VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2013

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures									Letter
Words									

CHEMISTRY

Written examination

Tuesday 12 November 2013

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	11	11	90
			Total 120

- 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 32 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

Consider the following.

'Calculate the pressure exerted by 6.9 g of argon in a 0.07500 L container at 11.5 °C.'

The number of significant figures that should be expressed in the answer is

A. 2

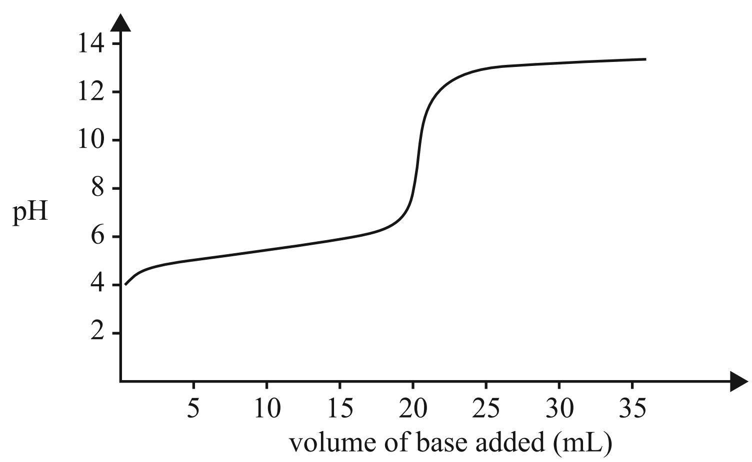
B. 3

C. 4

D. 5

Question 2

The change in pH as a 0.10 M solution of a strong base is added to 20.0 mL of a 0.10 M solution of a weak acid is shown below.



Refer to the acid-base indicator data provided in the data book and identify the indicator that would be **least suitable** to detect the end point of this neutralisation.

A. phenol red

B. thymol blue

C. phenolphthalein

D. bromothymol blue

Question 3

In a titration, a 25.00 mL titre of 1.00 M hydrochloric acid neutralised a 20.00 mL aliquot of sodium hydroxide solution.

If, in repeating the titration, a student failed to rinse one of the pieces of glassware with the appropriate solution, the titre would be

A. equal to 25.00 mL if water was left in the titration flask after final rinsing.

B. less than 25.00 mL if the final rinsing of the burette is with water rather than the acid.

C. greater than 25.00 mL if the final rinsing of the 20.00 mL pipette is with water rather than the base.

D. greater than 25.00 mL if the titration flask had been rinsed with the acid prior to the addition of the aliquot.

Question 4

In volumetric analysis, the properties of the reactants, as well as the nature of the reaction between them, will determine if a back titration is to be used.

Consider the following cases.

I The substance being analysed is volatile.

II The substance being analysed is insoluble in water but is soluble in dilute acid.

III The end point of the reaction is difficult to detect.

In which cases would a back titration be more suitable than a simple forward titration?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Question 5

Two identical flasks, A and B, contain, respectively, 5.0 g of N_2 gas and 14.4 g of an unknown gas. The gases in both flasks are at standard laboratory conditions (SLC).

The gas in flask B is

A. H_2

B. SO_2

C. HBr

D. C_4H_{10}

Question 6

Which one of the following reactions is a redox reaction?

A. $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

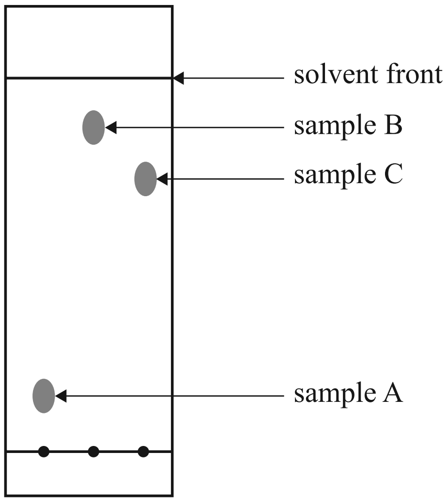
B. $Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$

C. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

D. $CH_3OH(l) + HCOOH(l) \rightarrow HCOOCH_3(l) + H_2O(l)$

Question 7

The thin layer chromatography plate shown below has a polar stationary phase. It was developed using hexane as the solvent.



Which sample has the most polar molecules?

A. sample A

B. sample B

C. sample C

D. There is not enough information to determine which sample has the most polar molecules.

Question 8

A forensic chemist tests mud from a crime scene to determine whether the mud contains zinc.

Which one of the following analytical techniques would be best suited to this task?

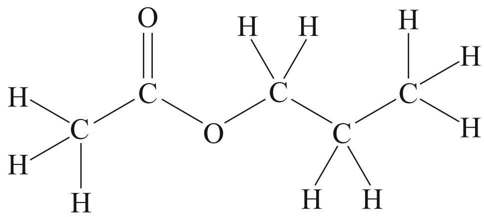
A. infrared spectroscopy

B. thin layer chromatography

C. atomic absorption spectroscopy

D. nuclear magnetic resonance spectroscopy

Question 9



The systematic IUPAC name for the molecule shown above is

A. ethyl ethanoate.

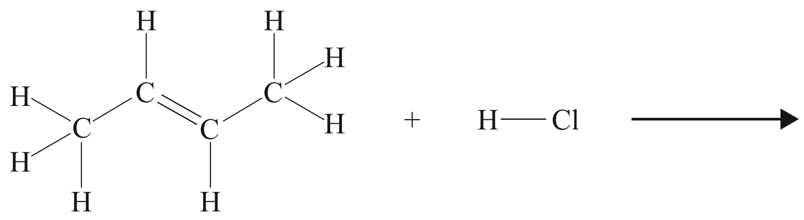
B. ethyl propanoate.

C. propyl ethanoate.

D. methyl propanoate.

NO WRITING ALLOWED IN THIS AREA

Question 10



The systematic IUPAC name for the product of the above chemical reaction is

A. 1-chlorobutane.

B. 2-chlorobutane.

C. 3-chlorobutane.

D. 4-chlorobutane.

Question 11

Australian jellyfish venom is a mixture of proteins for which there is no antivenom. Jellyfish stings are painful, can leave scars and, in some circumstances, can cause death.

Some commercially available remedies disrupt ionic interactions between the side chains on amino acid residues.

