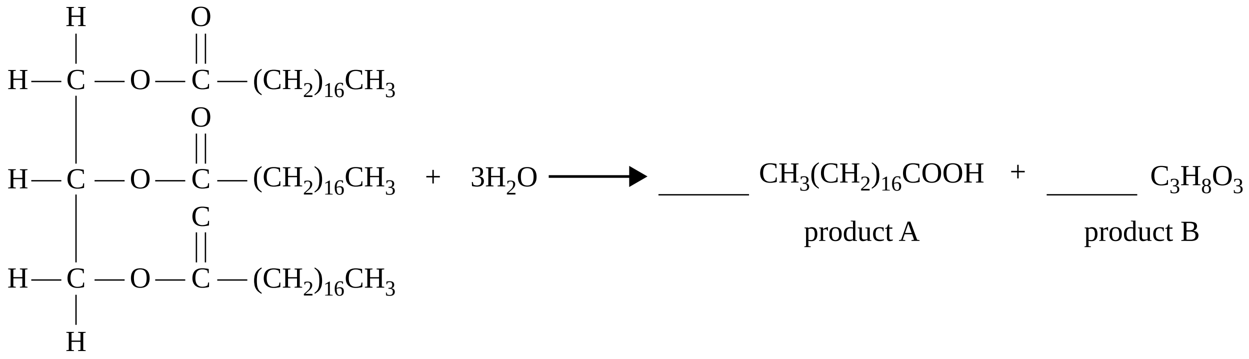
$$C_6H_{12}O_6\ (aq) \longrightarrow \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_$$

iii. Ethanol can be manufactured directly from ethene gas in the presence of a catalyst. Write a balanced equation for this reaction.

---

1 + 1 + 1 = 3 marks

b. Triglycerides are an important source of energy in the body. During digestion, triglycerides are broken down in the small intestine by the enzyme lipase. An incomplete chemical equation that shows the hydrolysis of a triglyceride is shown below.



$$\text{triglyceride} + 3H_2O \longrightarrow \underline{\quad\quad} CH_3(CH_2)_{16}COOH + \underline{\quad\quad} C_3H_8O_3$$

i. In the spaces provided above, balance the equation by adding appropriate coefficients for product A and product B.

ii. Name the fatty acid that is produced by the hydrolysis of this triglyceride.

____

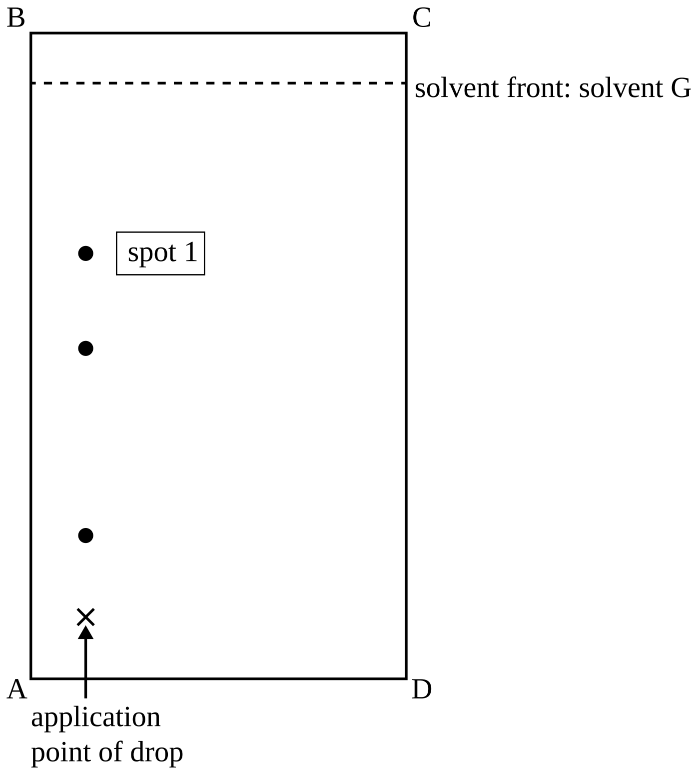
iii. The fatty acid produced in the above reaction is completely oxidised to produce carbon dioxide and water. Write a balanced equation for the oxidation reaction.

