



# 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

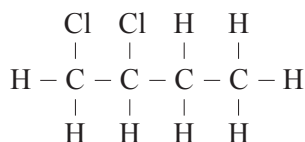
Which one of the following compounds is **least** soluble in water at room temperature?

- A. ethane
- B. ethanol
- C. ethylamine
- D. ethanoic acid

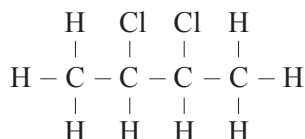
## Question 2

The structure of the product that is formed from the addition reaction between but-2-ene and chlorine,  $\text{Cl}_2$ , is

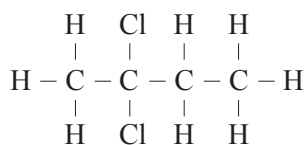
A.



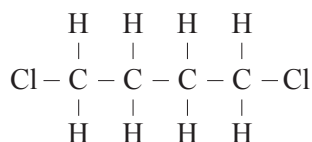
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C.



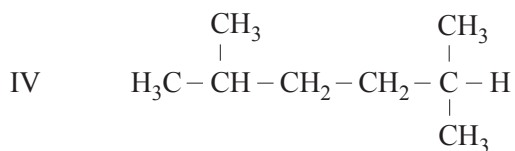
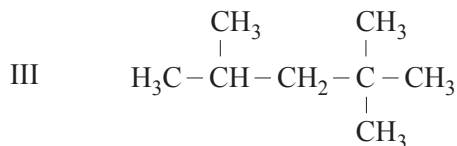
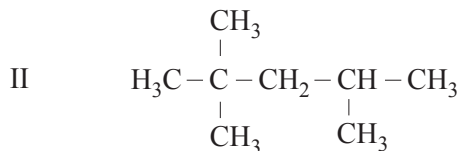
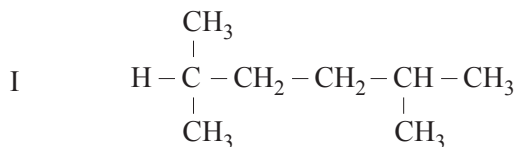
D.



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**Question 3**

Consider the following structures.



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

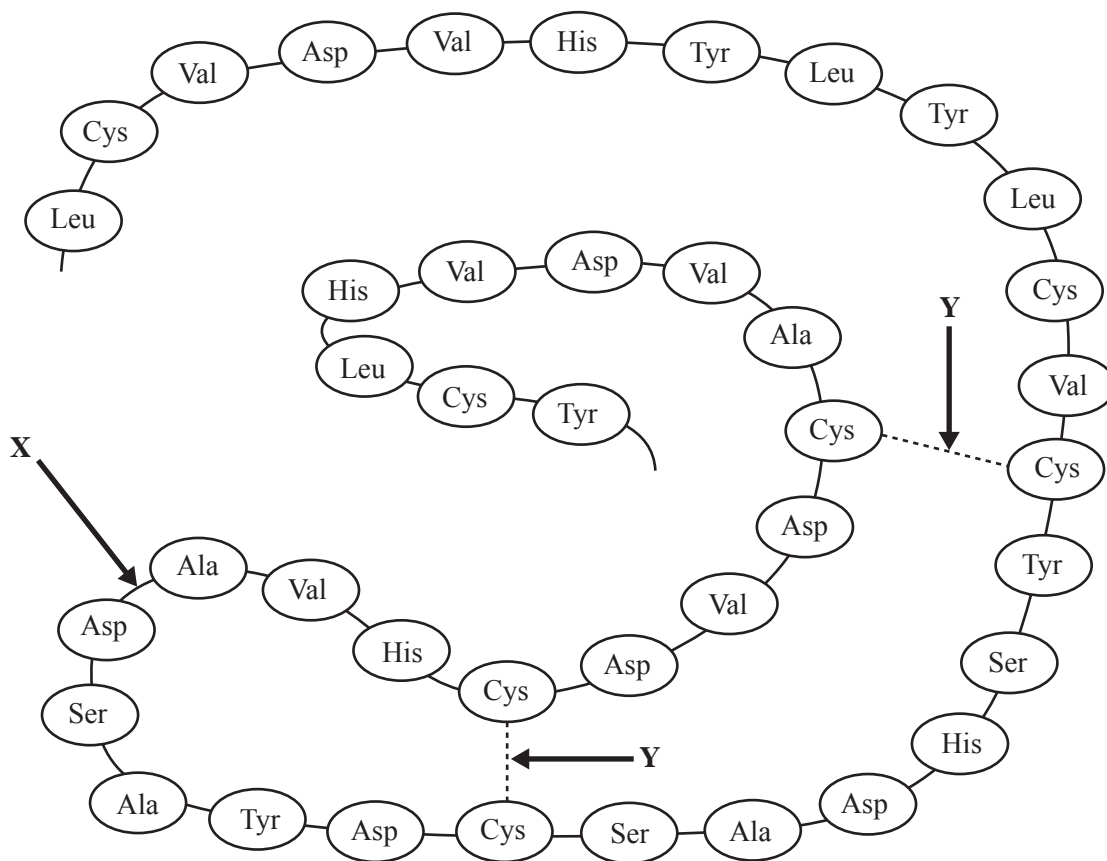
**Question 4**

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.

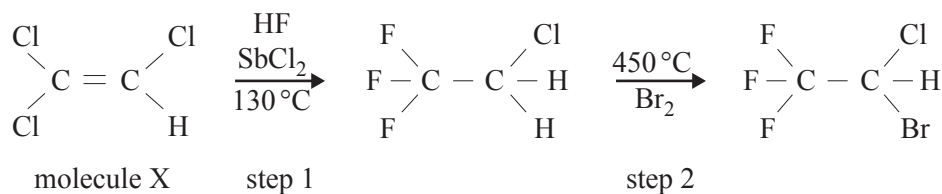
Which of these will react with 1.0 M HCl(aq)?

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

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**Question 7**

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

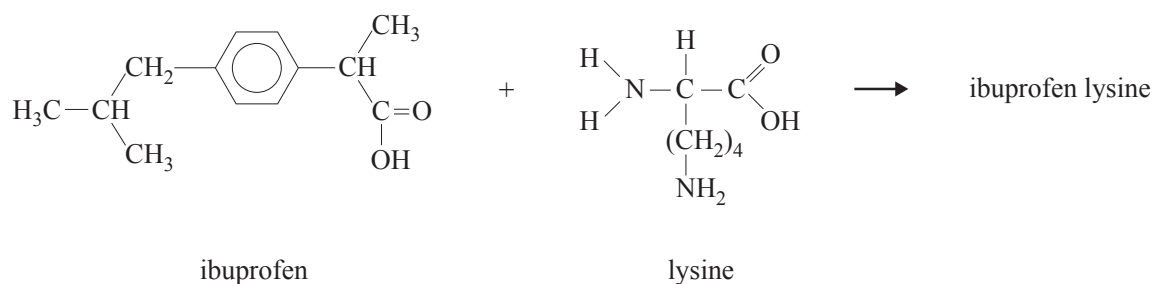


Which one of the following correctly identifies the type of reaction occurring in step 2 and correctly states the systematic name of molecule X?

