VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2011

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

										Letter
Figures										
Words										

CHEMISTRY

Written examination 1

Wednesday 15 June 2011

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	52
			Total 72

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 25 pages.
- A data book.
- Answer sheet for multiple-choice questions.

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

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

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

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

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

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

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

Question 1

Which one of the following compounds is **least** soluble in water at room temperature?

A. ethane

B. ethanol

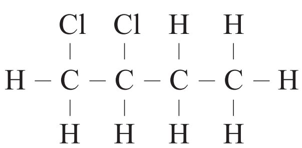
C. ethylamine

D. ethanoic acid

Question 2

The structure of the product that is formed from the addition reaction between but-2-ene and chlorine, Cl_2, is

A.



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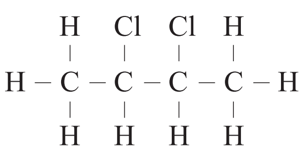

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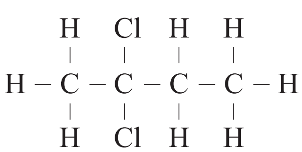

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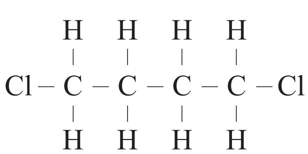
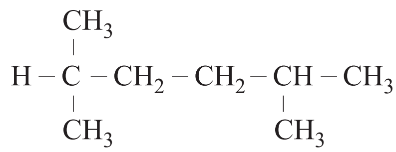


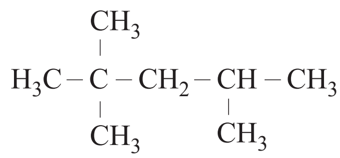
Question 3

Consider the following structures.

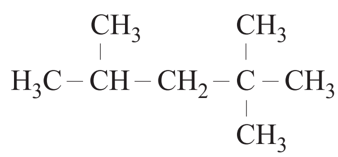
I



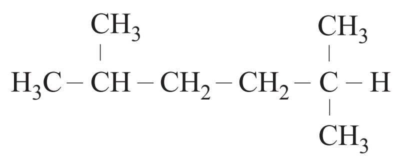
II



III



IV



Which of the above structures is that of 2,2,4-trimethylpentane?

A. I and III only

B. I and IV only

C. II and III only

D. II and IV only

Question 4

The compound that is **not** an isomer of 2,2,4-trimethylpentane is

A. octane.

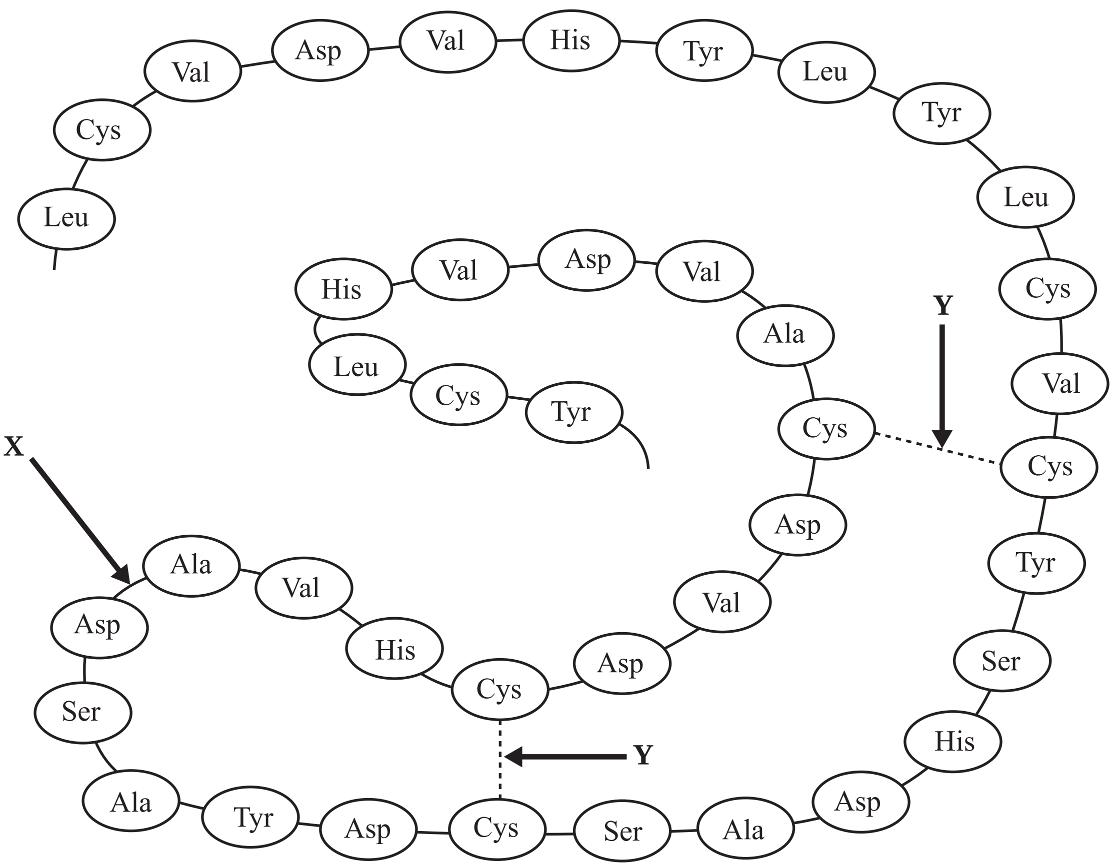
B. 3-ethylhexane.

C. 2,4-dimethylpentane.

D. 2,4-dimethylhexane.

Question 5

The following is a diagram of a section of a protein chain.



The bonds represented by X and Y are

	X	Y
A.	amide bond	disulfide bond
B.	covalent bond	ionic bond
C.	hydrogen bond	peptide bond
D.	dipole-dipole bond	covalent bond

Question 6

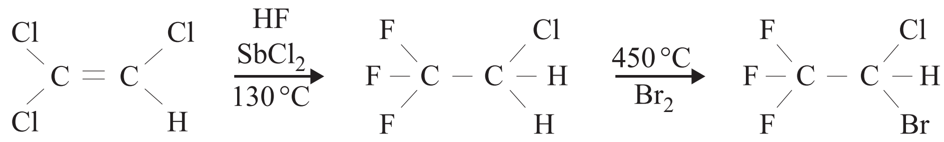
Alanine, lysine and aspartic acid are amino acids.

Which of these will react with 1.0 M HCl(aq)?

