Chemistry 2008–2011

Written examination – Mid-year

Examination Specifications

Overall conditions

The examination will be sat at a (mid-year) time and date to be set annually by the Victorian Curriculum and Assessment Authority.

There will be 15 minutes reading time and 90 minutes writing time.

VCAA examination rules will apply. Details of these rules are published annually in the *VCE and VCAL Administrative Handbook.*

The examination will be marked by a panel appointed by the VCAA.

The examination will contribute 33 per cent to the Study Score.

Content

All of the key knowledge in Unit 3 is examinable. All the key skills, as outlined on page 12 of the *Chemistry VCE Study Design*, are examinable.

Approved materials and equipment

Dictionaries are not allowed in the examination room in this study.

A scientific calculator is allowed in the examination room for this study.

Format

The examination paper will be in the form of a question and answer book. There will be a Data Book supplied with the examination.

The examination will consist of two sections, Section A and Section B.

Section A will contain approximately 20 multiple-choice questions. Each question in Section A will be worth one mark, and all questions will be compulsory.

Section B will contain compulsory short answer questions worth 45–60 marks.

Advice

The VCE study, Chemistry, has been reaccredited for implementation in Units 3 and 4 in 2008.

During the 2007(8)–2011 accreditation period for VCE Chemistry, examinations will be prepared according to the Examination specifications above. Each examination will conform to these specifications and will test a representative sample of the key knowledge and skills.

August 2007

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2008

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

CHEMISTRY

Written examination 1

Day Date 2008

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (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	6	6	47
			Total 67

- 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 18 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.

August 2007

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

Gravimetric analysis is used to determine the purity of a sample of potassium chloride. A 5.00 g sample of impure potassium chloride is dissolved in water and excess silver nitrate, $AgNO_3(aq)$, added. The precipitate of silver chloride, AgCl, was dried and weighed. Its mass was found to be 4.85 g.

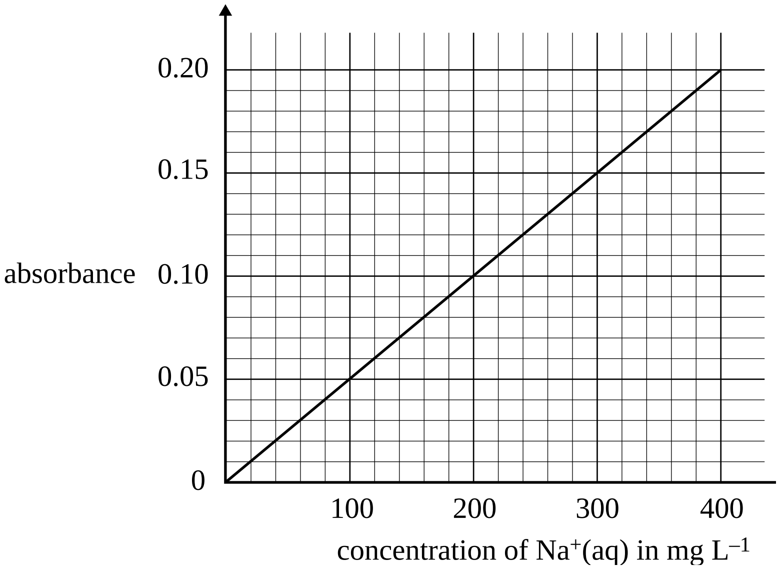
The percentage by mass of KCl in the impure sample of KCl is closest to

A. 0.15
B. 3.00
C. 50.5
D. 97.0

Question 2

The sodium ion content of a particular brand of soy sauce is determined using atomic absorption spectroscopy.

Four aqueous samples of known Na^+ concentration are prepared as standard solutions and their absorbance measured to obtain the following calibration graph.



20.0 mL of the soy sauce is diluted to 250.0 mL in a volumetric flask. The absorbance of this diluted solution, measured in the same way as the standard solutions, is found to be 0.175.

The concentration, in mg L^{-1}, of Na^+ in the sauce is closest to

A. 1.4
B. 28
C. 350
D. 4380

Question 3

The volume, in mL, of pure water that must be **added** to 50.0 mL of 0.0100 M HNO_3 to produce a diluted solution of pH 4.00 is closest to

A. 50

B. 450

C. 4950

D. 5000

Question 4

The mass, in gram, of one molecule of propanoic acid is

A. 74

B. 88

C. 1.2×10^{-22}

D. 1.5×10^{-22}

Question 5

Aspirin ($C_9H_8O_4$; molar mass 180 g mol^{-1}) can be prepared by the acid-catalysed reaction of salicylic acid ($C_7H_6O_3$; molar mass 138 g mol^{-1}) with acetic anhydride ($C_4H_6O_3$; molar mass 102 g mol^{-1}), according to the equation

$$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + CH_3COOH$$

If 30.0 g of salicylic acid is reacted with 100 g of acetic anhydride and 27.5 g of aspirin is formed, the percentage yield of aspirin is closest to

A. 91.7

B. 70.3

C. 27.5

D. 15.6

Question 6

The oxidation number of Mn in $KMnO_4$ is

A. +2

B. +3

C. +6

D. +7

Question 7

Which one of the following equations represents a redox reaction?