These products most likely disrupt the protein's

A. primary structure only.

B. secondary structure only.

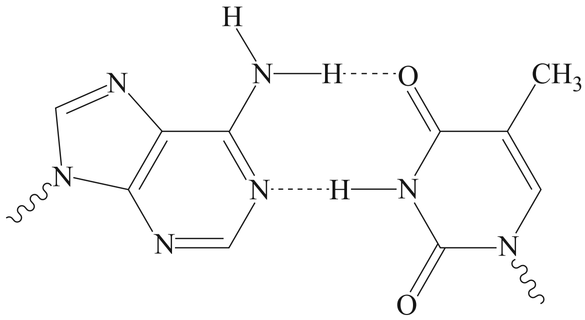
C. tertiary structure only.

D. primary, secondary and tertiary structures.

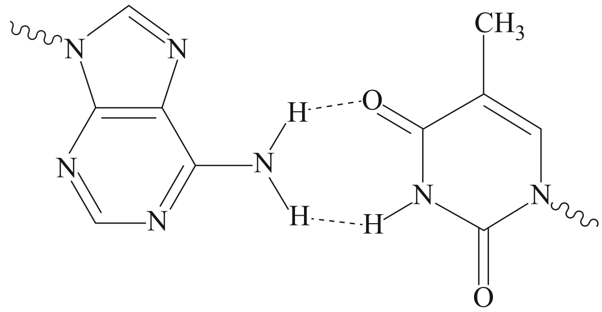
Question 12

Which figure best represents the bonding between adenine and thymine in the structure of DNA?

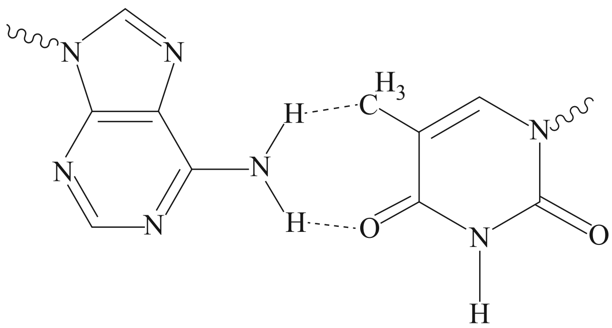
A.



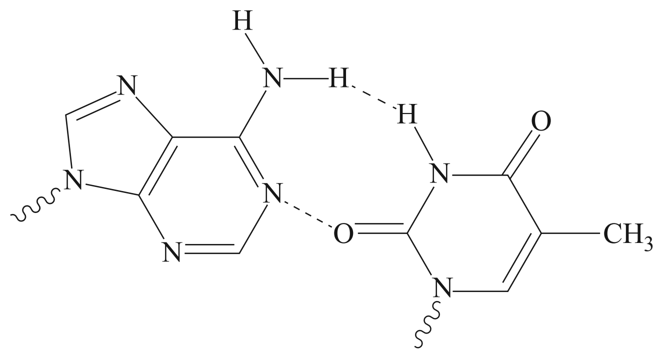
B.



C.

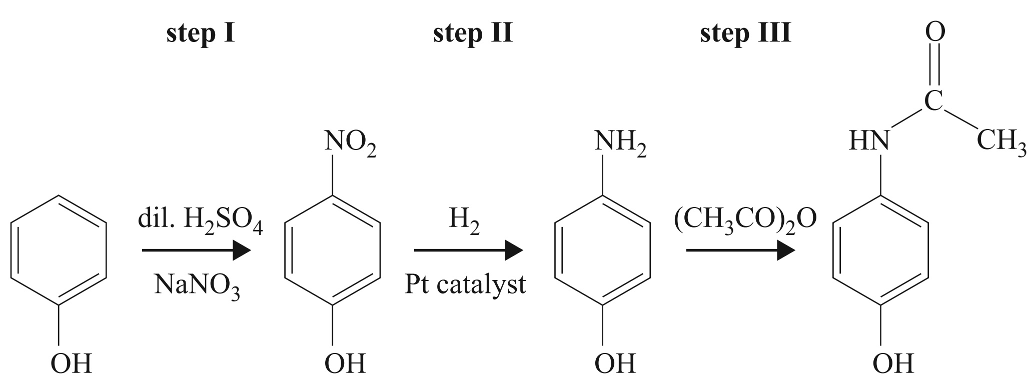


D.



Question 13

The reaction pathway for the synthesis of paracetamol, a mild painkiller, is provided below.



phenol paracetamol

Which step or steps in this synthesis involve(s) a reduction reaction?

A. step I only

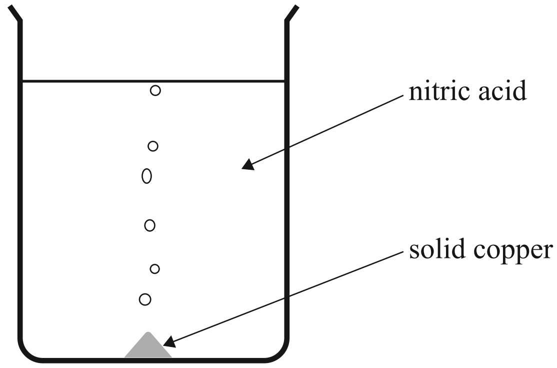
B. step II only

C. steps I and III only

D. steps I, II and III

Use the following information to answer Questions 14 and 15.

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$



Question 14

Which one of the following will **not** increase the rate of the above reaction?

A. decreasing the size of the solid copper particles

B. increasing the temperature of HNO_3 by 20 °C

C. increasing the concentration of HNO_3

D. allowing NO_2 gas to escape

Question 15

In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions.

The **major** reason for this is that

A. the nitric acid is ionised in solution.

B. some reactant particles have too much kinetic energy.

C. the kinetic energy of the particles is reduced when they collide with the container's walls.

D. not all reactant particles have the minimum kinetic energy required to initiate the reaction.

Question 16

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -393.5 \text{ kJ mol}^{-1}$$

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -571.6 \text{ kJ mol}^{-1}$$

Given the information above, what is the enthalpy change for the following reaction?

$$C(s) + 2H_2O(l) \rightarrow CO_2(g) + 2H_2(g)$$

A. -965.1 kJ mol^{-1}

B. -107.7 kJ mol^{-1}

C. $+178.1$ kJ mol^{-1}

D. $+679.3$ kJ mol^{-1}

Use the following information to answer Questions 17 and 18.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H \text{ is positive.}$$