____

1 + 1 + 2 = 4 marks

Question 2

A drop that contains a mixture of four amino acids was applied to a thin layer chromatography plate. The plate was placed in solvent G and the following chromatogram was obtained.



chromatogram I

The R_f values for each of the amino acids in solvent G are provided in Table 1 below.

Table 1. R_f values in solvent G

amino acid	**R_f (solvent G)**
alanine	0.51
arginine	0.16
threonine	0.51
tyrosine	0.68

a. Name the amino acid that corresponds to spot 1.

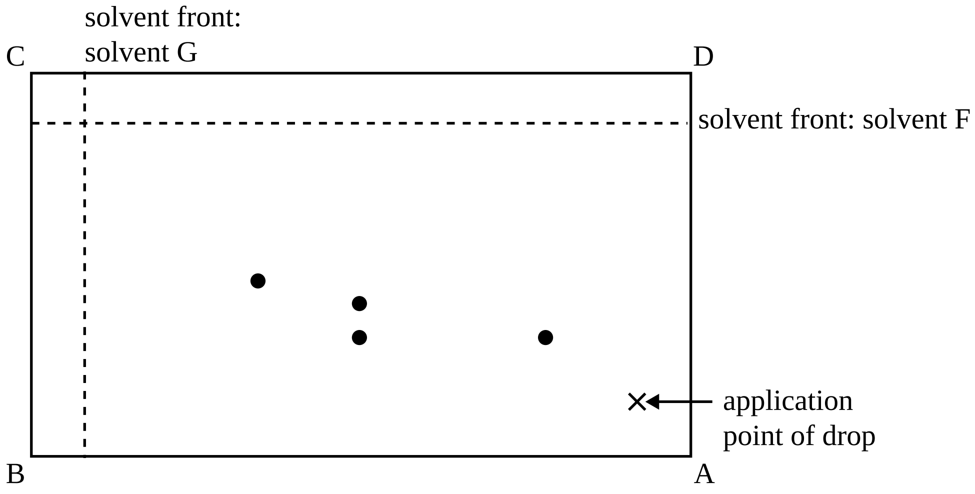
1 mark

The plate was dried, rotated through 90° in an anticlockwise direction and then placed in solvent F. The R_f values for each of the amino acids in solvent F are provided in Table 2 below.

Table 2. R_f values in solvent F

amino acid	R_f (solvent F)
alanine	0.21
arginine	0.21
threonine	0.34
tyrosine	0.43

The following chromatogram was obtained.



chromatogram II

b. Circle the spot on chromatogram II that represents alanine.

1 mark

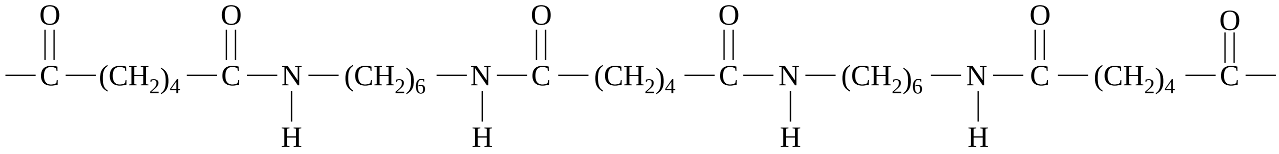
c. Explain, in terms of the data provided, why only three spots are present in chromatogram I while four spots are present in chromatogram II.