A. $H_2S(g) + 2OH^-(aq) \rightarrow S^{2-}(aq) + 2H_2O(l)$

B. $SO_4^{2-}(aq) + H_3O^+(aq) \rightarrow HSO_4^-(aq) + H_2O(l)$

C. $NH_4^+(aq) + CO_3^{2-}(aq) \rightarrow NH_3(g) + HCO_3^-(aq)$

D. $I_2(aq) + 2OH^-(aq) \rightarrow I^-(aq) + IO^-(aq) + H_2O(l)$

Question 8

1-propyl butanoate is the product of a reaction involving concentrated H_2SO_4 and

A. $CH_3CH_2CH_2CH_2OH$ and CH_3CH_2COOH

B. $CH_3CH_2CH_2OH$ and $CH_3CH_2CH_2COOH$

C. $CH_3CH_2CH_2CH_2OH$ and $CH_3CH_2CH_2COOH$

D. $CH_3CH_2CH_3OH$ and $CH_3CH_2CH_2CH_2COOH$

Question 9

When a molecule absorbs infrared radiation this is most likely to lead to

A. transitions between electronic energy levels in the molecule.

B. transitions between vibrational energy levels in the molecule.

C. transitions within nuclei of atoms in the molecule when the molecule is placed in a strong magnetic field.

D. the removal of an electron from the molecule leading to the formation of the molecular ion.

Question 10

Which of the following instruments would be best suited to the detection of unburnt hydrocarbon pollutants found in the atmosphere?

A. gas chromatography

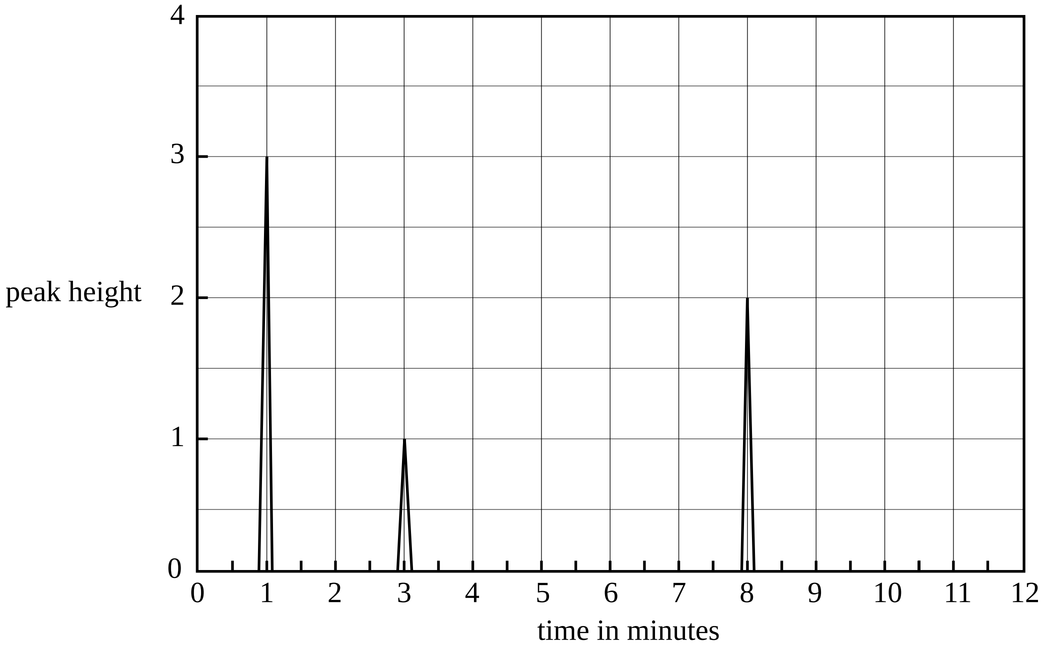
B. UV– visible spectroscopy

C. thin layer chromatography

D. atomic absorption spectroscopy

Question 11

A mixture of butane (C_4H_{10}), pentane (C_5H_{12}) and hexane (C_6H_{14}) was analysed in a gas-liquid chromatography column. The following output was obtained.



Given that the sensitivity of the detector is the same per mole for all three substances, the mole percentage of hexane in the sample is closest to

A. 20

B. 30

C. 33

D. 50

Question 12

Which combination of the following factors will affect the time taken for a sample to pass through a high-performance liquid chromatography column?