	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.



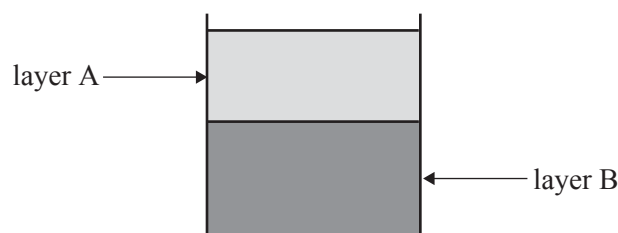
The structure of the ibuprofen lysine is

- A.
- $$\begin{array}{c}
 \text{CH}_3 \\
 | \\
 \text{CH}_3-\text{CH}-\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}-\text{C} \\
 | \quad \quad \quad | \\
 \text{CH}_3 \quad \quad \quad \text{OH} \\
 \text{C}=\text{O} \\
 \text{O} \\
 | \\
 \text{C}-\text{N}-(\text{CH}_2)_4-\text{C}-\text{H} \\
 || \quad | \quad | \\
 \text{O} \quad \text{H} \quad \text{OH} \\
 \text{NH}_2
 \end{array}$$
- B.
- $$\begin{array}{c}
 \text{CH}_3 \\
 | \\
 \text{CH}_3-\text{CH}-\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}-\text{C} \\
 | \quad \quad \quad | \\
 \text{CH}_3 \quad \quad \quad \text{O} \\
 \text{C}=\text{O} \\
 \text{O} \\
 | \\
 \text{C}-\text{O}-\text{C}-\text{C}-\text{NH}_2 \\
 || \quad || \quad | \\
 \text{O} \quad \text{O} \quad (\text{CH}_2)_4 \\
 | \\
 \text{NH}_2
 \end{array}$$
- C.
- $$\begin{array}{c}
 \text{CH}_3 \\
 | \\
 \text{CH}_3-\text{CH}-\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}-\text{C} \\
 | \quad \quad \quad | \\
 \text{CH}_3 \quad \quad \quad \text{H} \quad \text{OH} \\
 \text{C}=\text{O} \\
 \text{O} \\
 | \\
 \text{C}-\text{N}-\text{C}-\text{C}=\text{O} \\
 || \quad | \quad | \\
 \text{O} \quad \text{H} \quad (\text{CH}_2)_4 \\
 | \\
 \text{NH}_2
 \end{array}$$
- D.
- $$\begin{array}{c}
 \text{CH}_3 \\
 | \\
 \text{CH}_3-\text{CH}-\text{CH}_2-\text{C}_6\text{H}_4-\text{CH}-\text{C} \\
 | \quad \quad \quad | \\
 \text{CH}_3 \quad \quad \quad \text{O}^- \\
 \text{C}=\text{O} \\
 \text{O} \\
 \text{H}_3\text{N}^+(\text{CH}_2)_4-\text{C}-\text{C}=\text{O} \\
 | \quad | \\
 \text{NH}_2 \quad \text{OH}
 \end{array}$$

**NO WRITING ALLOWED IN THIS AREA**

**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.

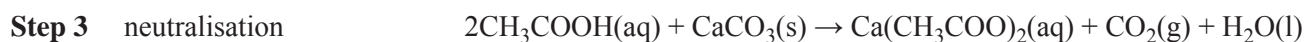
- I glycerol
- II potassium hydroxide
- III ethanol

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.

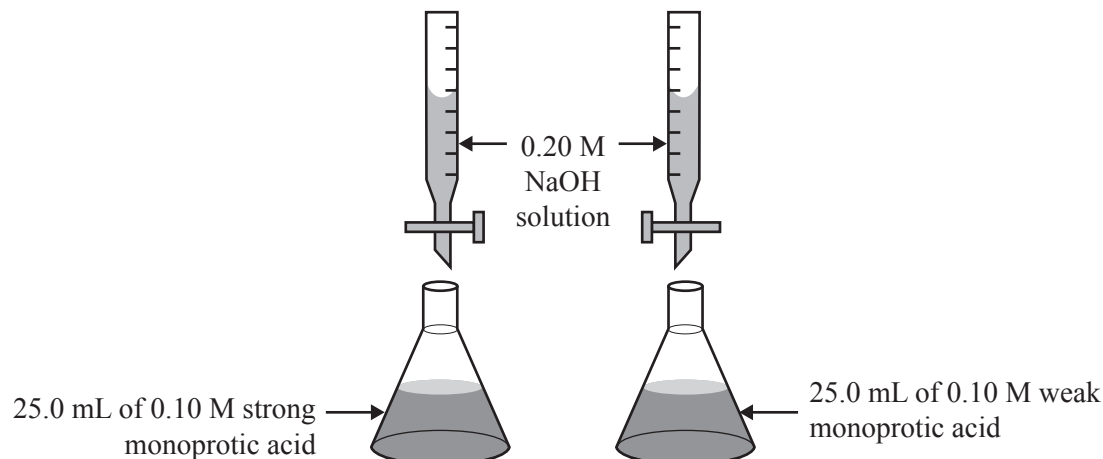


The ratio of the volume of methane produced to volume of carbon dioxide produced in the overall process is

- 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



**Question 13**

In an experiment, 172.1 g of gypsum,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ , ( $M = 172.1 \text{ g mol}^{-1}$ ), 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.  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{s}) \rightarrow \text{CaSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{g})$   
B.  $2\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{s}) \rightarrow 2\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}(\text{s}) + 3\text{H}_2\text{O}(\text{g})$   
C.  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{s}) \rightarrow \text{CaSO}_4 \cdot \text{H}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{g})$   
D.  $2\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{s}) \rightarrow 2\text{CaSO}_4 \cdot \frac{3}{2}\text{H}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{g})$

**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.  $\text{Cl}_2$   
C.  $\text{NO}_2$   
D.  $\text{SO}_2$

**Question 15**

Airbags are an important safety feature of today's cars. The airbag contains a mixture of solid sodium azide,  $\text{NaN}_3$ , and potassium nitrate,  $\text{KNO}_3$ . 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.