A. lysine only
B. alanine and lysine only
C. aspartic acid and lysine only
D. alanine, aspartic acid and lysine

Question 7

Halothane is a general anaesthetic. The following diagram represents the reaction pathway that produces halothane.



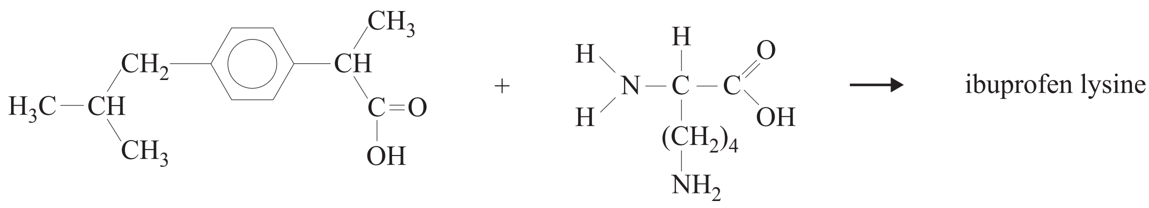
molecule X step 1 step 2

Which one of the following correctly identifies the type of reaction occurring in step 2 and correctly states the systematic name of molecule X?

	Type of reaction in step 2	Systematic name of molecule X
A.	substitution	1,2,2-trichloroethane
B.	addition	1,1,2-trichloroethane
C.	substitution	1,1,2-trichloroethene
D.	addition	1,2,2-trichloroethene

Question 8

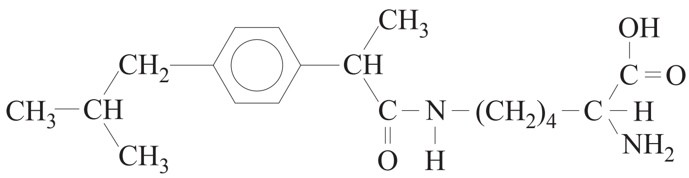
The pain killer ibuprofen lysine is **more** soluble in water than ibuprofen and can therefore be administered intravenously. Ibuprofen lysine is formed when ibuprofen and the amino acid, lysine, react with each other.



ibuprofen lysine

The structure of the ibuprofen lysine is

A.



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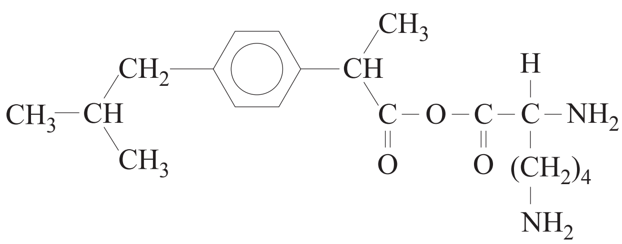

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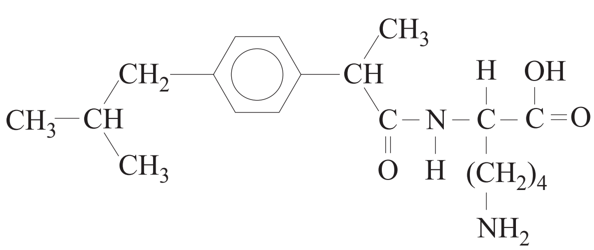

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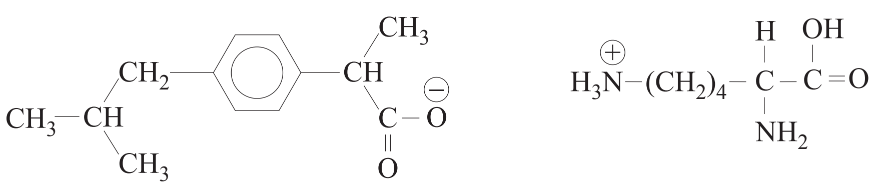
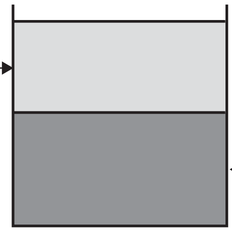


Question 9

Canola oil is completely converted to biodiesel fuel. One of the components of this biodiesel is ethyl stearate. Once cooled, the product mixture of the conversion of canola oil to biodiesel separates into two layers. The top layer, layer A, in the diagram, is the biodiesel fuel.



The following chemicals are involved in the production of biodiesel.

I glycerol
II potassium hydroxide
III ethanol

Which of the above chemicals are found in layer B?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

Question 10

Biogas can be generated as a by-product of many farming activities. Waste waters often contain sugars, such as glucose, which can be converted to methane. A simplified reaction sequence is given below.

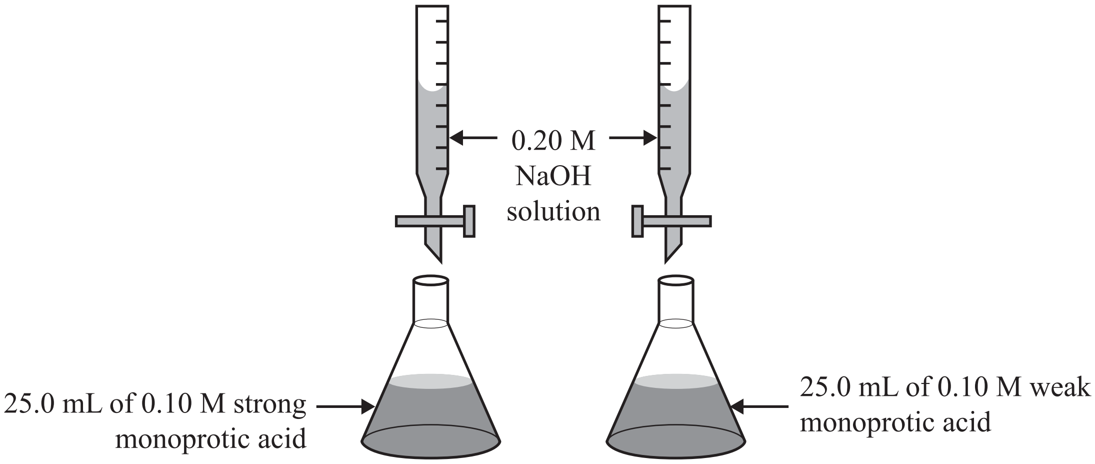
Step 1	fermentation	$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$
Step 2	oxidation	$CH_3CH_2OH(aq) + O_2(aq) \rightarrow CH_3COOH(aq) + H_2O(l)$
Step 3	neutralisation	$2CH_3COOH(aq) + CaCO_3(s) \rightarrow Ca(CH_3COO)_2(aq) + CO_2(g) + H_2O(l)$
Step 4	bacterial conversion	$Ca(CH_3COO)_2(aq) + H_2O(l) \rightarrow 2CH_4(g) + CO_2(g) + CaCO_3(s)$

The ratio of the volume of methane produced to volume of carbon dioxide produced in the overall process is

A. 1:1
B. 1:2
C. 2:1
D. 2:3

Question 11

Two titrations were performed as shown below.