I temperature

II length of the column

III flow rate of the carrier gas

A. I and II only

B. II and III only

C. I and III only

D. I, II and III

Question 13

Which one of the following amino acids has five carbon atoms and when placed into water will most likely result in a solution with a pH greater than 7?

A. lysine

B. glutamine

C. aspartic acid

D. glutamic acid

Question 14

Compound A is converted to compound X as shown

$$\underset{\text{compound A}}{CH_3CHCHCH_3} \xrightarrow{H_2/Pd} \text{compound X}$$

In the mass spectrum at which m/e value would you expect to observe the molecular ion corresponding to compound X?

A. 56

B. 57

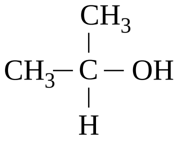
C. 58

D. 59

Question 15

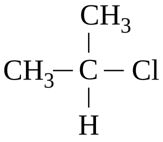
Which one of the following compounds will show an absorption band in the infrared spectrum at about 3500 cm^{-1}?

A.



$CH_3-\overset{CH_3}{\underset{H}{C}}-OH$

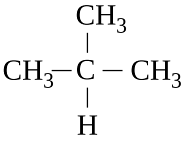
B.



$CH_3-\overset{CH_3}{\underset{H}{C}}-Cl$

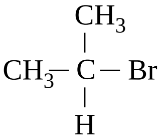
C. $CH_3-O-CH_2-CH_3$

D.



$CH_3-\overset{CH_3}{\underset{H}{C}}-CH_3$

Question 16



$CH_3-\overset{CH_3}{\underset{H}{C}}-Br$ $CH_3-CH_2-CH_2-Br$

The structure of the molecules shown above could most readily be distinguished based on the results of

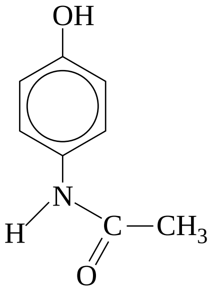
A. measurements of the ^1H NMR spectra of the compounds.

B. the ratio of m/e for the molecular ion in their mass spectra.

C. measurements of the UV– visible absorption spectra of the compounds.

D. a determination of the percentage composition of each substance.

Question 17



paracetamol

Paracetamol (above) is widely used in the treatment of pain.

Which one of the following statements about paracetamol and the chemistry of this compound is **not** correct?

A. Paracetamol contains the amide functional group.

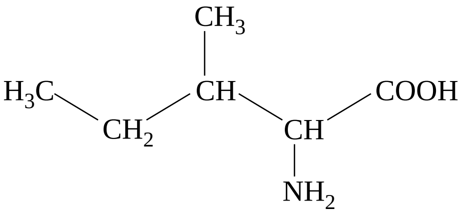
B. When paracetamol undergoes a hydrolysis reaction, CH_3OH is one of the products.

C. Paracetamol would be expected to display a singlet at about 2.0 ppm in the ^1H NMR spectrum.

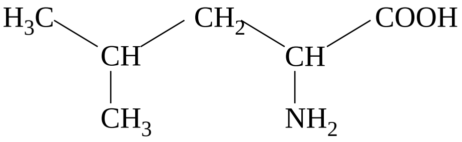
D. Paracetamol would be expected to show an infrared absorption at about 1700 cm^{-1}.

Question 18

The structures of the two amino acids isoleucine and leucine are shown below.



isoleucine



leucine

The ^{13}C NMR spectra can be used to uniquely identify each amino acid.

Isoleucine and leucine respectively will produce ^{13}C NMR spectra with the following number of peaks.

A. 6 and 6

B. 5 and 4

C. 6 and 4

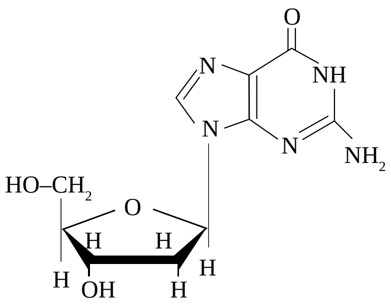
D. 6 and 5

Question 19

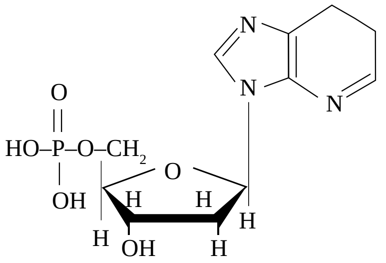
It is possible to synthesise DNA in the laboratory using the DNA nucleotides as starting materials.

Which of the following molecules is a nucleotide that could be used in the synthesis of a DNA sample?