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  $36.6^\circ\text{C}$ . The molar mass of  $\text{NaN}_3$  is  $65.0 \text{ g mol}^{-1}$ .

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**

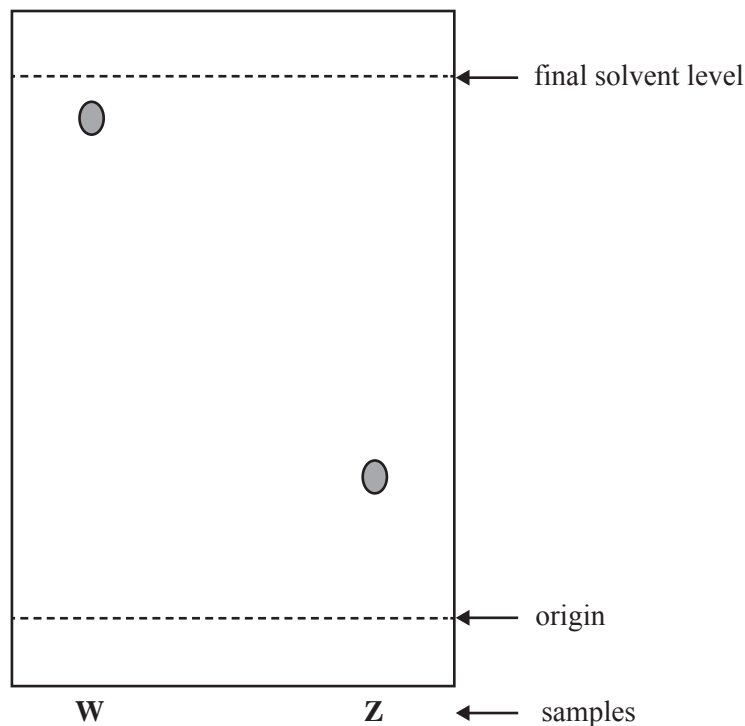
A starch molecule contains 500 glucose units.

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

- A.  $8982 \text{ g mol}^{-1}$
- B.  $81018 \text{ g mol}^{-1}$
- C.  $90000 \text{ g mol}^{-1}$
- D.  $98982 \text{ g mol}^{-1}$

**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 ( $1000 - 1300 \text{ cm}^{-1}$ ) is lower than for a C-H bond ( $2850 - 3300 \text{ cm}^{-1}$ ).

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.

**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  
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## SECTION B – Short answer questions

## Instructions for Section B

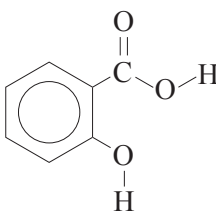
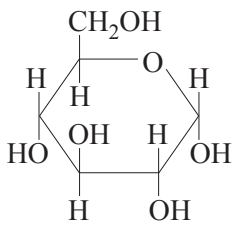
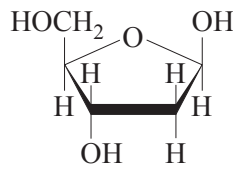
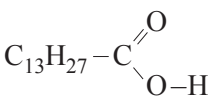
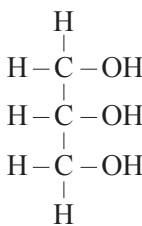
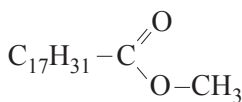
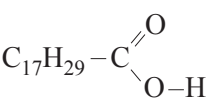
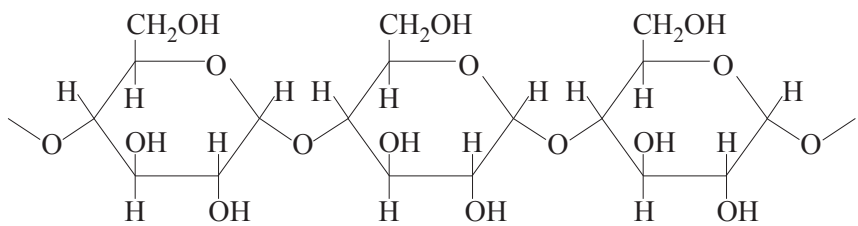
Answer **all** questions in the spaces provided. Write using black or blue pen.

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,  $\text{H}_2(\text{g})$ ;  $\text{NaCl}(\text{s})$

## Question 1

Below are the structures of a number of important molecules.

<p><b>A.</b></p> 	<p><b>B.</b></p> 	<p><b>C.</b></p> 
<p><b>D.</b></p> 	<p><b>E.</b></p> 	<p><b>F.</b></p> 
<p><b>G.</b></p> 	<p><b>H.</b></p> 	

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

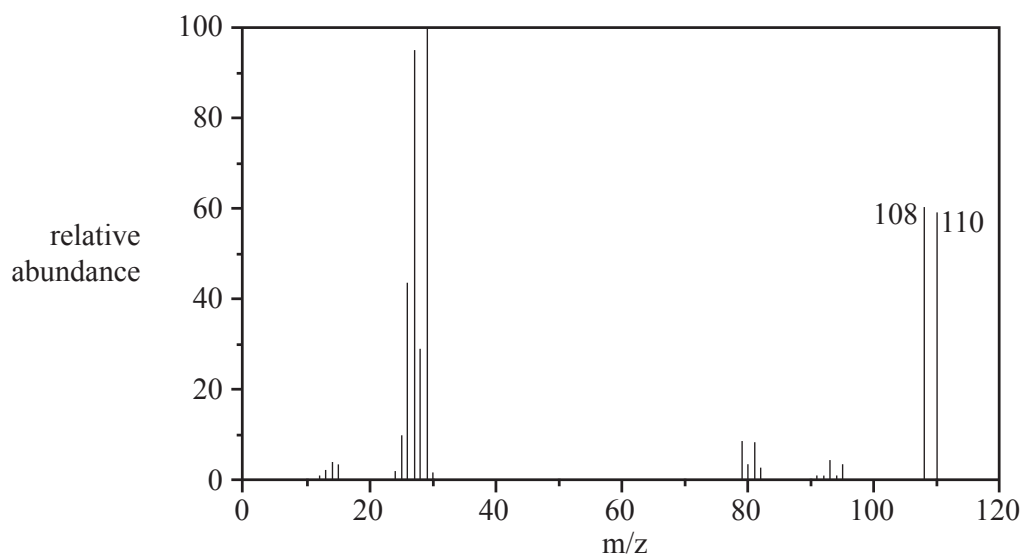
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SECTION B – continued  
TURN OVER

**Question 2**

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

The mass spectrum of bromoethane,  $\text{C}_2\text{H}_5\text{Br}$ , with two molecular ion peaks at  $m/z$  108 and 110, is shown below.