Which one of the following statements is true?

A. The weak acid will require a greater volume of NaOH solution than the strong acid to reach the equivalence point.

B. The weak acid will require a smaller volume of NaOH solution than the strong acid to reach the equivalence point.

C. The weak acid will require the same amount of NaOH solution as the strong acid to reach the equivalence point.

D. The equivalence point in a titration of a weak monoprotic acid with NaOH solution cannot be determined.

Question 12

To each of three samples of a solution, a different acid-base indicator is added. The following colours are observed.

Indicator	**Colour**
thymol blue	yellow
methyl red	yellow
phenolphthalein	colourless

The pH of the solution is between

A. pH = 2.8 and pH = 4.2

B. pH = 4.2 and pH = 6.3

C. pH = 6.3 and pH = 8.3

D. pH = 8.3 and pH = 10.0

NO WRITING ALLOWED IN THIS AREA

Question 13

In an experiment, 172.1 g of gypsum, $CaSO_4.2H_2O$, ($M = 172.1$ g mol^{-1}), was heated to constant mass in a large crucible. The **loss** in mass of the crucible and contents was 27.0 g.

The reaction that occurred when the gypsum was heated was

A. $CaSO_4.2H_2O(s) \rightarrow CaSO_4(s) + 2H_2O(g)$

B. $2CaSO_4.2H_2O(s) \rightarrow 2CaSO_4.\frac{1}{2}H_2O(s) + 3H_2O(g)$

C. $CaSO_4.2H_2O(s) \rightarrow CaSO_4.H_2O(s) + H_2O(g)$

D. $2CaSO_4.2H_2O(s) \rightarrow 2CaSO_4.\frac{3}{2}H_2O(s) + H_2O(g)$

Question 14

An analysis is carried out on a sample of unknown gas. The density of the gas is 2.86 grams per litre at STP.

The molecular formula of the gas is

A. HCl

B. Cl_2

C. NO_2

D. SO_2

Question 15

Airbags are an important safety feature of today's cars. The airbag contains a mixture of solid sodium azide, NaN_3, and potassium nitrate, KNO_3. In the event of an accident, trip sensors send an electric signal to an igniter. The heat generated causes the reactants to decompose completely according to the following equation.

$$10NaN_3(s) + 2KNO_3(s) \rightarrow 5Na_2O(s) + K_2O(s) + 16N_2(g)$$

A particular car's airbag was found to inflate to a volume of 62.0 L at a pressure of 100 kPa when the temperature reached 36.6 °C. The molar mass of NaN_3 is 65.0 g mol^{-1}.

What was the mass of sodium azide contained in the car's airbag?

A. 97.9 g

B. 156.6 g

C. 250.6 g

D. 828.1 g

Question 16

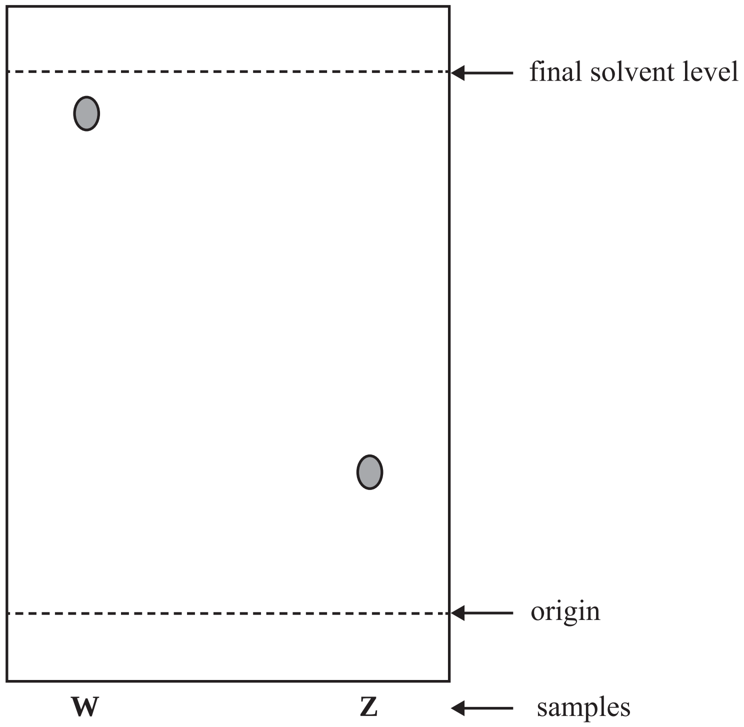
A starch molecule contains 500 glucose units.

If the molar mass of glucose is 180 g mol^{-1}, then the molar mass of the starch molecule is

A. 8 982 g mol^{-1}
B. 81 018 g mol^{-1}
C. 90 000 g mol^{-1}
D. 98 982 g mol^{-1}

Question 17

Two different food dye samples, W and Z, were compared using thin layer chromatography as shown below.



A. Z is more strongly adsorbed than W and has a lower R_f value.
B. Z is more strongly adsorbed than W and has a higher R_f value.
C. W is more strongly adsorbed than Z and has a lower R_f value.
D. W is more strongly adsorbed than Z and has a higher R_f value.

Question 18

The IR wavenumber for bond stretching in a C-O bond (1000 – 1300 cm^{-1}) is lower than for a C-H bond (2850 – 3300 cm^{-1}).

Which one of the following statements best explains this fact?

A. Oxygen atoms are more electronegative than hydrogen atoms.
B. Oxygen atoms have a greater atomic mass than hydrogen atoms.
C. Oxygen atoms have a greater atomic radius than hydrogen atoms.
D. Oxygen atoms have a higher nuclear charge than hydrogen atoms.

NO WRITING ALLOWED IN THIS AREA

SECTION A – continued

Question 19

Petrol is a mixture of hydrocarbon molecules varying in size from six to ten carbon atoms. Forensic investigators suspect that traces of a substance found at a suspicious fire could be petrol that was used to start the fire.

Which one of the following techniques could best be used to identify the substance?

A. NMR spectroscopy

B. UV-visible spectroscopy

C. atomic absorption spectroscopy

D. gas chromatography followed by mass spectroscopy

Question 20

The amount of copper in a solution of copper (II) sulfate can be determined using atomic absorption spectroscopy.