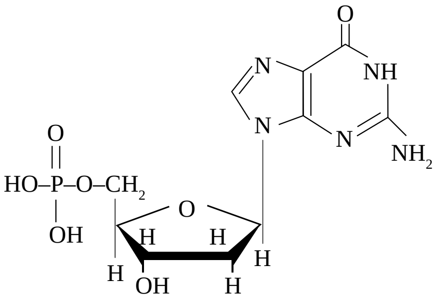
A.



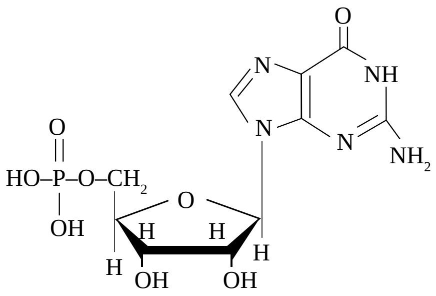
B.



C.



D.



Question 20

A piece of double stranded DNA, which is 100 base pairs in length, contains 30 guanine bases.

The number of thymine bases in the piece of DNA will be

A. 20
B. 30
C. 50
D. 70

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

Citric acid, $C_6H_8O_7$, is an acid found in the juice of many fruit. The following analysis was carried out to determine the concentration of citric acid in a sample of lemon juice.

A 25.00 mL sample of the lemon juice was diluted to 100.0 mL in a volumetric flask. A 20.00 mL aliquot of this diluted solution was added to a 100 mL conical flask with two drops of indicator. A burette was filled with a solution of 0.142 M sodium hydroxide, NaOH, and the titration produced an average titre of 11.88 mL.

The equation for the reaction is

$$C_6H_8O_7(aq) + 3NaOH(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$$

a. Calculate the concentration, in mol L^{-1}, of $C_6H_8O_7$ in the undiluted lemon juice.

4 marks

b. The pH at the equivalence point of this titration is very close to 9. Select, from the list of indicators in your data book, a suitable indicator for this titration and indicate the colour change you would expect as the end point is reached.

Name of indicator ____________________________

Colour change from _______________ to _______________

2 marks

c. Solid NaOH is unsuitable as a primary standard in volumetric analysis.

i. Explain the meaning of the term ‘primary standard’.

ii. Suggest why solid NaOH is not suitable for use as a primary standard.

iii. Prior to the experiment, the concentration of the NaOH was experimentally determined by titrating the NaOH against a standard solution of HCl. Suppose about 10 mL of the HCl were spilt on the floor during the experiment.

How would you safely neutralise the spill?

1 + 1 + 1 = 3 marks

d. The table below shows different ways in which particular items of glassware could be rinsed immediately before use. Indicate, by ticking the appropriate box in the table, what effect each rinsing would have on the calculated concentration of citric acid.

	Glassware	**Solution(s) used for final rinsing**	**Result too low**	**Result too high**	**Correct result**
i.	burette	water			
ii.	20.00 mL pipette	diluted lemon juice			
iii.	100 mL conical flask	0.142 M NaOH(aq)			
iv.	100.0 mL volumetric flask	water			

4 marks

Total 13 marks

Question 2

A gaseous mixture of two alkanes, each with molecular formula C_4H_{10}, is reacted with bromine, Br_2, in the presence of UV light, to form a complex mixture of liquid bromoalkanes.

a. Name a suitable technique which would allow a large scale separation of this mixture into its various components.

1 mark

b. Four bromoalkanes with the same molecular formula but different structures, are isolated from the mixture. Their composition by mass is

C 35.0%; H 6.6 %; Br 58.4 %.

i. Determine the empirical formula of these bromoalkane isomers.

The molar mass of these bromoalkanes is found to be 137 g mol^{-1}.

ii. What is their molecular formula?

iii. In the boxes provided, draw the **structural formulas** and write the names of these four bromoalkanes.