Question 17

The equilibrium expression for this reaction is

A. $\dfrac{2[NO][Cl_2]}{2[NOCl]}$

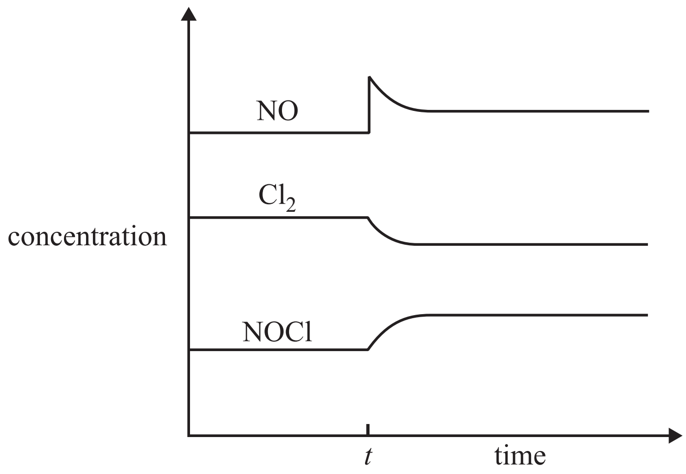
B. $\dfrac{[NO]^2[Cl_2]}{[NOCl]^2}$

C. $\dfrac{2[NOCl]}{2[NO][Cl_2]}$

D. $\dfrac{[NOCl]^2}{[NO]^2[Cl_2]}$

Question 18

A concentration–time graph for this system is shown below.



What event occurred at time *t* to cause the change in equilibrium concentrations?

A. The pressure was decreased at a constant temperature.

B. The temperature was increased at a constant volume.

C. A catalyst was added at a constant temperature and volume.

D. Additional NO gas was added at a constant volume and temperature.

Question 19

Which one of the following solutions has the highest pH?

A. 0.01 M HCOOH

B. 1.0 M HCOOH

C. 0.01 M CH_3COOH

D. 1.0 M CH_3COOH

Question 20

The ionisation of ethanoic acid can be represented by the equation

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

The percentage ionisation of ethanoic acid is greatest in a

A. 50 mL 1.0 M CH_3COOH solution.

B. 50 mL 0.1 M CH_3COOH solution.

C. 100 mL 0.1 M CH_3COOH solution.

D. 100 mL 0.01 M CH_3COOH solution.

Question 21

Phosphoric acid is present in cola-flavoured soft drinks and has been linked to decreased bone density.
It is a triprotic acid with the following K_a values at 25 °C.

$$H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq) \qquad K_{a1} = 7.25 \times 10^{-3}$$

$$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq) \qquad K_{a2} = 6.31 \times 10^{-8}$$

$$HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq) \qquad K_{a3} = 3.98 \times 10^{-13}$$

To determine the approximate pH of a 0.1 M phosphoric acid solution, a student should use the value of

A. K_{a1} only

B. K_{a3} only

C. $K_{a1} \times K_{a3}$ only

D. $K_{a1} \times K_{a2} \times K_{a3}$

Question 22

Which of the following alternatives lists only renewable energy resources?

A. coal, diesel, ethanol

B. coal, crude oil, uranium

C. ethanol, methane, diesel

D. crude oil, natural gas, ethanol

Question 23

What is the enthalpy change when 40 g of NaOH is dissolved in one litre of water, given that the temperature of the solution increased by 10.6 °C?

A. -0.44 kJ mol^{-1}

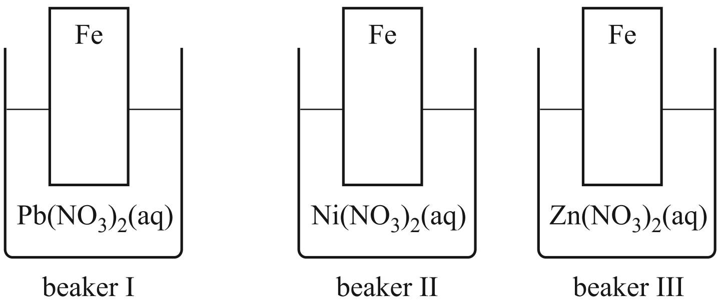
B. -4.4 kJ mol^{-1}

C. -44 kJ mol^{-1}

D. -440 kJ mol^{-1}

Question 24

Three beakers, each containing an iron strip and a 1.0 M solution of a metal salt, were set up as follows.



A reaction will occur in beaker(s)

A. I and II only.

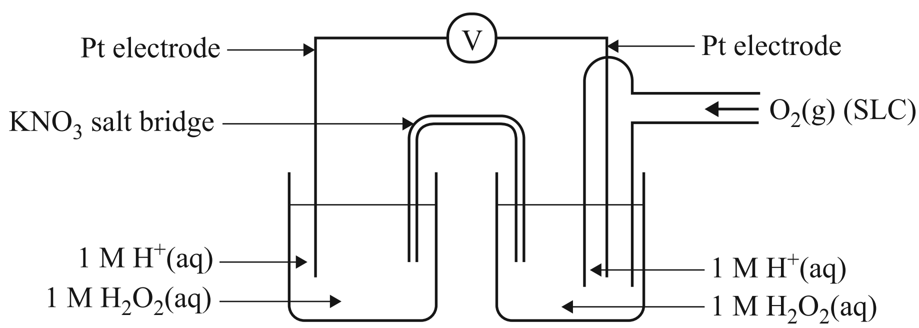
B. I and III only.

C. II and III only.

D. III only.

Question 25

A student constructs the following galvanic cell.



The student predicts that the following overall reaction will occur.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

However, no reaction is observed.

This is most likely because

A. the difference between the $E°$ values is too small for a reaction to occur.

B. hydrogen peroxide will oxidise water in preference to itself.

C. the student did not construct standard half-cells.

D. the rate of the reaction is extremely slow.

NO WRITING ALLOWED IN THIS AREA

Use the following information to answer Questions 26 and 27.

Four standard galvanic cells are set up as indicated below.

cell I a Br_2/Br^- standard half-cell connected to a Cu^{2+}/Cu standard half-cell

cell II an Sn^{2+}/Sn standard half-cell connected to a Zn^{2+}/Zn standard half-cell

cell III a Br_2/Br^- standard half-cell connected to an I_2/I^- standard half-cell

cell IV a Co^{2+}/Co standard half-cell connected to an Fe^{3+}/Fe^{2+} standard half-cell

Question 26

Which cell would be expected to develop the largest potential difference?

A. I
B. II
C. III
D. IV

Question 27

The reaction occurring at the cathode as cell IV is discharged is

A. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$
B. $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$
C. $Co(s) \rightarrow Co^{2+}(aq) + 2e^-$
D. $Co^{2+}(aq) + 2e^- \rightarrow Co(s)$

Question 28

The main reason an aqueous solution of potassium nitrate, KNO_3, is used in salt bridges is

A.	$K^+(aq)$ is a strong oxidant.	$NO_3^-(aq)$ is a weak reductant.
B.	$K^+(aq)$ is a weak reductant.	$NO_3^-(aq)$ is a strong oxidant.
C.	$K^+(aq)$ salts are soluble in water.	$NO_3^-(aq)$ salts are soluble in water.
D.	$K^+(aq)$ ions will migrate to the anode half-cell.	$NO_3^-(aq)$ ions will migrate to the cathode half-cell.