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

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

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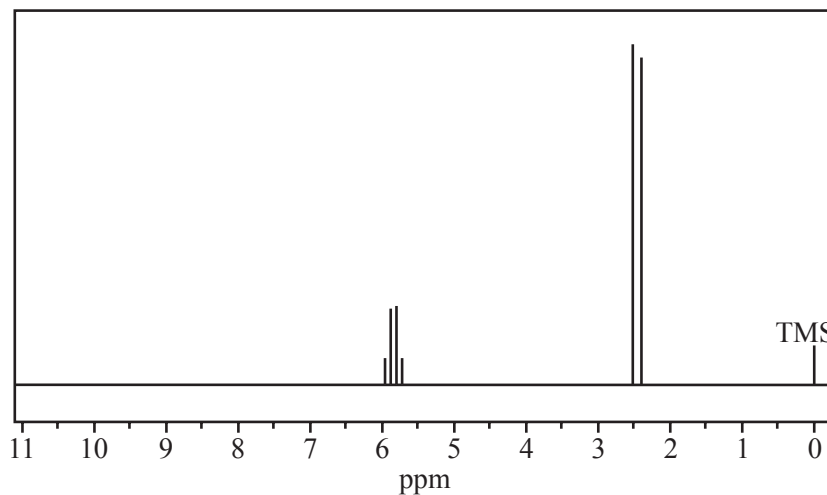
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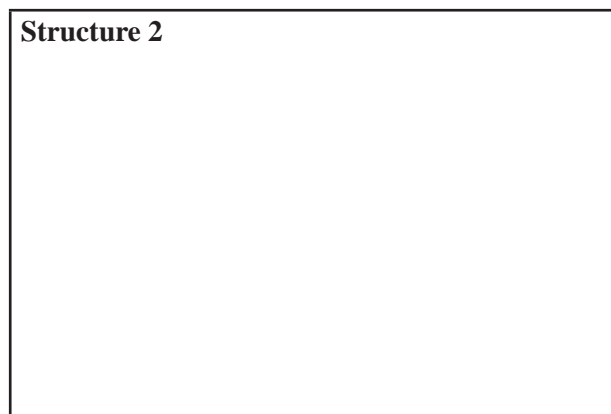
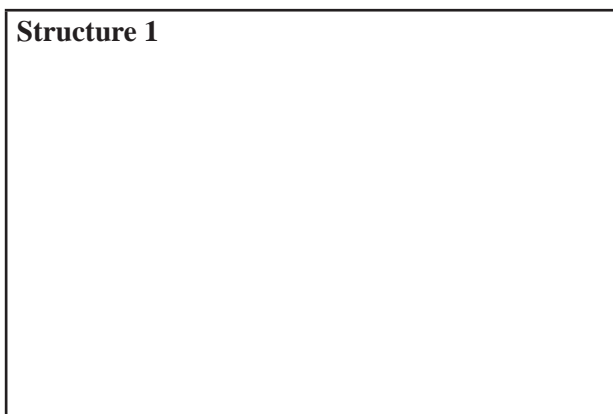
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1 + 2 = 3 marks

- b. There are two compounds that have the molecular formula  $C_2H_4Br_2$ .  
The  $^1H$  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  $C_2H_4Br_2$ .



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

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2 + 3 = 5 marks

Total 8 marks

**SECTION B – continued**  
**TURN OVER**

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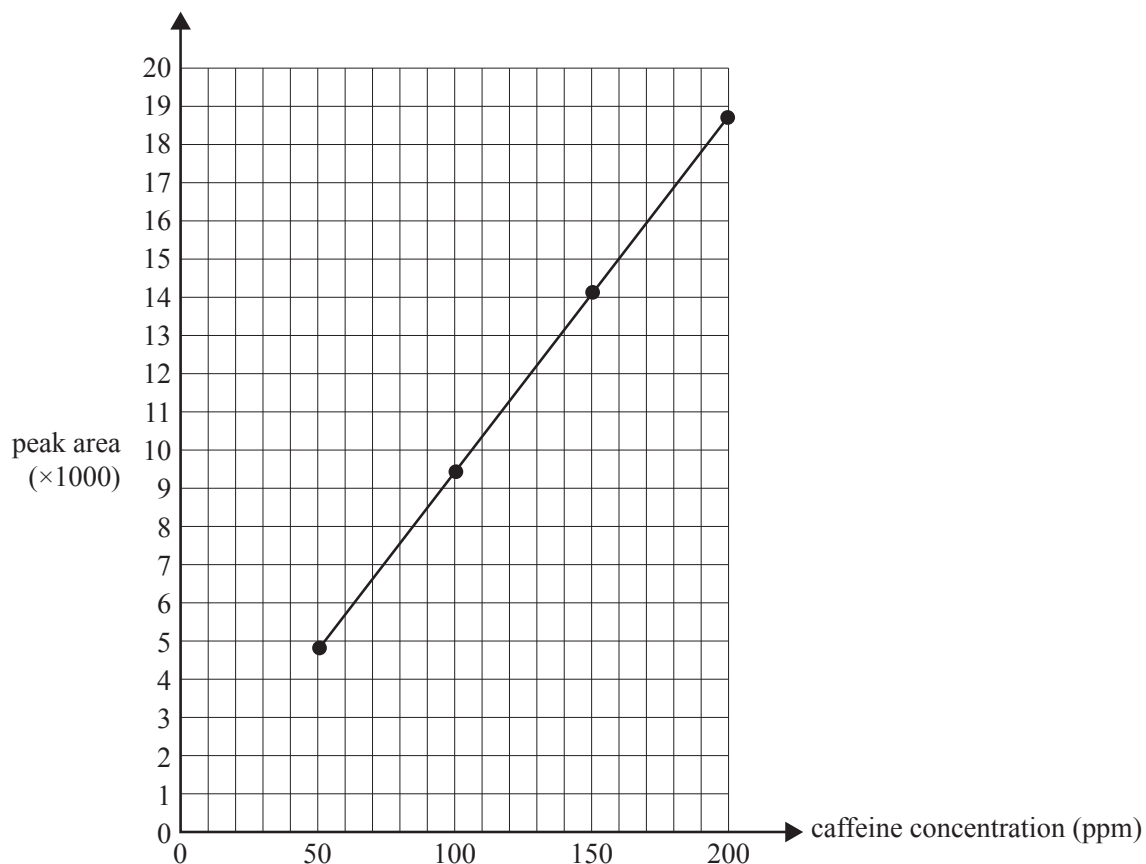
**Question 3**

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.  $25\mu\text{L}$  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.