2 marks

SECTION B – continued
TURN OVER

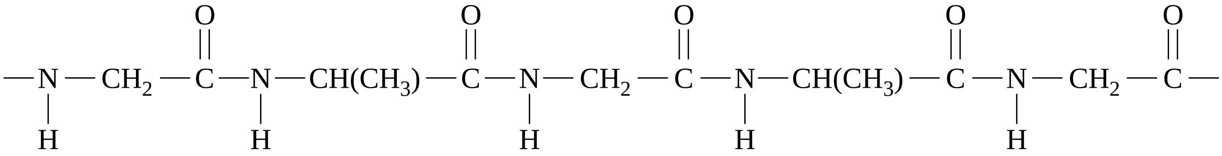
Question 3

Sections of the primary structure of nylon and the primary structure of a protein are shown below.



$$-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-(CH_2)_6-\underset{\underset{H}{|}}{N}-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-(CH_2)_6-\underset{\underset{H}{|}}{N}-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-$$

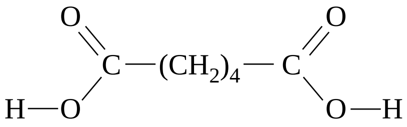
nylon



$$-\underset{\underset{H}{|}}{N}-CH_2-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-CH(CH_3)-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-CH_2-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-CH(CH_3)-\overset{O}{\overset{\|}{C}}-\underset{\underset{H}{|}}{N}-CH_2-\overset{O}{\overset{\|}{C}}-$$

protein

Nylon is composed of two monomers. The structure of one of the monomers is provided below.



a. Draw the structure of the other monomer.

1 mark

b. Name the functional groups that link the monomers in

nylon. ________________________________

protein. ________________________________

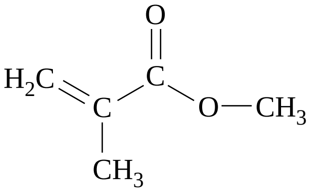
2 marks

c. Look carefully at the functional group that links monomers in protein and nylon. The functional groups that connect the protein monomers are oriented in the same direction. The functional groups that link the nylon monomers are oriented in opposing directions.

Explain why the functional groups that link the monomers in protein are oriented differently from the functional groups that link the monomers in nylon. Make appropriate reference to the structures of nylon and protein monomers in your answer.

2 marks

d. Perspex (polymethyl methacrylate) is a clear, colourless polymer used for optical applications. The structural formula of the only monomer used in the synthesis of perspex, methyl methacrylate, is shown below.



Draw a section of the polymer showing at least two units of the monomer.

2 marks

Question 4

a. Give the systematic names of the alkanol and the carboxylic acid that are required to synthesise propyl propanoate.

2 marks

b. Write a balanced chemical equation for the synthesis of propyl propanoate. Use the semi-structural formula for the reactants and products.

2 marks

c. Describe the steps that are required to prepare a sample of **pure** propyl propanoate using **only** a pure sample of the alkanol as the starting reagent. Include any reagents that are used in the synthesis. An annotated flow chart may be used in your answer.

3 marks

d. Identify one method that could be used to verify that the substance produced is pure propyl propanoate. Explain how this method would indicate that the product is pure propyl propanoate.