When a blue copper (II) sulfate solution is introduced into an atomic absorption spectrometer, a green flame is observed. Consider the following statements.

I A copper (II) sulfate solution appears blue because it absorbs red light.

II The metal species undergoes oxidation in the flame.

III The flame is green due to electron transitions from a higher energy state to a lower energy state.

Which of the above statements are true?

A. I only

B. I and III only

C. II and III only

D. I, II and III

END OF SECTION A

TURN OVER

SECTION B – Short answer questions

Instructions for Section B

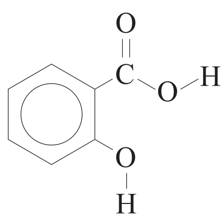
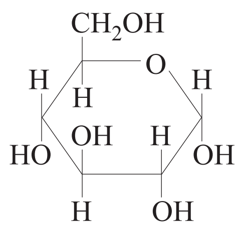
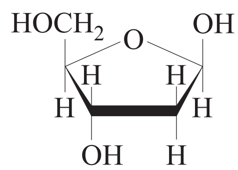
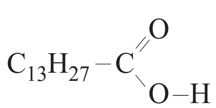
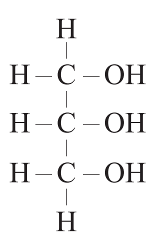
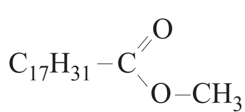
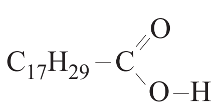
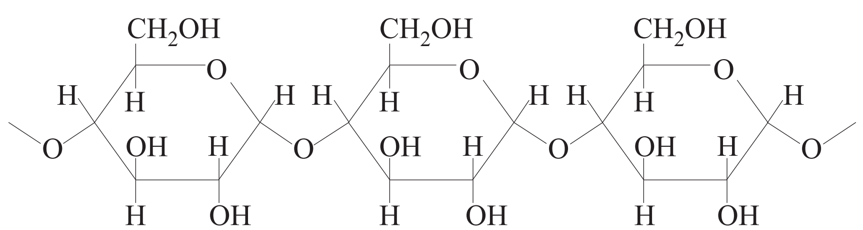
Answer **all** questions in the spaces provided. Write using black or blue pen.

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

Below are the structures of a number of important molecules.

A. 	**B.** 	**C.** 
D. 	**E.** 	**F.** 
G. 	**H.** 	

SECTION B – Question 1 – continued

In each of the following questions, circle the letter or letters that correspond to the compounds in the table on the previous page.

The same letter may be used in more than one response.

a. Which molecule is used in the production of acetylsalicylic acid?

A B C D E F G H

1 mark

b. Which molecule is the product of a condensation polymerisation reaction?

A B C D E F G H

1 mark

c. Which **two** molecules are produced when a triglyceride containing no carbon-carbon double bonds undergoes hydrolysis?

A B C D E F G H

2 marks

d. Which molecule could be a **major** component in biodiesel?

A B C D E F G H

1 mark

e. Which molecule is one of the components that react to form sucrose?

A B C D E F G H

1 mark

f. 0.001 mole of which molecule will react completely with 0.320 g of bromine?

A B C D E F G H

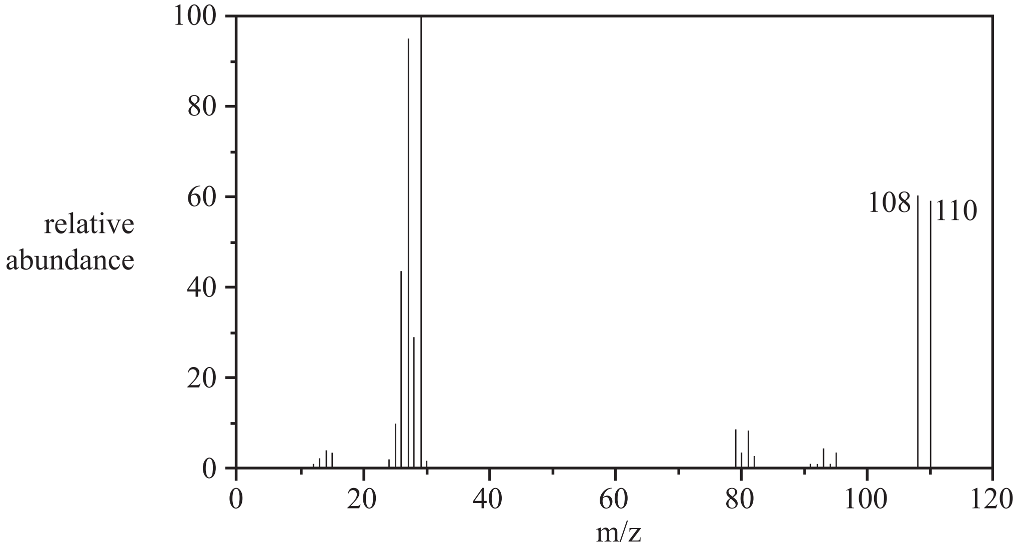
1 mark

Total 7 marks

Question 2

a. Bromine exists as two isotopes, ^{79}Br and ^{81}Br.

The mass spectrum of bromoethane, C_2H_5Br, with two molecular ion peaks at m/z 108 and 110, is shown below.



i. Identify the species that produces the peak at m/z = 29.

---

ii. What do the two molecular ion peaks indicate about the relative abundance of ^{79}Br and ^{81}Br?
Give a reason for your answer.

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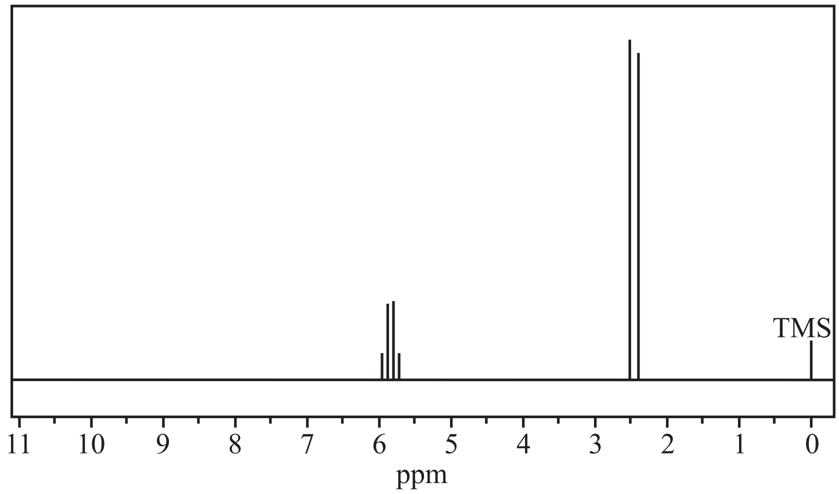
1 + 2 = 3 marks

NO WRITING ALLOWED IN THIS AREA

b. There are two compounds that have the molecular formula $C_2H_4Br_2$.
The ^{1}H NMR spectrum of **one** of these compounds is provided below.



i. In the boxes below, draw the structural formula of each of the two compounds that have the molecular formula $C_2H_4Br_2$.