Question 29

The lead acid battery used in cars consists of secondary galvanic cells.

The following equations relate to the lead acid battery.

$$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq) \qquad E° = -0.36\text{ V}$$

$$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l) \qquad E° = 1.69\text{ V}$$

When an external power source is used to recharge a flat lead acid battery

A. the concentration of sulfuric acid decreases.

B. $PbSO_4$ is both oxidised and reduced.

C. the mass of metallic lead decreases.

D. PbO_2 is oxidised to Pb.

Question 30

A student prepares 1.0 M aqueous solutions of $AgNO_3$, $Fe(NO_3)_2$ and KNO_3.

Equal volumes of each solution are placed in separate beakers, identical platinum electrodes are placed in each beaker and each solution undergoes electrolysis with the same current applied for 5.0 minutes under SLC. Each cathode is then dried and weighed to determine mass change.

Assume that the concentrations of the solutions have decreased only slightly.

In order of increasing mass, the metals deposited on the three cathodes are likely to be

A. potassium, silver, iron.

B. silver, iron, potassium.

C. iron, potassium, silver.

D. potassium, iron, silver.

END OF SECTION A

SECTION B

Instructions for Section B

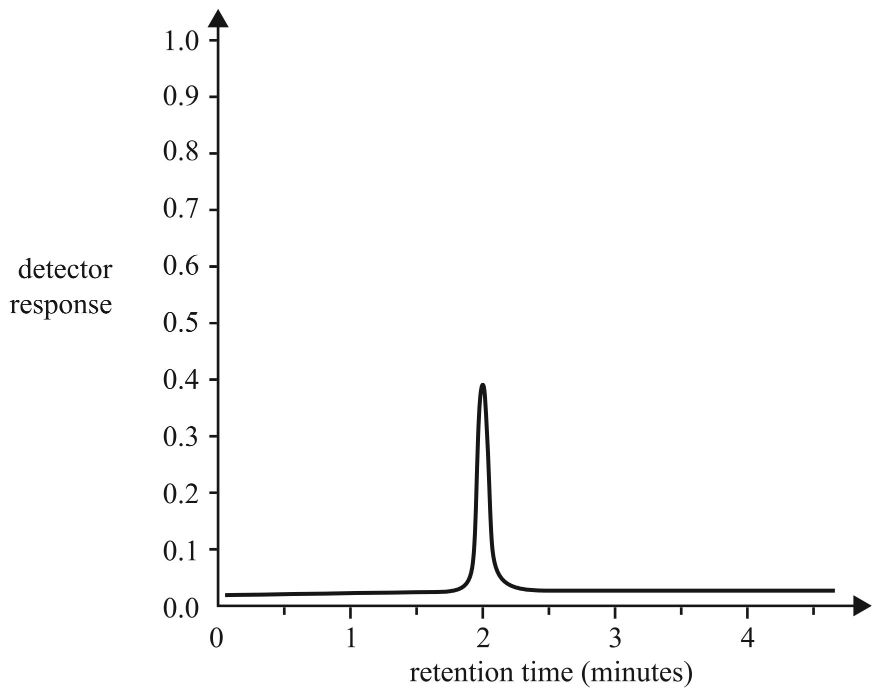
Answer **all** questions in the spaces provided. Write using black or blue pen.

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 marks 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 (2 marks)

High-performance liquid chromatography is used to determine the amount of caffeine in a sample of a soft drink. The chromatogram below shows the detector response when a standard solution of caffeine with a concentration of 200 mg L^{-1} is measured using the instrument.



a. What is the retention time of caffeine in this experiment? 1 mark

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b. On the chromatogram above, sketch the detector response when a commercial soft drink with a caffeine content of 350 mg L^{-1} is measured using the same instrument. 1 mark

Question 2 (4 marks)

The strength of the eggshell of birds is determined by the calcium carbonate, $CaCO_3$, content of the eggshell.

The percentage of calcium carbonate in the eggshell can be determined by gravimetric analysis.

0.412 g of clean, dry eggshell was completely dissolved in a minimum volume of dilute hydrochloric acid.

$$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

An excess of a basic solution of ammonium oxalate, $(NH_4)_2C_2O_4$, was then added to form crystals of calcium oxalate monohydrate, $CaC_2O_4.H_2O$.

The suspension was filtered and the crystals were then dried to constant mass.

0.523 g of $CaC_2O_4.H_2O$ was collected.

a. Write a balanced equation for the formation of the calcium oxalate monohydrate precipitate. 1 mark

b. Determine the percentage, by mass, of calcium carbonate in the eggshell. 3 marks

Question 3 (7 marks)

Spider webs are very strong and elastic. Spider web silk is a protein that mainly consists of glycine and alanine residues.

a. Assuming that these amino acid residues alternate in a spider web, draw a section of the spider web protein that contains at least **three** amino acid residues. 2 marks

b. What is the name of the bond between each amino acid residue? 1 mark

___

c. What type of polymerisation reaction occurs in the formation of spider web silk? 1 mark

___

Glycine forms an ion at a pH of 6 that has both a positive and negative charge.

d. Draw the structure of a glycine ion at a pH of less than 4. 1 mark

e. Describe the bonds that contribute to the spiral secondary structure of this protein. 2 marks

___

___

___

___

Question 4 (14 marks)

The industrial production of hydrogen involves the following two reactions.

reaction I $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206 \text{ kJ mol}^{-1}$

reaction II $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -41 \text{ kJ mol}^{-1}$

a. **i.** Write 'increase', 'decrease' or 'no change' in the table below to identify the expected effect of each change to reaction I and reaction II on the equilibrium yield of hydrogen. 3 marks

Change to reaction I and reaction II	**Effect of the change on the hydrogen yield in reaction I**	**Effect of the change on the hydrogen yield in reaction II**
addition of steam at a constant volume and temperature		
increase in temperature at a constant volume		
addition of a suitable catalyst at a constant volume and temperature		

ii. Explain the effect of decreasing the volume, at constant temperature, on the hydrogen equilibrium yield in each reaction. 4 marks

reaction I

reaction II

iii. What is the effect of an increase in temperature at constant volume on the rate of hydrogen production in each reaction? 2 marks

reaction I

reaction II

The reaction between hydrogen and oxygen is the basis of energy production in a number of fuel cells.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -571.6 \text{ kJ mol}^{-1}$$

b. An **alkaline** electrolyte is used in a particular hydrogen/oxygen fuel cell.
Write a balanced half-equation for the reaction occurring at the

i. cathode 1 mark

ii. anode. 1 mark

c. What is the maximum voltage predicted for one alkaline hydrogen/oxygen fuel cell under standard conditions? 1 mark

Much of the hydrogen used in fuel cells is produced from methane.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

d. Explain why methane generated by biomass is a renewable fuel while methane derived from fossil fuels is not. 2 marks

Question 5 (10 marks)

A 20.00 mL aliquot of 0.200 M CH_3COOH (ethanoic acid) is titrated with 0.150 M NaOH.