Peak area of caffeine standard solutions: retention time = 96 seconds



$25\mu\text{L}$  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.

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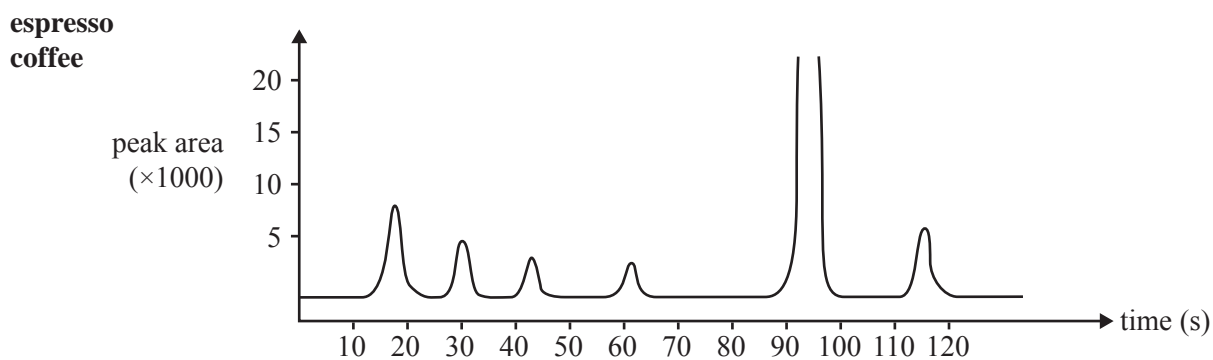
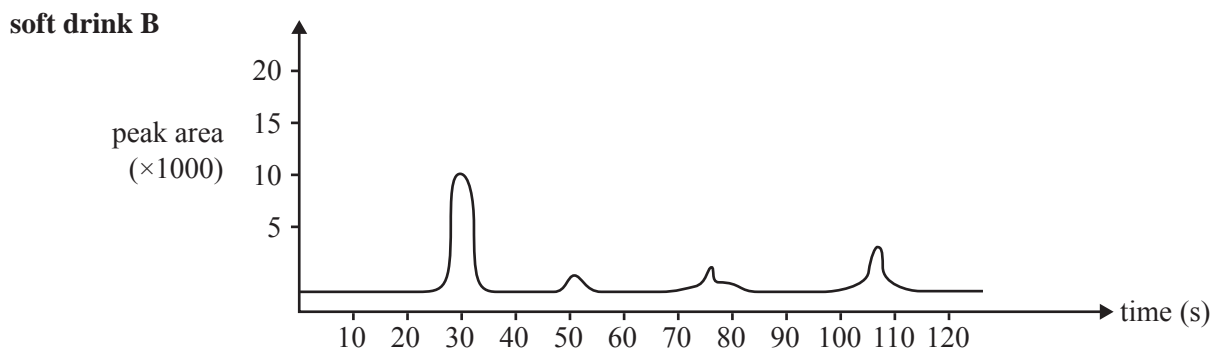
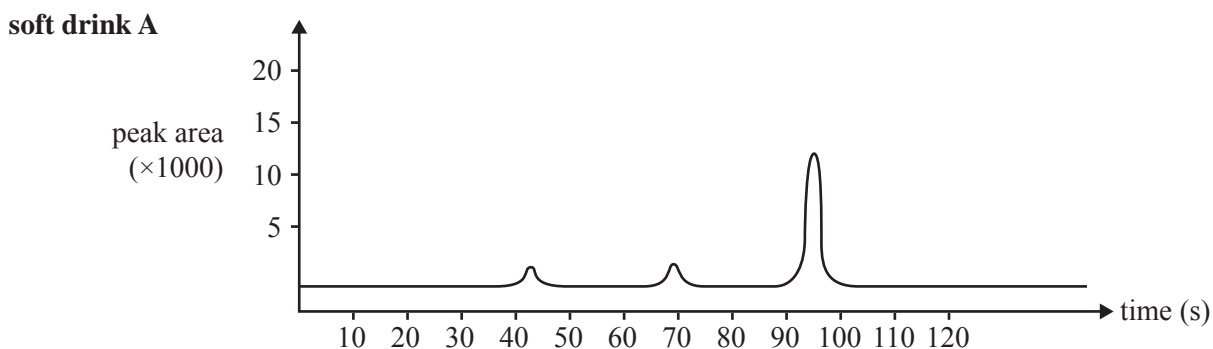
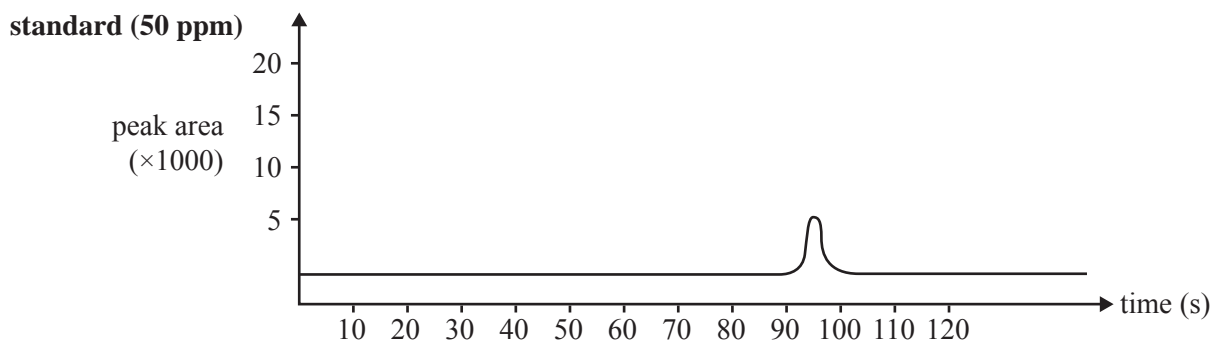


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1 mark



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



**NO WRITING ALLOWED IN THIS AREA**

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

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1 mark

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

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

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1 + 1 = 2 marks

Total 4 marks

**NO WRITING ALLOWED IN THIS AREA**

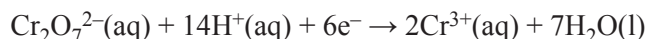


**Question 5**

Glass made with the mineral tellurite,  $\text{TeO}_2$  ( $M = 159.6 \text{ g mol}^{-1}$ ), 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  $\text{TeO}_2$  is converted to  $\text{H}_2\text{TeO}_4$  and  $\text{Cr}_2\text{O}_7^{2-}$  is converted to  $\text{Cr}^{3+}$ .