Structure 1	**Structure 2**

ii. Circle the structure above that corresponds to the ^{1}H NMR spectrum provided.
Justify your selection by referring to both the ^{1}H NMR spectrum and to the structure of the compound.

2 + 3 = 5 marks

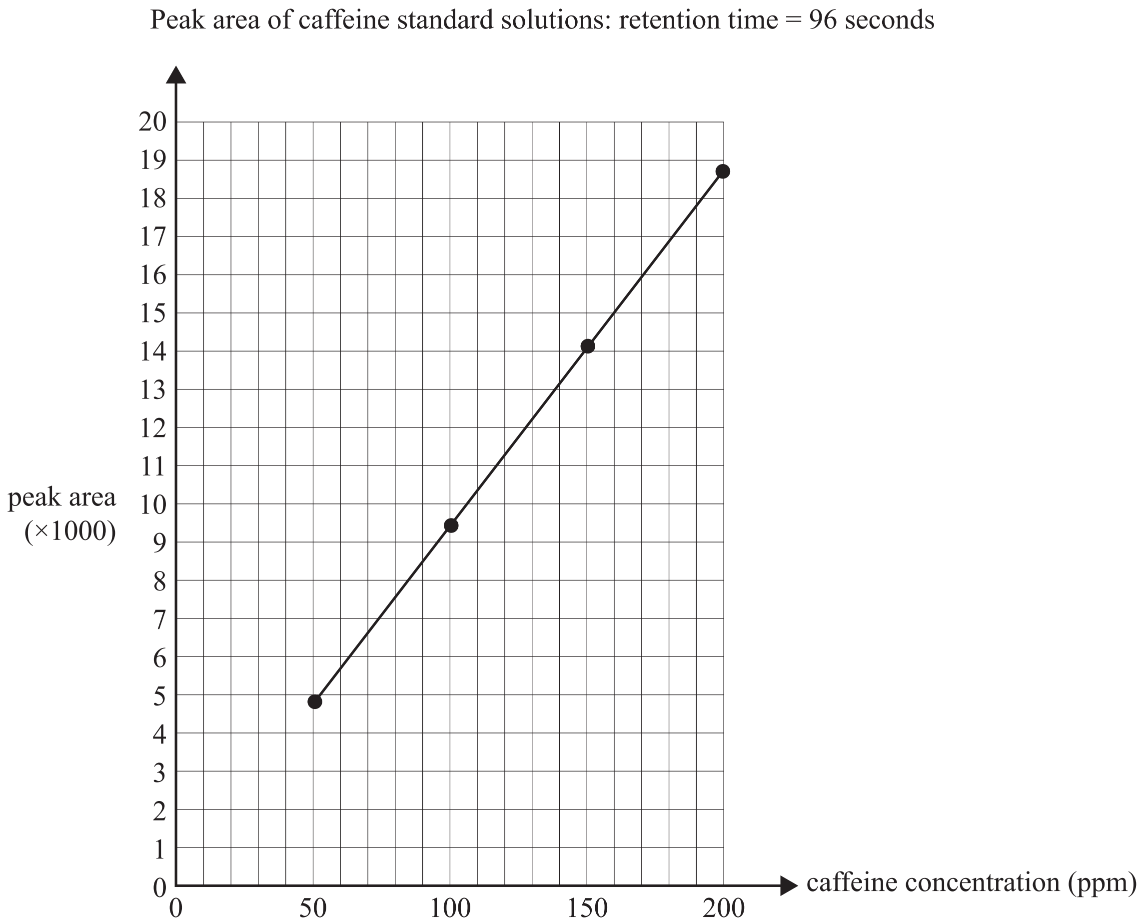
Total 8 marks

Question 3

Caffeine is a stimulant drug that is found in coffee, tea, energy drinks and some soft drinks.

The concentration of caffeine in drinks can be determined using HPLC.

Four caffeine standard solutions containing 50 ppm, 100 ppm, 150 ppm and 200 ppm were prepared. 25μL of each sample was injected into the HPLC column. The peak areas were measured and used to construct the calibration graph below. The chromatograms of the standard solutions each produced a single peak at a retention time of 96 seconds.