Name ______________________

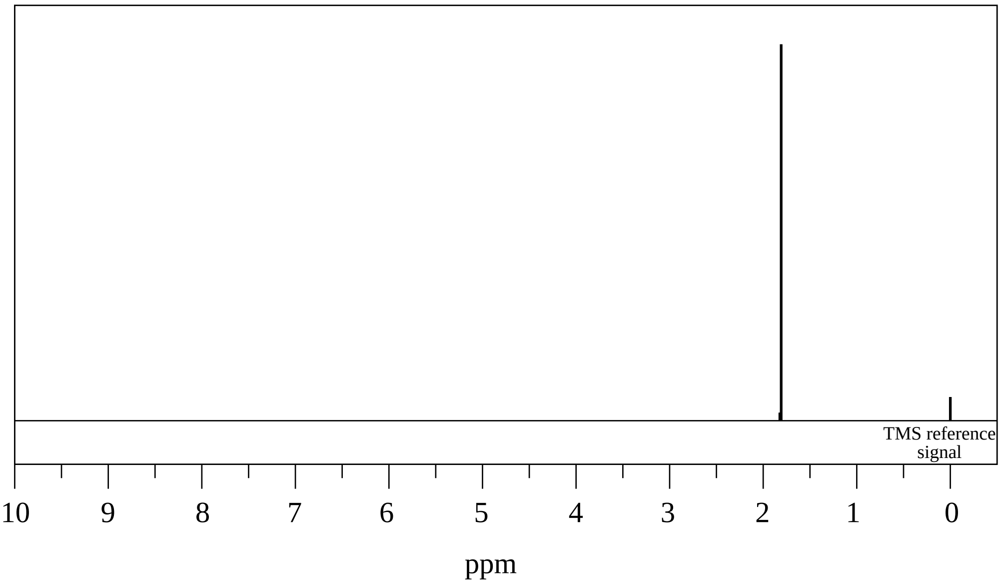
Name ______________________

Name ______________________

Name ______________________

2 + 1 + 4 = 7 marks

c. One of the bromoalkane isomers described in **part b.** shows two lines in the ^{13}C NMR spectrum and its ^{1}H NMR spectrum is shown below.



i. **Circle** the box in which you have drawn the formula of this compound in **part b.**

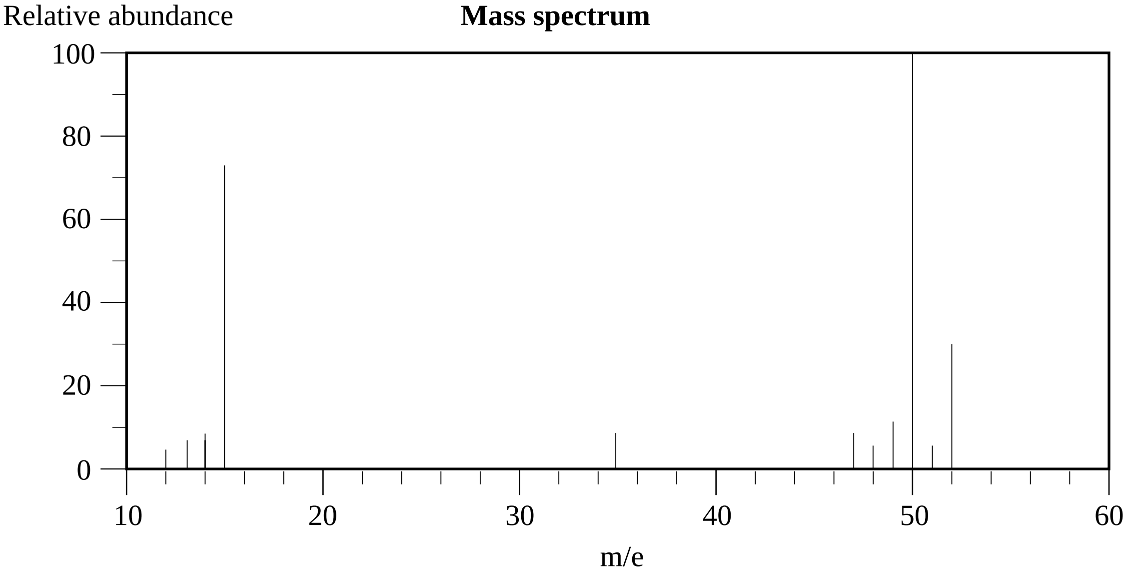
ii. Explain how you have used the NMR data to identify this bromoalkane isomer.

1 + 2 = 3 marks

Total 11 marks

Question 3

There are two isotopes of naturally occurring chlorine, $^{35}C1$ and $^{37}C1$. Chlorine reacts with methane in the presence of ultraviolet light to form a mixture of compounds. One of the products, X, is known to be either chloromethane or dichloromethane. It is analysed using mass spectroscopy and the following mass spectrum obtained.



a. Explain the presence of

i. the two lines at 50 and 52

ii. the line at 15.

1 + 1 = 2 marks

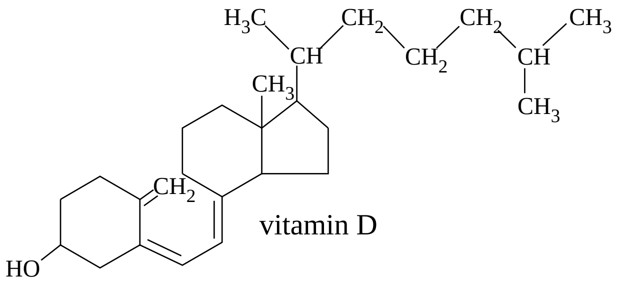
b. On the basis of this mass spectrum, determine whether X is chloromethane or dichloromethane, giving an explanation for your choice.