The equation for the reaction between the ethanoic acid and NaOH solution is represented as

$$OH^-(aq) + CH_3COOH(aq) \rightarrow H_2O(l) + CH_3COO^-(aq)$$

a. What volume of the NaOH solution is required to completely react with the ethanoic acid? 2 marks

b. Define the terms ‘equivalence point’ and ‘end point’. 2 marks

c. Ethanoic acid is a weak acid.

i. Write an expression for the acidity constant of ethanoic acid. 1 mark

ii. Calculate the pH of the 0.200 M ethanoic acid solution before any NaOH solution has been added. Assume that the equilibrium concentration of the ethanoic acid is 0.200 M. 3 marks

d. Consider the point in the titration where the volume of NaOH added is exactly half that required for complete neutralisation.

i. Tick (✓) the box next to the statement that best describes the relative concentrations of ethanoic acid and ethanoate ions at this point. 1 mark

☐ The concentration of ethanoic acid is less than the concentration of ethanoate ions.

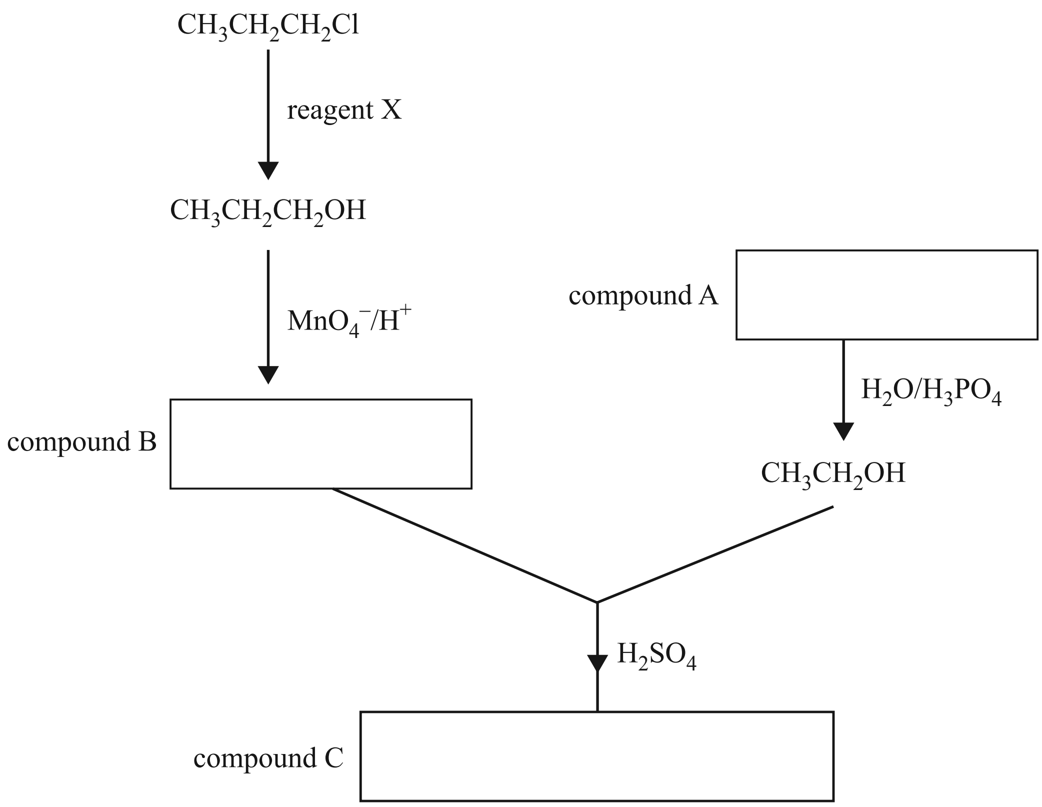
☐ The concentration of ethanoic acid is equal to the concentration of ethanoate ions.

☐ The concentration of ethanoic acid is greater than the concentration of ethanoate ions.

ii. What is the relationship between the concentration of H_3O^+ and K_a at this point? 1 mark

Question 6 (7 marks)

The reaction pathway below represents the synthesis of compound C.



a. Identify reagent X. 1 mark

___

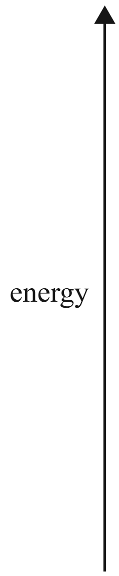
b. In the appropriate boxes above, write the semi-structural formulas for compounds A, B and C. 3 marks

c. Give the systematic IUPAC names for compounds A and B. 2 marks

compound A ___

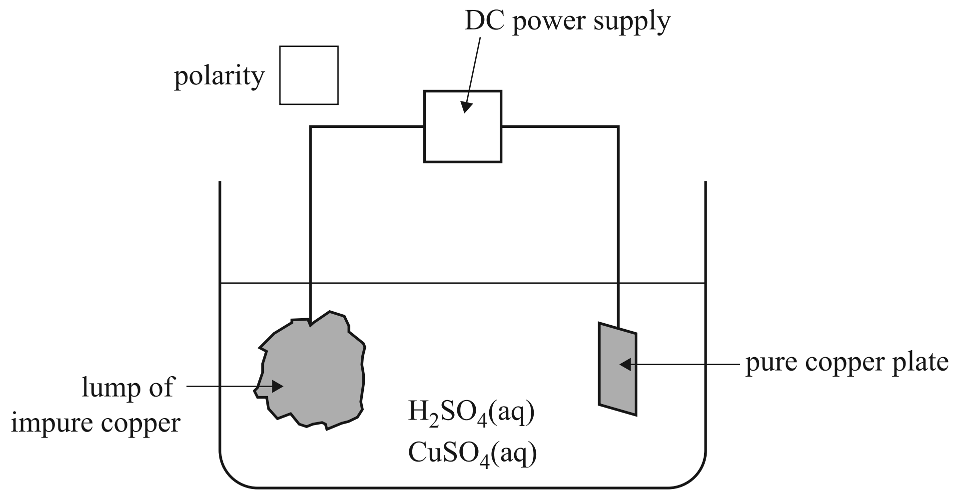
compound B ___

d. Sketch the energy profile for the complete combustion of compound C using the axis below, labelling the energy of the reactants, the products and the activation energy. 1 mark