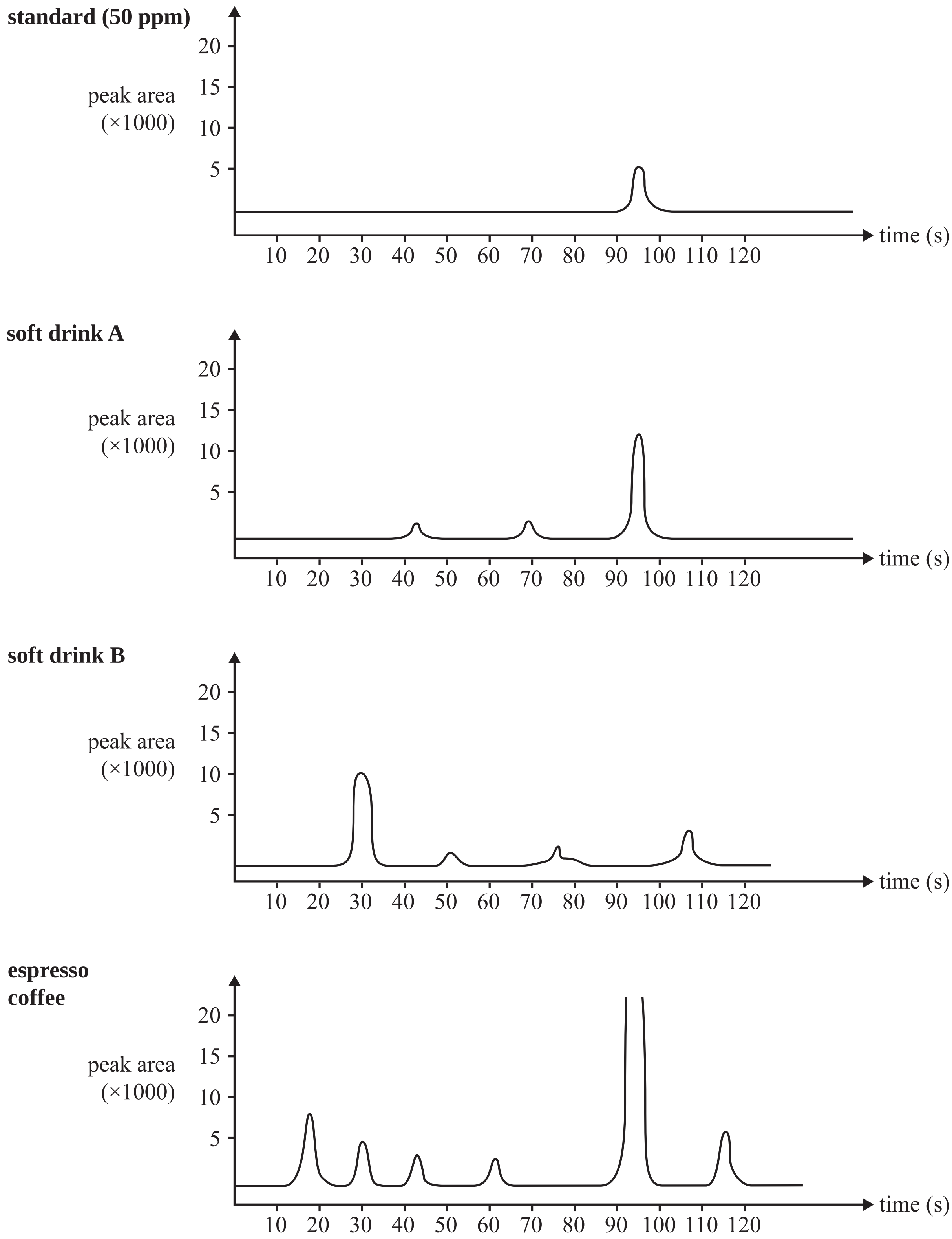
25μL samples of various drinks thought to contain caffeine were then separately passed through the HPLC column. The results are summarised below.

Sample	Retention time of major peak (seconds)	Peak area of largest peak
Soft drink A	96	12 000
Soft drink B	32	8 500
Espresso coffee	96	211 000

a. Determine the caffeine content, in ppm, of soft drink A.

1 mark

Chromatograms of 50 ppm standard caffeine solution, soft drink A, soft drink B and espresso coffee



b. What evidence is presented in the chromatogram that supports the conclusion that soft drink B does not contain any caffeine?

1 mark

c. **i.** Explain why the caffeine content of the espresso coffee sample cannot be reliably determined using the information provided.

ii. Describe what could be done to the espresso coffee sample so that its caffeine content can be reliably determined using the information provided.

1 + 1 = 2 marks

Total 4 marks

Question 4

Phosphorus is an essential ingredient in plant fertiliser. The phosphorus content in fertiliser can be determined as a percentage, by mass, of P_2O_5.

A 3.256 g sample of fertiliser is mixed with 40.0 mL of deionised water and the insoluble residue is then removed using vacuum filtration. 45.0 mL of 10% $MgSO_4.7H_2O$ solution is added to the filtrate followed by 150.0 mL of 2 M NH_3 solution. A white precipitate forms. This precipitate is filtered and washed with three 5 mL portions of deionised water. The final mass of the precipitate, once thoroughly dried, was 4.141 g. The formula of the precipitate is known to be $MgNH_4PO_4.6H_2O$. Assume that the experiment was conducted at 25 °C and that all the phosphorus had been precipitated as $MgNH_4PO_4.6H_2O$.

a. Calculate the percentage, by mass, of P_2O_5 in the fertiliser.

Molar mass of $MgNH_4PO_4.6H_2O$ = 245.3 g mol^{-1}. Molar mass of P_2O_5 = 142.0 g mol^{-1}.

4 marks

b. When $MgNH_4PO_4.6H_2O$ is heated above 100 °C it is completely converted to $MgNH_4PO_4$ according to the following equation.

$$MgNH_4PO_4.6H_2O(s) \rightarrow MgNH_4PO_4(s) + 6H_2O(g)$$

Would the calculated percentage by mass of P_2O_5 be higher, lower or the same as that determined in **part a.** if the precipitate collected had been deliberately heated above 100 °C to completely convert the precipitate to $MgNH_4PO_4$ before weighing? Explain your answer.

2 marks

Total 6 marks

Question 5

Glass made with the mineral tellurite, TeO_2 (M = 159.6 g mol^{-1}), is often used to manufacture optical fibres.

The amount of tellurite in an ore sample can be determined by reaction with acidified dichromate. In this reaction TeO_2 is converted to H_2TeO_4 and $Cr_2O_7^{2-}$ is converted to Cr^{3+}.

a. The half equation for the reduction of the $Cr_2O_7^{2-}$ ion is

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

i. Write a balanced half equation for the oxidation of TeO_2.

___

ii. Balance the chemical equation below by writing the coefficient of each chemical species in the spaces provided.

____ $TeO_2(s)$ + ____ $Cr_2O_7^{2-}(aq)$ + ____ $H^+(aq)$ → ____ $H_2TeO_4(aq)$ + ____ $Cr^{3+}(aq)$ + ____ $H_2O(l)$

1 + 1 = 2 marks

A 1.054 g ore sample containing tellurite is dissolved in acid. The resulting solution was then reacted with 50.00 mL of 0.03052 M potassium dichromate, $K_2Cr_2O_7$, solution to form telluric acid, H_2TeO_4.

The amount of unreacted dichromate ions, $Cr_2O_7^{2-}$, in the above reaction, was then determined by titrating the solution with 0.0525 M iron (II) nitrate, $Fe(NO_3)_2$, solution. An average titre volume of 19.71 mL was required to reach the equivalence point. The equation for this reaction is

$$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

b. **i.** Calculate the amount, in moles, of excess dichromate ion.

___

___

___

___

ii. Calculate the amount, in moles, of dichromate that reacted with the tellurite.

iii. Calculate the mass of tellurite in the ore sample.

2 + 2 + 2 = 6 marks

Total 8 marks

Question 6

a. **i.** The letters GATAC represent a part of the base sequence in one strand of DNA.

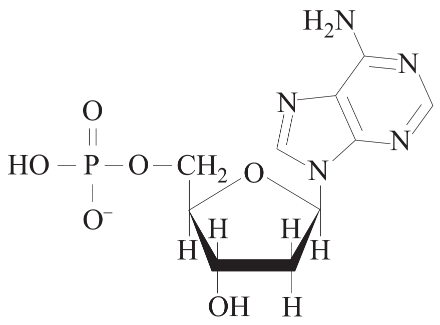
In the boxes provided write the base sequence of the complementary strand of DNA.