1 mark

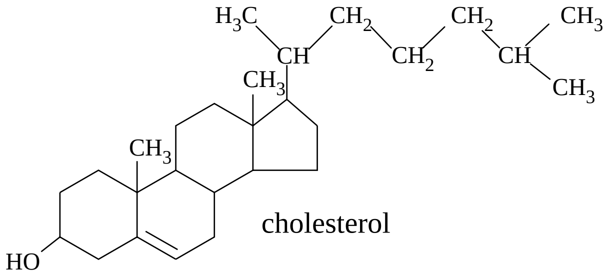
Total 3 marks

Question 4

a. Vitamin D and cholesterol are biomolecules with very similar structures. Circle two functional groups that are present in both vitamin D and cholesterol. **Next to** the functional groups circled, give their name.



vitamin D

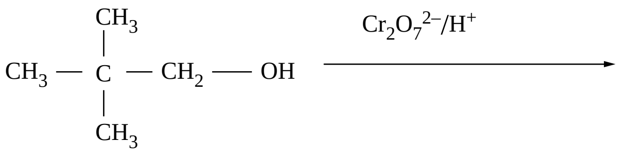


cholesterol

2 marks

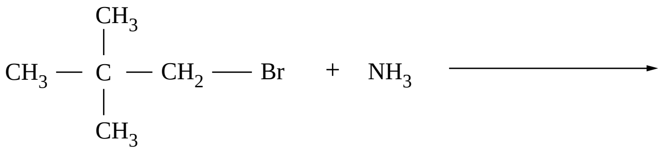
b. In the space provided, give the structural formulas, showing all bonds, of the carbon-containing products of the following reactions.

i.



$$CH_3 - \underset{CH_3}{\overset{CH_3}{C}} - CH_2 - OH \xrightarrow{Cr_2O_7^{2-}/H^+}$$

ii.



$$CH_3 - \underset{CH_3}{\overset{CH_3}{C}} - CH_2 - Br \quad + \quad NH_3 \longrightarrow$$

iii.

$C_6H_{12}O_6 \xrightarrow{\textit{yeast enzymes}}$ +

1 + 1 + 1 = 3 marks

c. Write an equation for each of the reactions in the organic reaction pathway for the conversion of propane to 1-propanol.

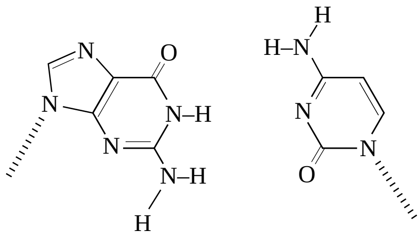
2 marks

Total 7 marks

SECTION B – continued

Question 5

a. On the diagram below, draw in the hydrogen bonds between a guanine and cytosine base pair as they would exist in the DNA double helix.



1 mark

b. When double stranded DNA samples are heated, the strands begin to separate in a process which is called DNA ‘melting’. The following diagram depicts two fragments of double stranded DNA.

—A	T—
—T	A—
—G	C—
—A	T—
—C	G—
—T	A—
—A	T—
—C	G—
—T	A—

fragment A

—C	G—
—T	A—
—G	C—
—A	T—
—C	G—
—G	C—
—C	G—
—C	G—
—T	A—

fragment B

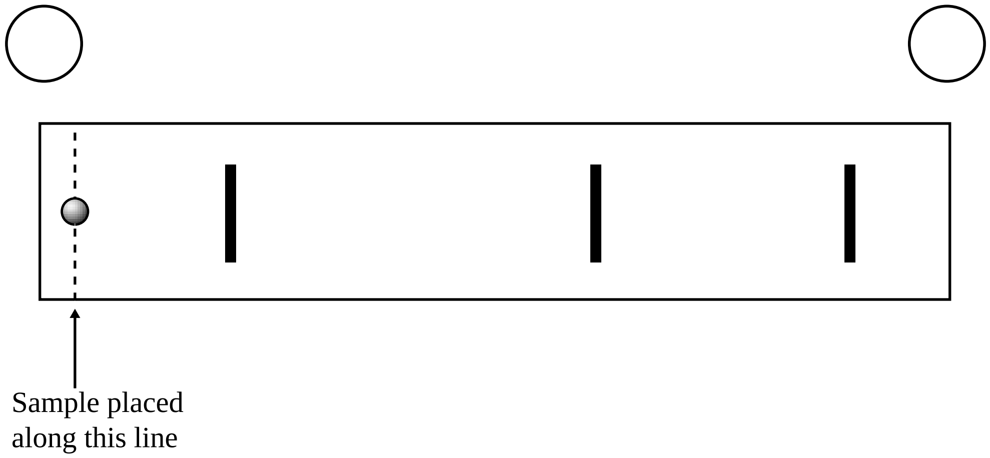
i. Identify which fragment will separate more readily as the temperature is raised. Explain your answer.

ii. How many water molecules would be required to hydrolyse fragment A into its constituent nucleotides?