2 marks

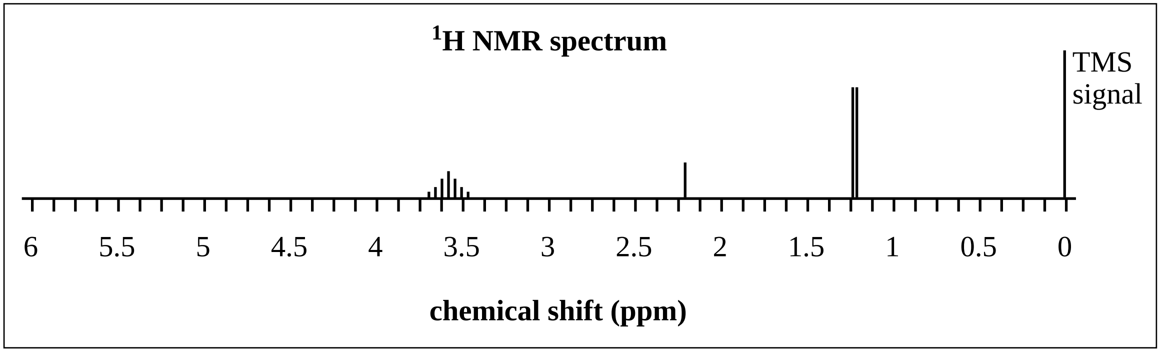
CONTINUES OVER PAGE

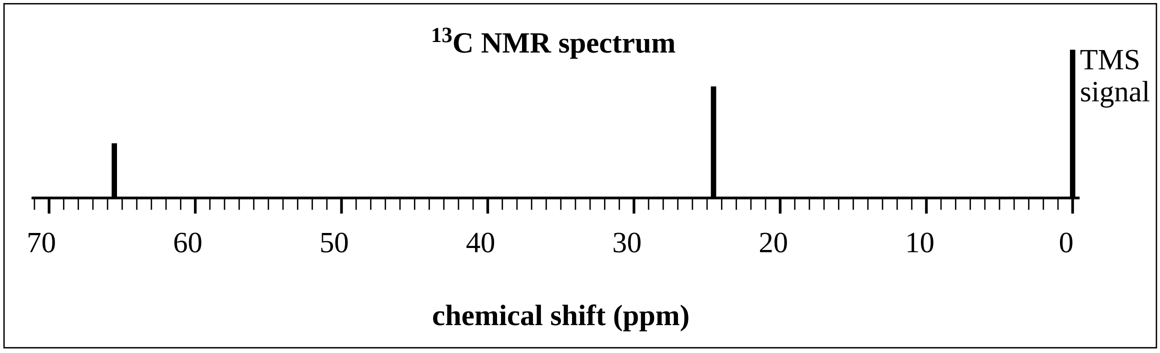
Question 5

An organic chemist found a bottle in the laboratory that was labelled 'organic cleaning fluid, C_3H_8O'. She decided to test the liquid. The chemist obtained the following data about the compound in the cleaning fluid: the ^1H NMR and ^{13}C NMR spectra, and the infrared spectrum.

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

Chemical shift (ppm)	**Relative peak area**	**Peak splitting**
1.2	6	doublet (2)
2.2	1	singlet (1)
3.6	1	septet (7)



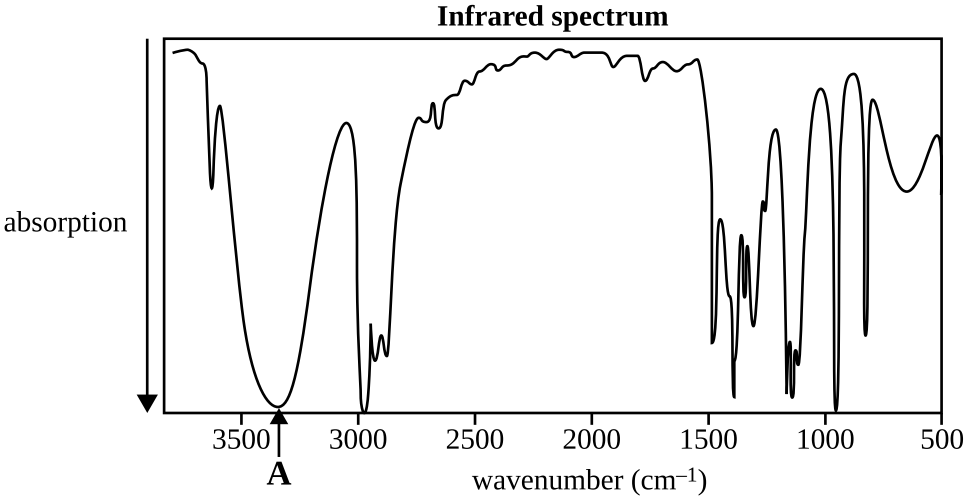


a. **i.** How many different carbon environments are present in the compound?

ii. How many different hydrogen environments are present in the compound?

iii. In the ^1H NMR spectrum, the signal at 3.6 ppm is split into a septet (7 peaks). What is the number of equivalent protons that are bonded to the adjacent carbon atom(s)?

1 + 1 + 1 = 3 marks



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

1 mark

c. Draw a structure of the compound in the cleaning fluid that is consistent with the NMR and IR data.