G	A	T	A	C

ii. Determine the number of hydrogen bonds between the base pairings in this section of DNA.

1 + 1 = 2 marks

Four different monomers known as nucleotides undergo condensation reactions to form a strand of DNA. The structure of one such nucleotide is shown below.



b. Name the reactants that have combined in condensation reactions to form this nucleotide.

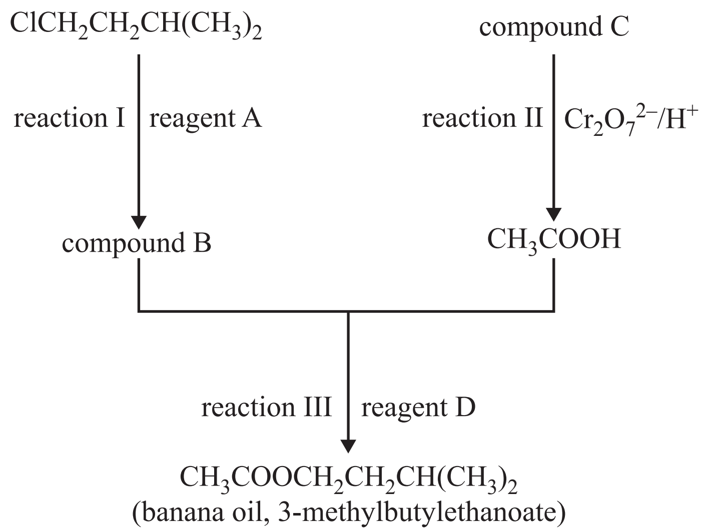
3 marks

Total 5 marks

Question 7

Banana oil, 3-methylbutylethanoate, $CH_3COOCH_2CH_2CH(CH_3)_2$, is a sweet smelling liquid that gives bananas their characteristic odour.

a. A chemist working for Go Bananas Pty Ltd has proposed the following reaction pathway for the synthesis of banana oil.



i. Identify reagent A.

____

ii. Compound B is an alcohol.
Draw a structure of compound B.

iii. Give the systematic name of compound B.

____

iv. Give the systematic name of compound C.

____

v. Identify reagent D.

____

vi. Which reaction is an oxidation reaction? Circle the correct answer below.

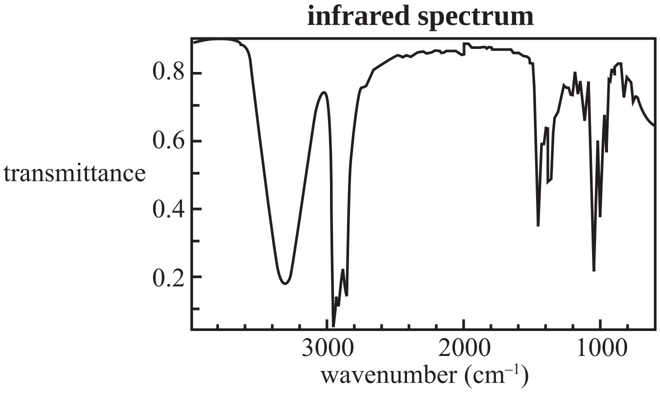
reaction I   reaction II   reaction III

1 + 1 + 1 + 1 + 1 + 1 = 6 marks

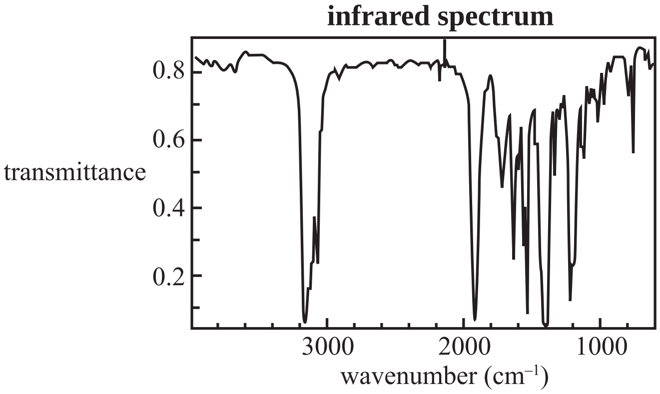
b. The chemist decided to use fractional distillation to separate the final product from the reaction mixture. Describe the principles of fraction distillation.

2 marks

The chemist compared the IR spectrum of the banana oil after distillation with the IR spectrum of a pure sample of compound B.



infrared spectrum of compound B



infrared spectrum of the banana oil obtained after distillation

The chemist claimed that these IR spectra indicate that a complete separation of the banana oil from the reaction mixture has been achieved.

c. Explain how the evidence provided by these spectra supports the chemist's claim.

2 marks

Total 10 marks

Question 8

Bradykinin is a peptide that lowers blood pressure.

Diagram I shows the amino acid sequence of bradykinin.

Arg–Pro–Pro–Gly–Phe–Ser–Pro–Phe–Arg

diagram I

Diagram II shows the structure of a section of the bradykinin molecule.

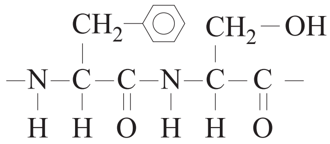


diagram II

a. On **diagram I**, circle the section of bradykinin that is represented in diagram II.

1 mark

b. Peptides can be completely hydrolysed to their component amino acids by treatment with 6 M HCl. Identify the two functional groups that are formed as a result of the hydrolysis of the peptide link.

2 marks

c. Draw the chemical structure, showing all bonds, of the amino acid glycine as it would exist in solution at pH = 1.