1 + 1 = 2 marks

c. Gel electrophoresis is a technique which can be used to separate DNA fragments in forensic chemistry. A mixture containing fragments of DNA of size 0.55 kb, 6.3 kb and 25 kb is placed onto a gel. (Note: 1 kb equals 1000 base pairs.)

After an electric current has passed through the gel, the DNA fragments are stained to become visible as bands on the gel.



On the diagram above

i. label the negative and positive terminals of the gel (use the circles provided)

ii. label the DNA fragments according to their size.

1 + 1 = 2 marks

Total 5 marks

Question 6

a. Consider the following paragraph.

Australian scientists in the forefront of medical research

Much research is taking place in Australia into the field of Proteomics. Proteomics is the large scale study of the proteins present in a living organism. The DNA of a cell provides the blueprint for the assembly of the primary structure of proteins, the large biomolecules essential to life. In humans, at any one time, there may be as many as 1 000 000 different proteins and it is those proteins that do all the real work such as providing structure to skin, digesting food and fighting infections. So significant is the role of proteins in living things that considerable resources are invested into identifying proteins as markers for disease.

i. What is meant by the term 'markers for disease' in the above paragraph?

ii. How does the primary structure of a protein differ from its secondary structure?

1 + 2 = 3 marks

Proteins are large molecules formed from the polymerisation of amino acids. All the amino acids in proteins are **2**-amino acids (**α**-amino acids).

b. What characteristic structure must an amino acid have to be classified as a **2**-amino acid?

1 mark

c. A tripeptide is a molecule formed as a result of a condensation reaction between three amino acids.

i. How many different tripeptides can be formed from the reaction of one molecule of each of the amino acids alanine, glycine and serine?

ii. Draw the structure of **one** tripeptide formed from alanine, glycine and serine.

1 + 2 = 3 marks

Some students were using chromatography to identify amino acids in two different mixtures of amino acids. The students were instructed to use a clean dropper to place each of the two different samples of amino acid mixture onto the plate. One student accidentally used the same dropper for each sample without cleaning it between each use.

d. State one way in which this student's final chromatogram would be different from a chromatogram that resulted from using the correct procedure.

1 mark

Total 8 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2008

CHEMISTRY

Written examination

Day Date 2008

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (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.

August 2007

Table of contents

1. Periodic table of the elements

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

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

TURN OVER

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

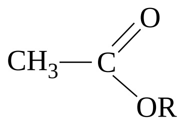
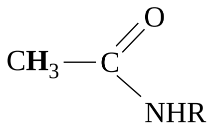
4. SI prefixes, their symbols and values

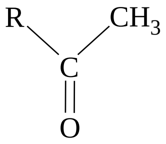
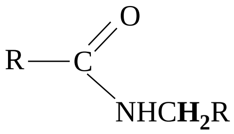
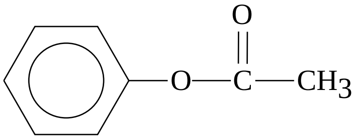
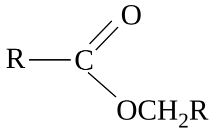
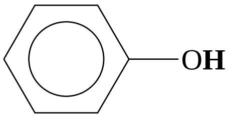
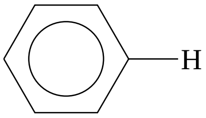
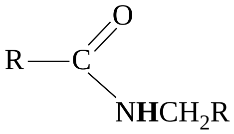
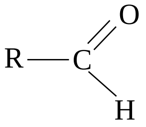
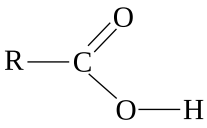
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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
$RCH = CH–C\mathbf{H_3}$	1.7
$R_3–CH$	2.0
 $CH_3–C(=O)OR$ or  $\mathbf{CH_3}–C(=O)NHR$	2.0

Type of proton	**Chemical shift (ppm)**
	2.1
$R{-}CH_2{-}X$ (X = F, Cl, Br or I)	3–4
$R{-}C\mathbf{H_2}{-}OH$	3.6
	3.2
$R{-}O{-}CH_3$ or $R{-}O{-}CH_2R$	3.3
	4.1
	4.1
$R{-}O{-}H$	1–6 (varies considerably under different conditions)
$R{-}NH_2$	1–5
$RHC{=}C\mathbf{H}_2$	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	11.5