1 mark

Question 6

The iron content in multivitamin tablets was determined using atomic absorption spectroscopy.

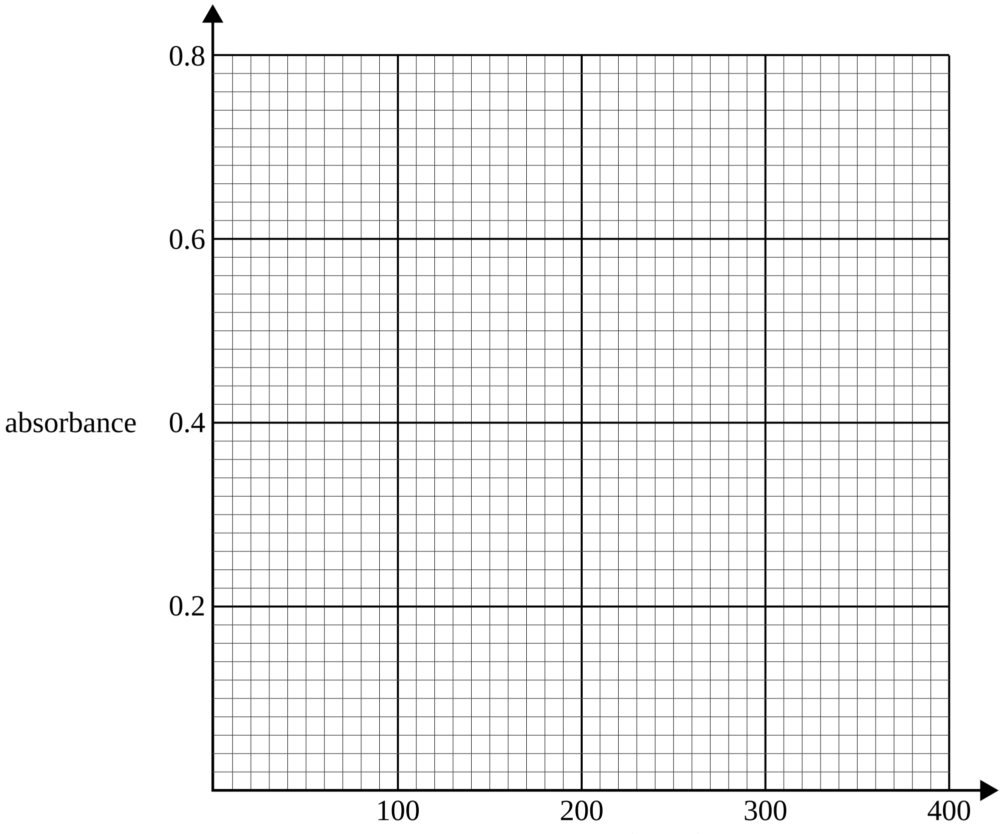
The absorbances of four standards were measured.

Three multivitamin tablets were selected. Each tablet was dissolved in 100.0 mL of water. The absorbance of each of the three solutions was then measured.

The following absorbances were obtained.

Solution	**Concentration mg/L**	**Absorbance**
Standard 1	0.00	0.06
Standard 2	100.0	0.16
Standard 3	200.0	0.25
Standard 4	300.0	0.36
Standard 5	400.0	0.46
Tablet 1	–	0.39
Tablet 2	–	0.42
Tablet 3	–	0.45

a. **i.** Use the grid below to construct a calibration graph of the absorbances of the standard solutions.



ii. Determine the average iron content, in milligrams, of the multivitamin tablets.

2 + 2 = 4 marks

Spectroscopic techniques work on the principle that, under certain conditions, atoms, molecules or ions will interact with electromagnetic radiation. The type of interaction depends on the wavelength of the electromagnetic radiation.

b. Name one spectroscopic technique that you have studied this year.

i. Which part of the electromagnetic spectrum does this technique use?

ii. How does this part of the electromagnetic spectrum interact with matter? What information does this spectroscopic technique provide?