1 mark

Total 4 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2011

CHEMISTRY

Written examination

Wednesday 15 June 2011

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

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

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

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

2. The electrochemical series

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

3. Physical constants

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

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

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

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

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

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

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

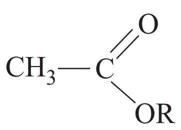
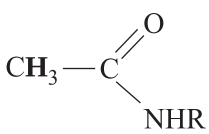
1 atm = 101.3 kPa = 760 mm Hg
0°C = 273 K

4. SI prefixes, their symbols and values

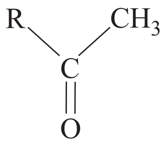
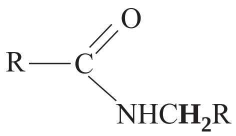
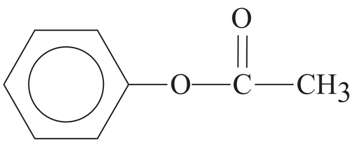
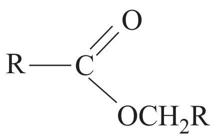
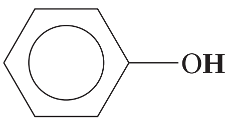
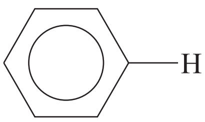
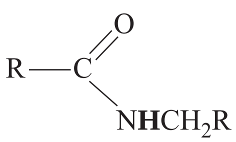
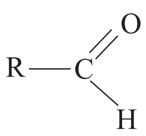
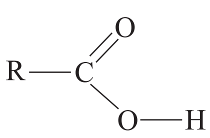
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

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

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

TURN OVER

Type of proton	Chemical shift (ppm)
	2.1
R–CH_2–X (X = F, Cl, Br or I)	3–4
R–C$\mathbf{H_2}$–OH	3.6
	3.2
R—O—CH_3 or R—O—CH_2R	3.3
	2.3
	4.1
R–O–H	1–6 (varies considerably under different conditions)
R–NH_2	1–5
RHC$=$C$\mathbf{H}_2$	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	11.5

6. ^{13}C NMR data

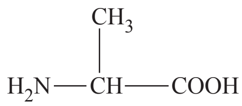
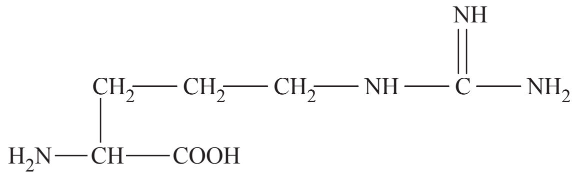
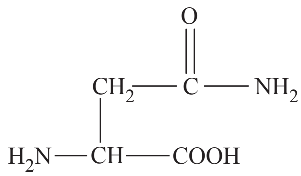
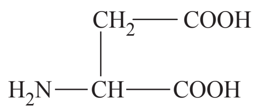
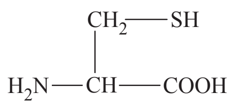
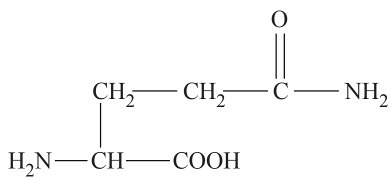
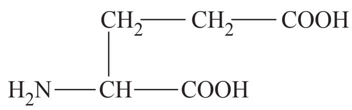
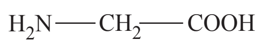
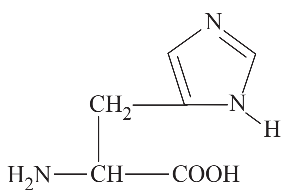
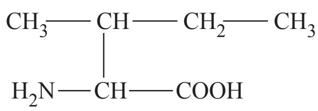
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C{=}CR_2$	110–150
RCOOH	160–185

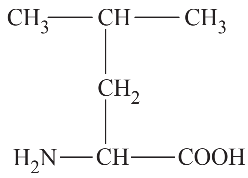
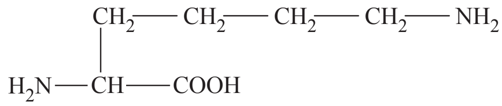
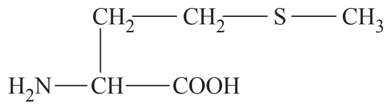
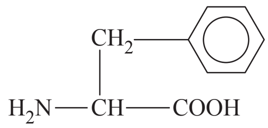
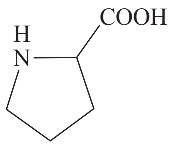
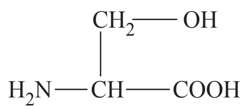
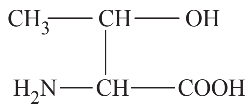
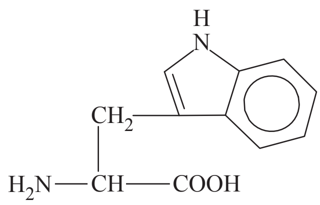
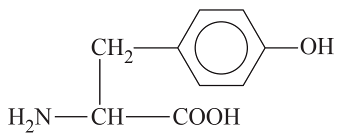
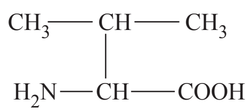
7. Infrared absorption data

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)

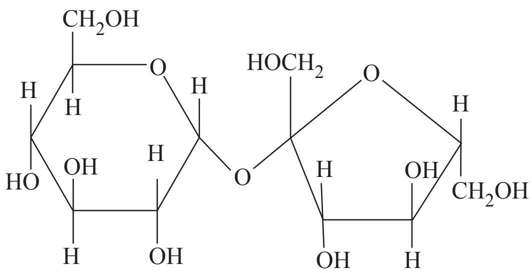
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

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

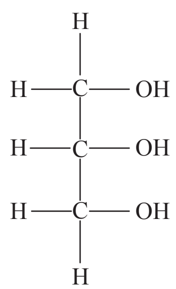
9. Formulas of some fatty acids

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

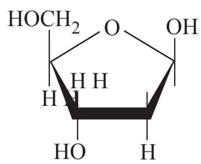
10. Structural formulas of some important biomolecules



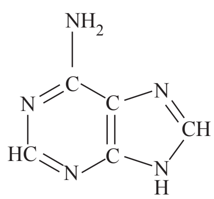
sucrose



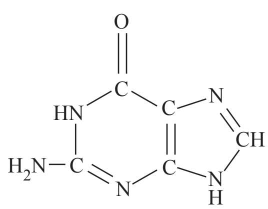
glycerol



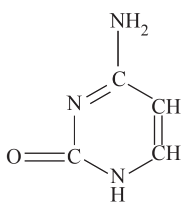
deoxyribose



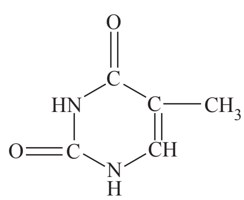
adenine



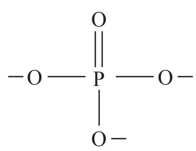
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

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

12. Acidity constants, K_a, of some weak acids 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}	l	–3509
hexane	C_6H_{14}	l	–4158
octane	C_8H_{18}	l	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	l	–725
ethanol	C_2H_5OH	l	–1364
1-propanol	$CH_3CH_2CH_2OH$	l	–2016
2-propanol	$CH_3CHOHCH_3$	l	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK

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Victoria