Question 7 (14 marks)

An electrolytic process known as electrorefining is the final stage in producing highly purified copper. In a small-scale trial, a lump of impure copper is used as one electrode and a small plate of pure copper is used as the other electrode. The electrolyte is a mixture of aqueous sulfuric acid and copper sulfate.



a. Indicate in the box labelled 'polarity' on the diagram above, the polarity of the impure copper electrode. 1 mark

In a trial experiment, the electrodes were weighed before and after electrolysis.
The results are provided in the following table.

	Mass of lump of impure copper	**Mass of pure copper**
before electrolysis	10.30 kg	1.55 kg
after electrolysis	0.855 kg	9.80 kg

b. On the basis of these results

- calculate a percentage purity of the lump of impure copper 4 marks

- indicate **one** factor that may affect the accuracy of these results.

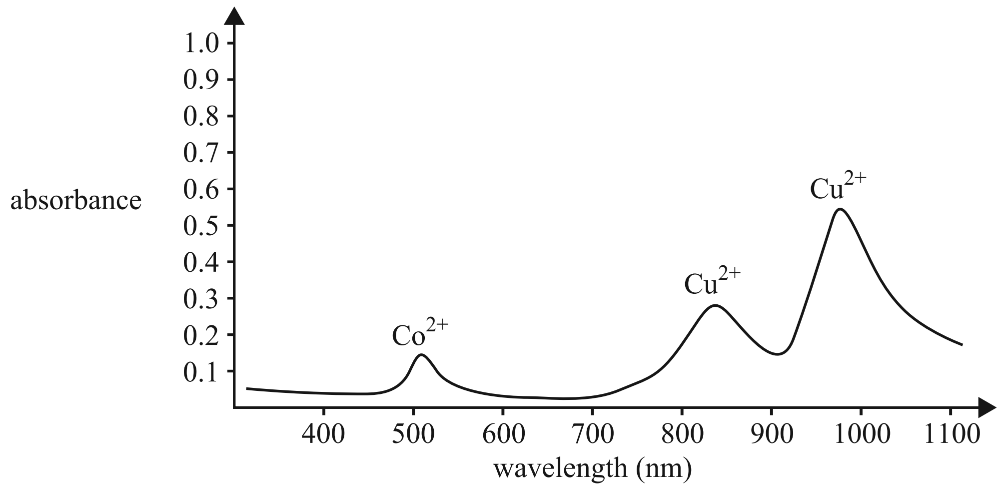
c. Conditions in the electrolytic cell shown in the diagram are carefully controlled to ensure a high degree of copper purity and electrical efficiency.

Use the mass of pure copper deposited that is given in the table in **part a.** to determine the time, in days, taken for this electrolysis reaction to be completed. Assume the current was a constant 24 A. 5 marks

Lumps of impure copper typically contain impurities such as silver, gold, cobalt, nickel and zinc. Cobalt, nickel and zinc are oxidised from the copper lump and exist as ions in the electrolyte. Silver and gold are not oxidised and form part of an insoluble sludge at the base of the cell.

d. Why is it important that silver and gold are not present as cations in the electrolyte? 1 mark

Chemists suspected that an impure copper lump contained a significant amount of cobalt. Cobalt would be oxidised to Co^{2+} ions that would remain in the electrolyte solution. The spectrogram below gives the results of analysis of the solution. The two ions absorb at distinctly different wavelengths.



e. **i.** Which analytical technique was used to perform this analysis? 1 mark

___

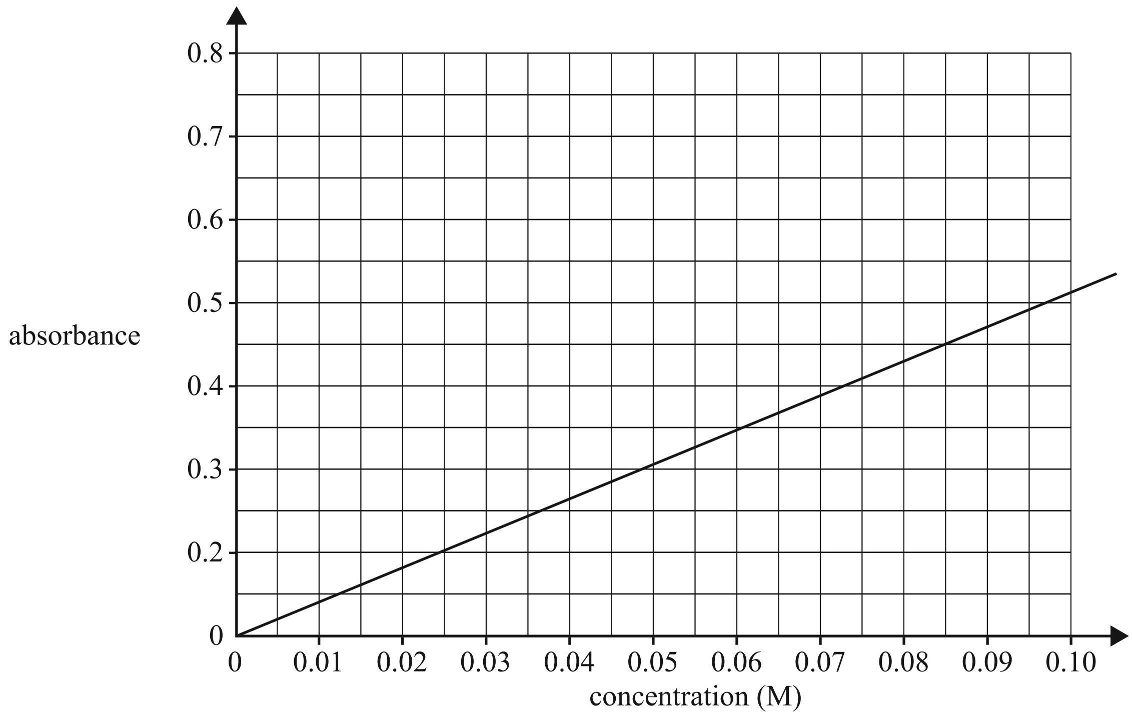
A calibration graph was constructed using $Co^{2+}(aq)$ solutions of known concentrations.