1 + 2 = 3 marks

Question 7

Students in a chemistry class were required to design a procedure to determine gravimetrically the concentration of lead(II) ethanoate, $Pb(CH_3COO)_2$, in a sample of hair dye. They were instructed to measure the mass of precipitate formed when a sample of the hair dye was added to **either** 0.1 M potassium iodide **or** 0.1 M potassium nitrate.

The students were also provided with the following data.

Name	Formula	Relative molar mass	Solubility at 25 °C (g/100 g)
lead(II) ethanoate	$Pb(CH_3COO)_2$	325.3	55.0
lead(II) iodide	PbI_2	461.0	0.076
lead(II) nitrate	$Pb(NO_3)_2$	331.2	60.0

Student A decided to precipitate the lead(II) ions in the hair dye as lead(II) iodide. She added an excess of 0.1 M KI solution to 20.0 mL of hair dye. The yellow precipitate was filtered using pre-weighed filter paper. The precipitate was then washed with distilled water. The precipitate and filter paper were gently heated, allowed to cool and then weighed. This step was repeated several times.

Student A's results are summarised below.

Volume of hair dye solution	20.0 mL
Mass of filter paper	0.3120 g
Mass of filter paper plus precipitate after first heating	0.4831 g
Mass of filter paper plus precipitate after second heating	0.4059 g
Mass of filter paper plus precipitate after third heating	0.4059 g
Mass of filter paper plus precipitate after fourth heating	0.4059 g

a. **i.** Write a balanced equation for the precipitation of lead(II) iodide.

ii. Explain why the filter paper and precipitate were heated and weighed several times.

iii. Calculate the mass, in grams, of lead(II) iodide formed.

iv. What is the mass, in grams, of lead(II) ethanoate that is present in 100.0 mL of hair dye solution?

1 + 1 + 1 + 3 = 6 marks

Student B decided to precipitate the lead(II) ions in the hair dye as lead(II) nitrate. However, he did not produce any precipitate.

b. Explain why no precipitate of lead(II) nitrate formed.

1 mark

Question 8

The solubility of highly soluble, thermally unstable salts such as ammonium chloride may be determined by back titration.

In one experiment a 5.00 mL saturated solution of ammonium chloride, NH_4Cl, at 20.0 °C, was diluted with distilled water to 250.0 mL in a standard flask.

A 20.0 mL aliquot of this solution was added to 10.0 mL of 0.400 M NaOH solution. The solution was heated to drive off the ammonia formed by this reaction.

When the flask had cooled, the excess hydroxide ions were neutralised by 14.7 mL of 0.125 M HCl solution. The molar mass of ammonium chloride is 53.5 g mol^{-1}.

a. **i.** Write an equation for the neutralisation reaction.

ii. Determine the amount, in mole, of NaOH that was originally added to the ammonium chloride solution.

iii. Determine the amount, in mole, of ammonium chloride in the 20.0 mL aliquot.

iv. Calculate the amount, in mole, of ammonium chloride in 5.00 mL of the saturated solution.

v. Calculate the solubility, in gL^{-1}, of ammonium chloride in water at 20 °C.

1 + 1 + 2 + 1 + 2 = 7 marks

b. If the burette was rinsed with water instead of acid before the titration, how would the calculated solubility of ammonium chloride be affected? Explain your answer.

2 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2012

CHEMISTRY
Written examination

Wednesday 13 June 2012

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**	
	Au	symbol of element
relative atomic mass	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** 20.2 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** 45.0 Scandium	**22** **Ti** 47.9 Titanium	**23** **V** 50.9 Vanadium	**24** **Cr** 52.0 Chromium	**25** **Mn** 54.9 Manganese	**26** **Fe** 55.8 Iron	**27** **Co** 58.9 Cobalt	**28** **Ni** 58.7 Nickel	**29** **Cu** 63.5 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** 96.0 Molybdenum	**43** **Tc** (98) 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** (210) 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** (267) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Cn** (285) Copernicium	**113** **Uut** (284)	**114** **Uuq** (289)	**115** **Uup** (288)	**116** **Uuh** (293)	**117** **Uus** (294)	**118** **Uuo** (294)

58 **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.4 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.3 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** 173.1 Ytterbium	**71** **Lu** 175.0 Lutetium

90 **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237) 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

The value in brackets indicates the mass number of the longest-lived isotope.