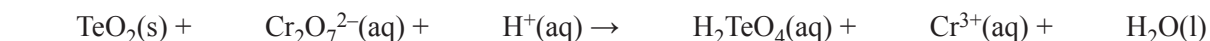
- a. The half equation for the reduction of the  $\text{Cr}_2\text{O}_7^{2-}$  ion is



- i. Write a balanced half equation for the oxidation of  $\text{TeO}_2$ .

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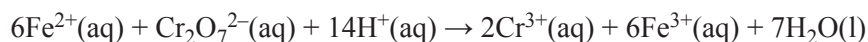
- ii. Balance the chemical equation below by writing the coefficient of each chemical species in the spaces provided.



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,  $\text{K}_2\text{Cr}_2\text{O}_7$ , solution to form telluric acid,  $\text{H}_2\text{TeO}_4$ .

The amount of unreacted dichromate ions,  $\text{Cr}_2\text{O}_7^{2-}$ , in the above reaction, was then determined by titrating the solution with 0.0525 M iron (II) nitrate,  $\text{Fe}(\text{NO}_3)_2$ , solution. An average titre volume of 19.71 mL was required to reach the equivalence point. The equation for this reaction is



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

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

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

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2 + 2 + 2 = 6 marks

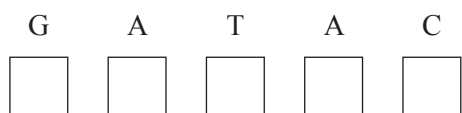
Total 8 marks

NO WRITING ALLOWED IN THIS AREA

SECTION B – continued  
TURN OVER

**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.



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

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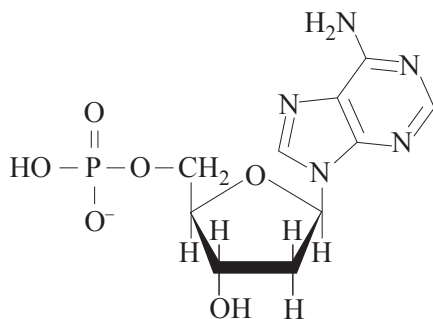
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1 + 1 = 2 marks

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.

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3 marks

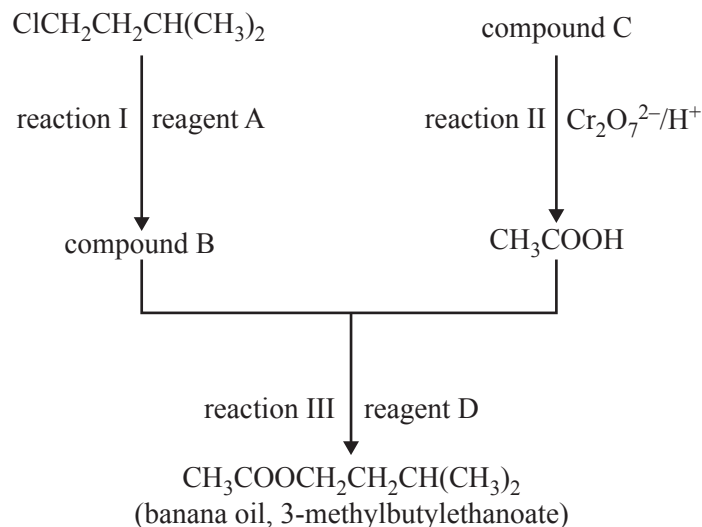
Total 5 marks

**NO WRITING ALLOWED IN THIS AREA**

**Question 7**

Banana oil, 3-methylbutylethanoate,  $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$ , 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.

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- ii. Compound B is an alcohol.

Draw a structure of compound B.

- iii. Give the systematic name of compound B.

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- iv. Give the systematic name of compound C.

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- v. Identify reagent D.

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- 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

**SECTION B – Question 7 – continued**

**TURN OVER**

NO WRITING ALLOWED IN THIS AREA

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

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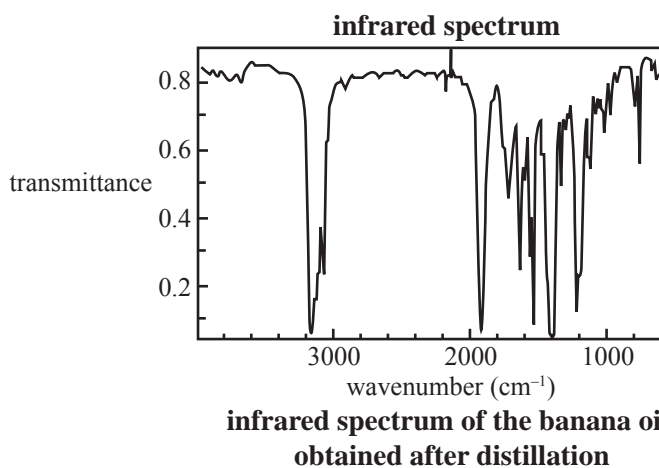
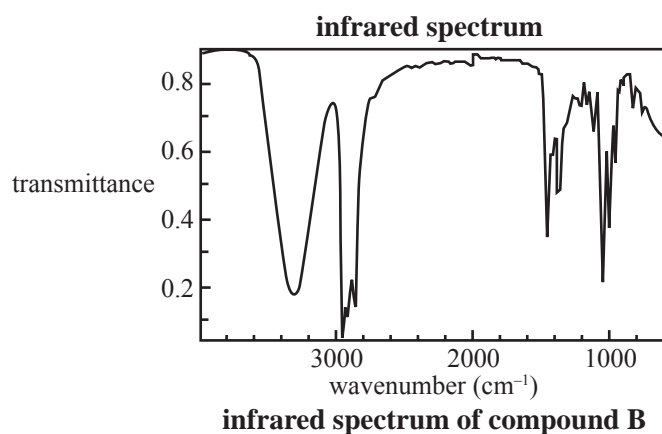
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2 marks

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



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.

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2 marks

Total 10 marks



**Question 8**

Bradykinin is a peptide that lowers blood pressure.