6. ^{13}C NMR data

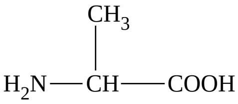
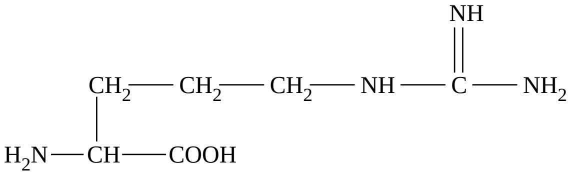
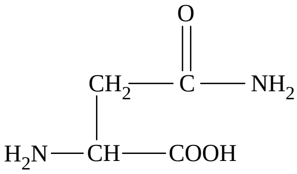
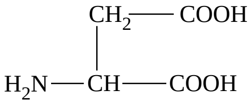
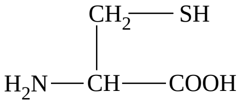
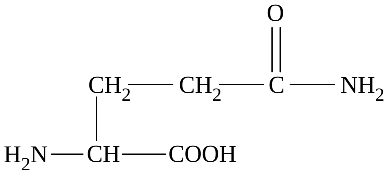
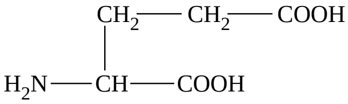
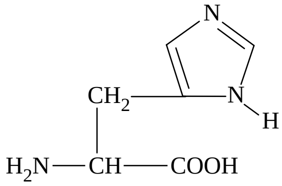
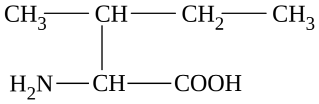
Type of carbon	**Chemical shift (ppm)**
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$RC–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
RC=CR	110–150
RCOOH	160–185

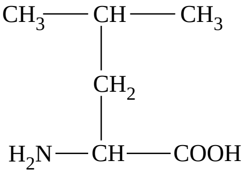
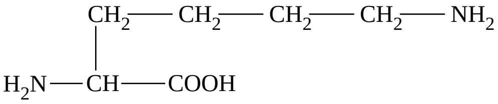
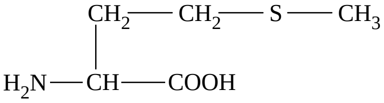
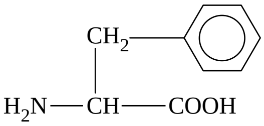
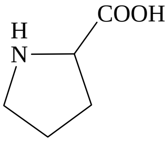
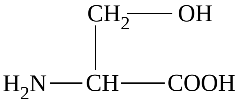
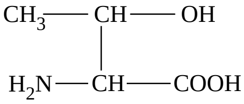
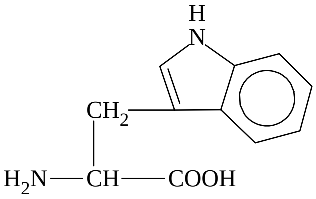
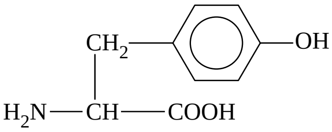
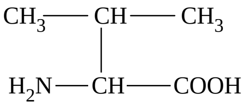
7. Infrared absorption data

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

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

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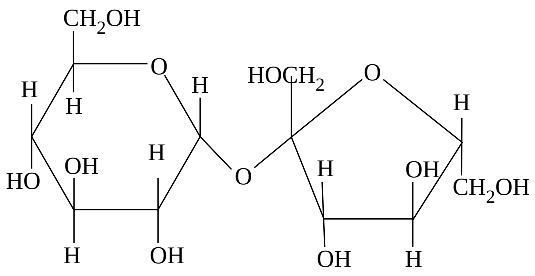
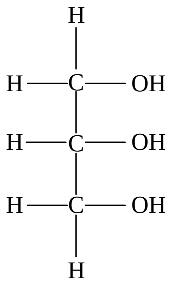
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

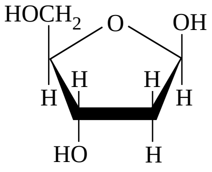
10. Structural formulas of some important biomolecules



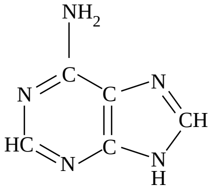
sucrose



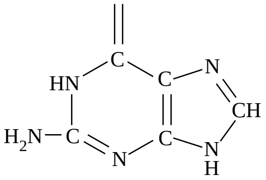
glycerol



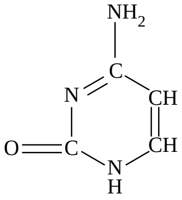
deoxyribose



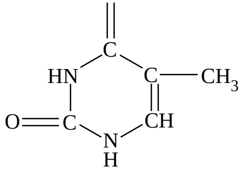
adenine



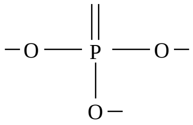
guanine



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 combustions 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