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

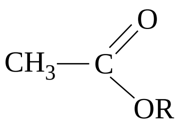
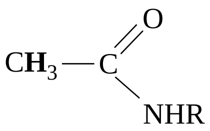
4. SI prefixes, their symbols and values

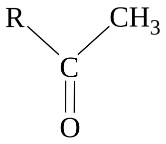
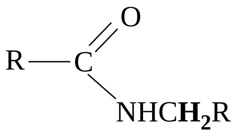
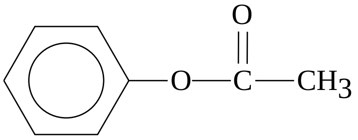
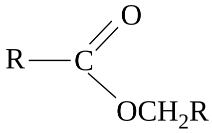
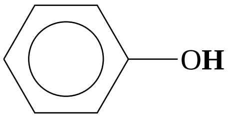
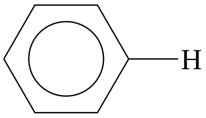
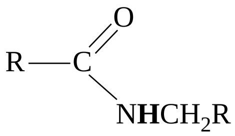
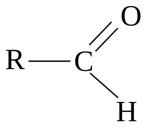
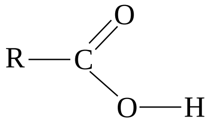
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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	0.8–1.0
R–CH_2–R	1.2–1.4
RCH = CH–C$\mathbf{H_3}$	1.6–1.9
R_3–CH	1.4–1.7
 $CH_3-C(=O)OR$ or  $\mathbf{CH_3}-C(=O)NHR$	2.0

Type of proton	Chemical shift (ppm)
	2.1–2.7
R–CH_2–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H_2**–OH, R_2–C**H**–OH	3.3–4.5
	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
	9–13

6. ^{13}C NMR data

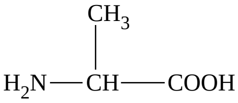
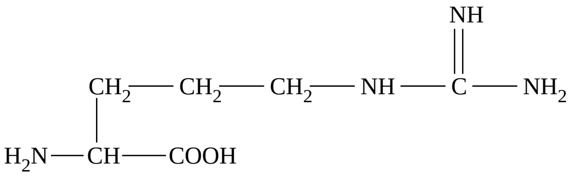
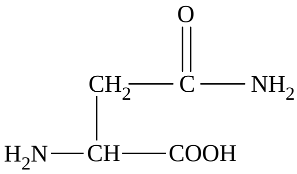
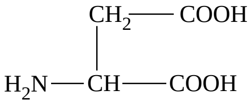
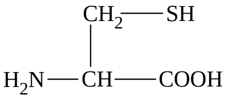
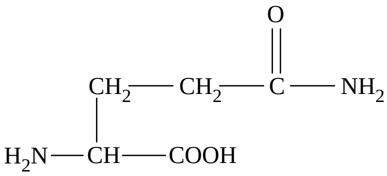
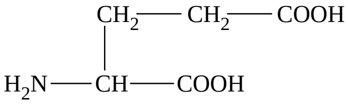
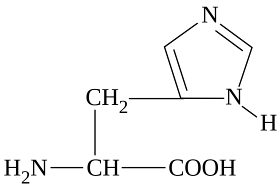
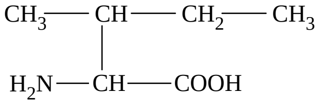
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