Diagram I shows the amino acid sequence of bradykinin.



diagram I

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

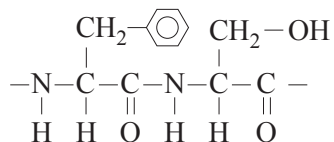


diagram II

- 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



**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.**

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## 1. Periodic table of the elements

1 <b>H</b> Hydrogen 1.0		2 <b>He</b> Helium 4.0	
3 <b>Li</b> Lithium 6.9		4 <b>Be</b> Beryllium 9.0	
11 <b>Na</b> Sodium 23.0		12 <b>Mg</b> Magnesium 24.3	
19 <b>K</b> Potassium 39.1		20 <b>Ca</b> Calcium 40.1	
37 <b>Rb</b> Rubidium 85.5		38 <b>Sr</b> Strontium 87.6	
55 <b>Cs</b> Caesium 132.9		56 <b>Ba</b> Barium 137.3	
87 <b>Fr</b> Francium (223)		88 <b>Ra</b> Radium (226)	
21 <b>Sc</b> Scandium 44.9		22 <b>Ti</b> Titanium 47.9	
39 <b>Y</b> Yttrium 88.9		40 <b>Zr</b> Zirconium 91.2	
71 <b>Lu</b> Lutetium 174.9		72 <b>Hf</b> Hafnium 178.5	
89 <b>Ac</b> Actinium (227)		90 <b>Th</b> Thorium 232.0	
103 <b>Lr</b> Lawrencium (262)		104 <b>Rf</b> Rutherfordium (261)	
105 <b>Db</b> Dubnium (262)		106 <b>Sg</b> Seaborgium (266)	
107 <b>Bh</b> Bohrium (264)		108 <b>Hs</b> Hassium (277)	
111 <b>Rg</b> Roentgenium (272)		112 <b>Uub</b> Ununbium (285)	
113 <b>Nh</b> Nihonium (284)		114 <b>Uuq</b> Ununquadium (289)	
115 <b>Mt</b> Meitnerium (276)		116 <b>Uuh</b> Ununhexium (288)	
117 <b>Ts</b> Tennessine (289)		118 <b>Uuo</b> Ununoctium (289)	
119 <b>Uue</b> Ununennium (289)		120 <b>Uuq</b> Ununquadium (289)	
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397 <b>Ubu</b> Ununbium (289)		398 <b>Uub</b> Ununbium (289)	
399 <b>Ubu</b> Ununbium (289)		400 <b>Uub</b> Ununbium (289)	
401 <b>Ubu</b> Ununbium (289)		402 <b>Uub</b> Ununbium (289)	
403 <b>Ubu</b> Ununbium (289)		404 <b>Uub</b> Ununbium (289)	
405 <b>Ubu</b> Ununbium (289)		406 <b>Uub</b> Ununbium (289)	
407 <b>Ubu</b> Ununbium (289)		408 <b>Uub</b> Ununbium (289)	
409 <b>Ubu</b> Ununbium (289)		410 <b>Uub</b> Ununbium (289)	
411 <b>Ubu</b> Ununbium (289)		412 <b>Uub</b> Ununbium (289)	
413 <b>Ubu</b> Ununbium (289)		414 <b>Uub</b> Ununbium (289)	
415 <b>Ubu</b> Ununbium (289)		416 <b>Uub</b> Ununbium (289)	
417 <b>Ubu</b> Ununbium (289)		418 <b>Uub</b> Ununbium (289)	
419 <b>Ubu</b> Ununbium (289)		420 <b>Uub</b> Ununbium (289)	

**2. The electrochemical series**

	$E^\circ$ in volt
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$	+2.87
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{Au}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.68
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	+1.09
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightleftharpoons 4\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{S}(\text{s}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0.14
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.23
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.03
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.67
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.34
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.02

### 3. Physical constants

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

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

Faraday constant ( $F$ ) =  $96\,500 \text{ C mol}^{-1}$

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

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

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

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

Specific heat capacity ( $c$ ) of water =  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

Density ( $d$ ) of water at 25°C =  $1.00 \text{ g mL}^{-1}$

1 atm = 101.3 kPa = 760 mm Hg

0°C = 273 K

### 4. SI prefixes, their symbols and values

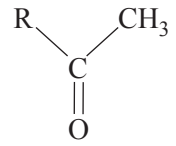
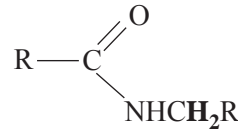
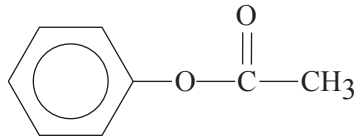
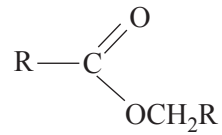
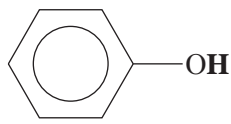
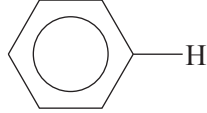
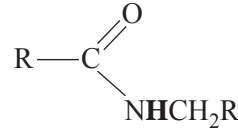
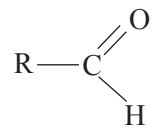
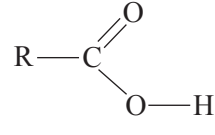
SI prefix	Symbol	Value
giga	G	$10^9$
mega	M	$10^6$
kilo	k	$10^3$
deci	d	$10^{-1}$
centi	c	$10^{-2}$
milli	m	$10^{-3}$
micro	$\mu$	$10^{-6}$
nano	n	$10^{-9}$
pico	p	$10^{-12}$

### 5. $^1\text{H}$ 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 <sub>3</sub>	0.9
R-CH <sub>2</sub> -R	1.3
RCH = CH- <b>CH<sub>3</sub></b>	1.7
R <sub>3</sub> -CH	2.0
$\text{CH}_3-\text{C} \begin{array}{l} \text{=O} \\ \text{OR} \end{array}$ or $\text{CH}_3-\text{C} \begin{array}{l} \text{=O} \\ \text{NHR} \end{array}$	2.0

Type of proton	Chemical shift (ppm)
	2.1
R-CH <sub>2</sub> -X (X = F, Cl, Br or I)	3-4
R-CH <sub>2</sub> -OH	3.6
	3.2
R-O-CH <sub>3</sub> or R-O-CH <sub>2</sub> R	3.3
	2.3
	4.1
R-O-H	1-6 (varies considerably under different conditions)
R-NH <sub>2</sub>	1-5
RHC = CH <sub>2</sub>	4.6-6.0
	7.0
	7.3
	8.1
	9-10
	11.5

**6.  $^{13}\text{C}$  NMR data**

Type of carbon	Chemical shift (ppm)
R-CH <sub>3</sub>	8–25
R-CH <sub>2</sub> -R	20–45
R <sub>3</sub> -CH	40–60
R <sub>4</sub> -C	36–45
R-CH <sub>2</sub> -X	15–80
R <sub>3</sub> C-NH <sub>2</sub>	35–70
R-CH <sub>2</sub> -OH	50–90
RC≡CR	75–95
R <sub>2</sub> C=CR <sub>2</sub>	110–150
RCOOH	160–185