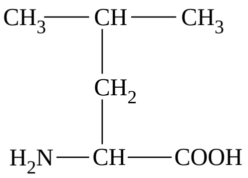
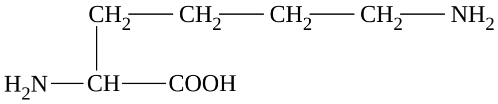
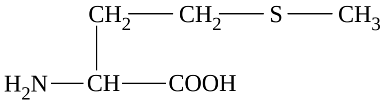
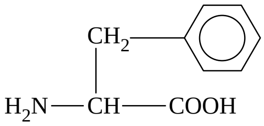
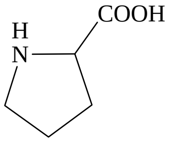
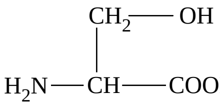
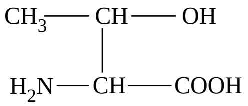
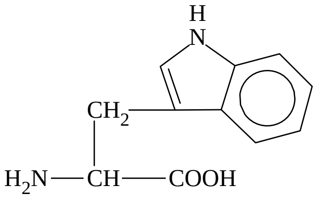
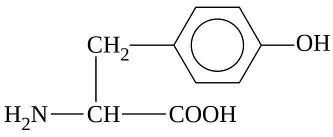
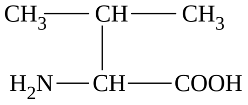
7. Infrared absorption data

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)

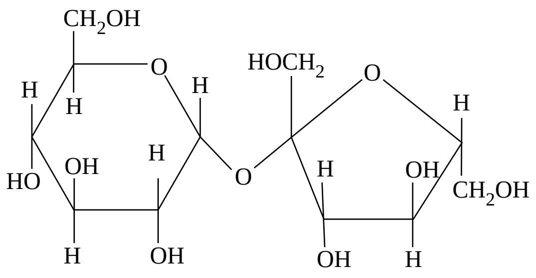
Name	**Symbol**	**Structure**
alanine	Ala	 $H_2N-\overset{\overset{\displaystyle CH_3}{\vert}}{CH}-COOH$
arginine	Arg	 $H_2N-\overset{\overset{\displaystyle CH_2-CH_2-CH_2-NH-\overset{\overset{\displaystyle NH}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
asparagine	Asn	 $H_2N-\overset{\overset{\displaystyle CH_2-\overset{\overset{\displaystyle O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
aspartic acid	Asp	 $H_2N-\overset{\overset{\displaystyle CH_2-COOH}{\vert}}{CH}-COOH$
cysteine	Cys	 $H_2N-\overset{\overset{\displaystyle CH_2-SH}{\vert}}{CH}-COOH$
glutamine	Gln	 $H_2N-\overset{\overset{\displaystyle CH_2-CH_2-\overset{\overset{\displaystyle O}{\Vert}}{C}-NH_2}{\vert}}{CH}-COOH$
glutamic acid	Glu	 $H_2N-\overset{\overset{\displaystyle CH_2-CH_2-COOH}{\vert}}{CH}-COOH$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	 $H_2N-\overset{\overset{\displaystyle CH_3-CH-CH_2-CH_3}{\vert}}{CH}-COOH$

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

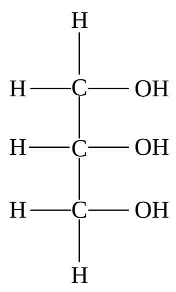
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

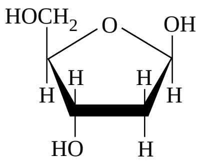
10. Structural formulas of some important biomolecules



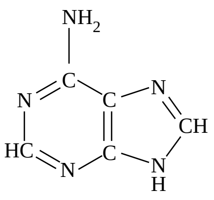
sucrose



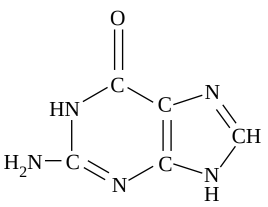
glycerol



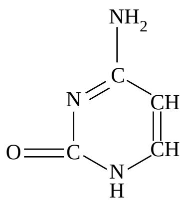
deoxyribose



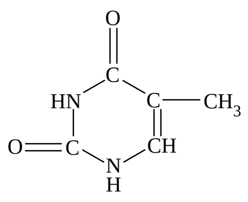
adenine



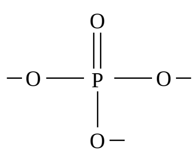
guanine



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 at 25 °C

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