**7. Infrared absorption data**

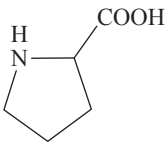
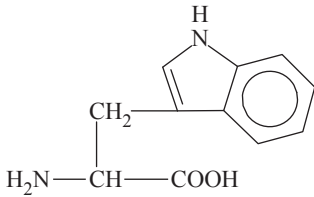
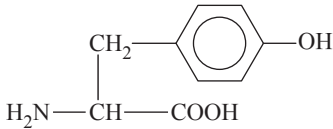
Characteristic range for infrared absorption

Bond	Wave number (cm <sup>-1</sup> )
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 ( $\alpha$ -amino acids)**

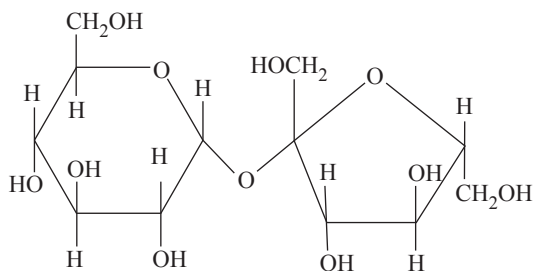
Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{NH} \\    \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}-\text{NH}_2 \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
asparagine	Asn	$\begin{array}{c} \text{O} \\    \\ \text{CH}_2-\text{C}-\text{NH}_2 \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
aspartic acid	Asp	$\begin{array}{c} \text{CH}_2-\text{COOH} \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
cysteine	Cys	$\begin{array}{c} \text{CH}_2-\text{SH} \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamine	Gln	$\begin{array}{c} \text{O} \\    \\ \text{CH}_2-\text{CH}_2-\text{C}-\text{NH}_2 \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamic acid	Glu	$\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{COOH} \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glycine	Gly	$\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$
histidine	His	$\begin{array}{c} \text{N} \\ // \quad \backslash \\ \text{CH}_2-\text{C} \quad \text{N}-\text{H} \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
isoleucine	Ile	$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_3 \\   \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$

Name	Symbol	Structure
leucine	Leu	$  \begin{array}{c}  \text{CH}_3 - \text{CH} - \text{CH}_3 \\    \\  \text{CH}_2 \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
lysine	Lys	$  \begin{array}{c}  \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH}_2 \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
methionine	Met	$  \begin{array}{c}  \text{CH}_2 - \text{CH}_2 - \text{S} - \text{CH}_3 \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
phenylalanine	Phe	$  \begin{array}{c}  \text{CH}_2 - \text{C}_6\text{H}_5 \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
proline	Pro	
serine	Ser	$  \begin{array}{c}  \text{CH}_2 - \text{OH} \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
threonine	Thr	$  \begin{array}{c}  \text{CH}_3 - \text{CH} - \text{OH} \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	$  \begin{array}{c}  \text{CH}_3 - \text{CH} - \text{CH}_3 \\    \\  \text{H}_2\text{N} - \text{CH} - \text{COOH}  \end{array}  $

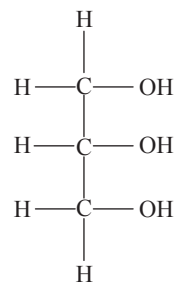
### 9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

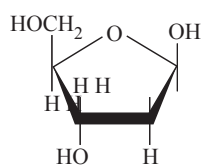
### 10. Structural formulas of some important biomolecules



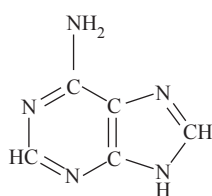
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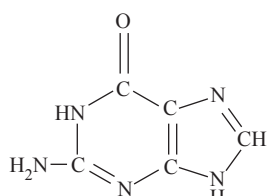
glycerol



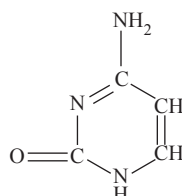
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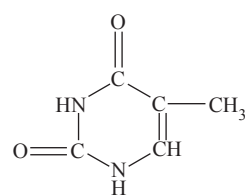
adenine



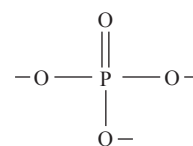
guanine



cytosine



thymine



phosphate

## 11. Acid-base indicators

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

12. Acidity constants,  $K_a$ , of some weak acids at 25°C

Name	Formula	$K_a$
Ammonium ion	$\text{NH}_4^+$	$5.6 \times 10^{-10}$
Benzoic	$\text{C}_6\text{H}_5\text{COOH}$	$6.4 \times 10^{-5}$
Boric	$\text{H}_3\text{BO}_3$	$5.8 \times 10^{-10}$
Ethanoic	$\text{CH}_3\text{COOH}$	$1.7 \times 10^{-5}$
Hydrocyanic	$\text{HCN}$	$6.3 \times 10^{-10}$
Hydrofluoric	$\text{HF}$	$7.6 \times 10^{-4}$
Hypobromous	$\text{HOBr}$	$2.4 \times 10^{-9}$
Hypochlorous	$\text{HOCl}$	$2.9 \times 10^{-8}$
Lactic	$\text{HC}_3\text{H}_5\text{O}_3$	$1.4 \times 10^{-4}$
Methanoic	$\text{HCOOH}$	$1.8 \times 10^{-4}$
Nitrous	$\text{HNO}_2$	$7.2 \times 10^{-4}$
Propanoic	$\text{C}_2\text{H}_5\text{COOH}$	$1.3 \times 10^{-5}$

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

Substance	Formula	State	$\Delta H_c$ (kJ mol <sup>-1</sup> )
hydrogen	$\text{H}_2$	g	-286
carbon (graphite)	C	s	-394
methane	$\text{CH}_4$	g	-889
ethane	$\text{C}_2\text{H}_6$	g	-1557
propane	$\text{C}_3\text{H}_8$	g	-2217
butane	$\text{C}_4\text{H}_{10}$	g	-2874
pentane	$\text{C}_5\text{H}_{12}$	l	-3509
hexane	$\text{C}_6\text{H}_{14}$	l	-4158
octane	$\text{C}_8\text{H}_{18}$	l	-5464
ethene	$\text{C}_2\text{H}_4$	g	-1409
methanol	$\text{CH}_3\text{OH}$	l	-725
ethanol	$\text{C}_2\text{H}_5\text{OH}$	l	-1364
1-propanol	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	l	-2016
2-propanol	$\text{CH}_3\text{CHOHCH}_3$	l	-2003
glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	s	-2816