ii. What wavelength would you select to construct this curve? 1 mark

___

NO WRITING ALLOWED IN THIS AREA

iii. A Co^{2+}(aq) solution of unknown concentration registered an absorbance reading of 0.350.
Determine the concentration of Co^{2+} ions in this solution. 1 mark



Question 8 (10 marks)

a. In an experiment, 5.85 g of ethanol was ignited with 14.2 g of oxygen.

i. Write an equation for the complete combustion of ethanol. 1 mark

ii. Which reagent is in excess? Calculate the amount, in moles, of the reagent identified as being in excess. 3 marks

Ethanol for use as a biofuel can be produced from the fermentation of monosaccharides, such as glucose, $C_6H_{12}O_6$, which is derived from polysaccharides found in plants.

b. Write an equation for the fermentation reaction of glucose. 1 mark

Genetically modified yeast is used to convert xylose, $C_5H_{10}O_5$, another monosaccharide found in plant fibres, to ethanol.

$$3C_5H_{10}O_5(aq) \rightarrow 5C_2H_5OH(l) + 5CO_2(g)$$

c. In a trial, 1.00 kg of pure xylose is completely converted to ethanol and carbon dioxide.

i. Calculate the volume, in mL, of ethanol that is produced.
Note: The density of ethanol is 0.785 g mL^{-1}. 3 marks

ii. Determine the volume of carbon dioxide gas at 20.0 °C and 750.0 mm pressure produced by the xylose. 2 marks

Question 9 (7 marks)

An unknown organic compound, molecular formula $C_4H_8O_2$, was presented to a spectroscopy laboratory for identification. A mass spectrum, infrared spectrum, and both ^1H NMR (proton NMR) and ^{13}C NMR spectra were produced. These are shown on the opposite page.

The analytical chemist identified the compound as ethyl ethanoate.

A report was submitted to justify the interpretation of the spectra. The chemist's report indicating information about the structure provided by the ^{13}C NMR spectrum has been completed for you.

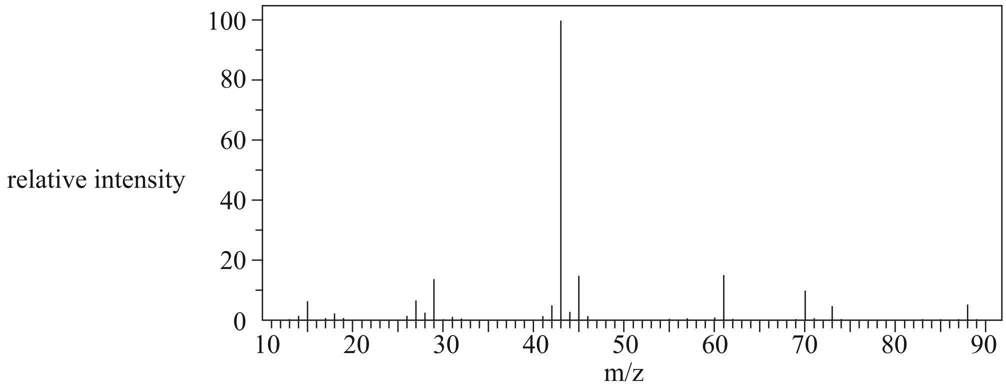
a. Complete the rest of the report by identifying **one** piece of information from each spectrum that can be used to identify the compound. Indicate how the interpretation of this information justifies the chemist's analysis. 6 marks

Spectroscopic technique	Information provided
^{13}C NMR spectrum	The four signals in the ^{13}C NMR spectrum indicate four different carbon environments. $CH_3COOCH_2CH_3$ has four different carbon environments.
mass spectrum	
infrared spectrum	
^1H NMR spectrum	

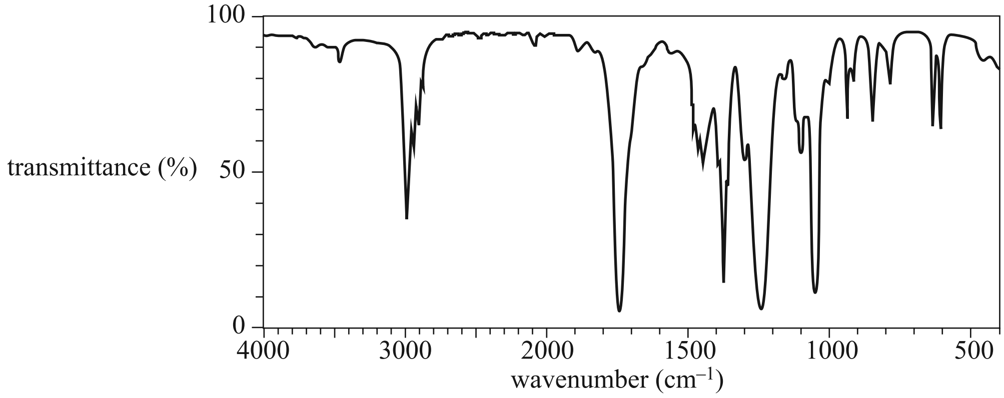
b. Another compound has the same molecular formula as ethyl ethanoate. However, the carbon ^{13}C NMR spectrum of this compound shows only three signals.

Draw a possible structure of this compound. 1 mark

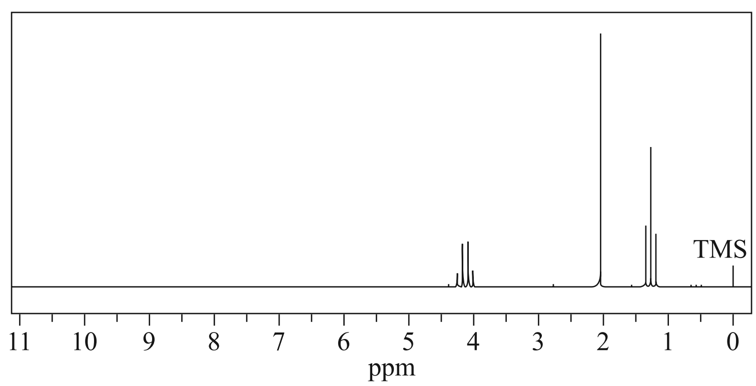
Mass spectrum



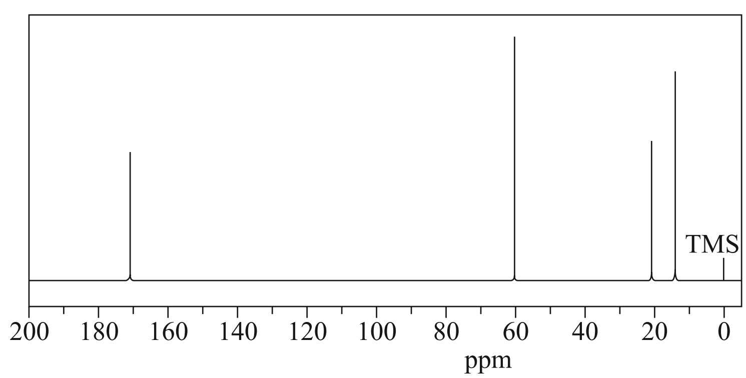
Infrared spectrum



Proton NMR spectrum



^{13}C NMR spectrum



Source: National Institute of Advanced Industrial Science and Technology;
http://sdbs.riodb.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi

Question 10 (8 marks)

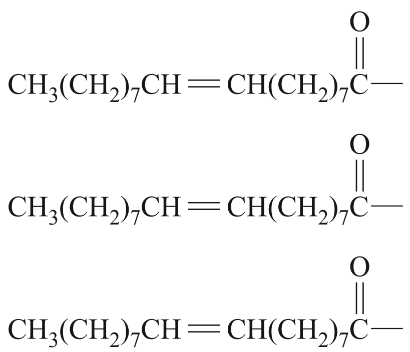
Olive oil, which has been part of the human diet for thousands of years, is derived from the fruit of the olive tree.

The main fatty acid that makes up olive oil is oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$.

The triglyceride formed from three oleic acid molecules is glycerol trioleate, $C_{57}H_{104}O_6$. The molar mass of glycerol trioleate is 884 g mol^{-1}.

a. **i.** An incomplete semi-structural formula of glycerol trioleate is provided below.

Complete the semi-structural formula of glycerol trioleate. 1 mark



ii. Explain why oleic acid is described as a mono-unsaturated fatty acid. 1 mark

b. **i.** 1.00 g of olive oil is burned in a bomb calorimeter with excess pure oxygen.

The calibration factor of the calorimeter is 9112 J °C^{-1}. The burning of the olive oil increased the temperature in the bomb calorimeter from 20.0 °C to 22.4 °C.

Calculate the heat released by 1.00 g of olive oil. 2 marks

ii. Assuming the only constituent of olive oil is glycerol trioleate, write a combustion reaction for this molecule. 2 marks

iii. Determine the ΔH for the reaction in **part b.ii.** 2 marks

Question 11 (7 marks)

The following is a student's summary of catalysts. It contains some correct and incorrect statements.

a. A catalyst increases the rate of a reaction.
b. All catalysts are solids.
c. The mass of a catalyst is the same before and after the reaction.
d. A catalyst lowers the enthalpy change of a reaction, enabling more particles to have sufficient energy to successfully react.
e. A catalyst increases the value of the equilibrium constant, thus favouring the extent of the forward reaction, resulting in a greater yield of product.
f. All catalysts align the reactant particles in an orientation that is favourable for a reaction to occur.
g. The effectiveness of a metal catalyst is not dependent upon its surface area.
h. Enzymes are biological catalysts that catalyse a specific biochemical reaction once only.
i. The effectiveness of an enzyme is independent of temperature.

a. Identify **two** correct statements. 1 mark

b. Evaluate the student's summary by identifying **three** incorrect statements. In each case, explain why it is incorrect. 6 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2013

CHEMISTRY

Written examination

Tuesday 12 November 2013

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 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** 20.2 Neon
11 **Na** 23.0 Sodium	**12** **Mg** 24.3 Magnesium											**13** **Al** 27.0 Aluminium	**14** **Si** 28.1 Silicon	**15** **P** 31.0 Phosphorus	**16** **S** 32.1 Sulfur	**17** **Cl** 35.5 Chlorine	**18** **Ar** 39.9 Argon
19 **K** 39.1 Potassium	**20** **Ca** 40.1 Calcium	**21** **Sc** 45.0 Scandium	**22** **Ti** 47.9 Titanium	**23** **V** 50.9 Vanadium	**24** **Cr** 52.0 Chromium	**25** **Mn** 54.9 Manganese	**26** **Fe** 55.8 Iron	**27** **Co** 58.9 Cobalt	**28** **Ni** 58.7 Nickel	**29** **Cu** 63.5 Copper	**30** **Zn** 65.4 Zinc	**31** **Ga** 69.7 Gallium	**32** **Ge** 72.6 Germanium	**33** **As** 74.9 Arsenic	**34** **Se** 79.0 Selenium	**35** **Br** 79.9 Bromine	**36** **Kr** 83.8 Krypton
37 **Rb** 85.5 Rubidium	**38** **Sr** 87.6 Strontium	**39** **Y** 88.9 Yttrium	**40** **Zr** 91.2 Zirconium	**41** **Nb** 92.9 Niobium	**42** **Mo** 96.0 Molybdenum	**43** **Tc** (98) Technetium	**44** **Ru** 101.1 Ruthenium	**45** **Rh** 102.9 Rhodium	**46** **Pd** 106.4 Palladium	**47** **Ag** 107.9 Silver	**48** **Cd** 112.4 Cadmium	**49** **In** 114.8 Indium	**50** **Sn** 118.7 Tin	**51** **Sb** 121.8 Antimony	**52** **Te** 127.6 Tellurium	**53** **I** 126.9 Iodine	**54** **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	**56** **Ba** 137.3 Barium	**57** **La** 138.9 Lanthanum	**72** **Hf** 178.5 Hafnium	**73** **Ta** 180.9 Tantalum	**74** **W** 183.8 Tungsten	**75** **Re** 186.2 Rhenium	**76** **Os** 190.2 Osmium	**77** **Ir** 192.2 Iridium	**78** **Pt** 195.1 Platinum	**79** **Au** 197.0 Gold	**80** **Hg** 200.6 Mercury	**81** **Tl** 204.4 Thallium	**82** **Pb** 207.2 Lead	**83** **Bi** 209.0 Bismuth	**84** **Po** (210) Polonium	**85** **At** (210) Astatine	**86** **Rn** (222) Radon
87 **Fr** (223) Francium	**88** **Ra** (226) Radium	**89** **Ac** (227) Actinium	**104** **Rf** (261) Rutherfordium	**105** **Db** (262) Dubnium	**106** **Sg** (266) Seaborgium	**107** **Bh** (264) Bohrium	**108** **Hs** (267) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Cn** (285) Copernicium	**113** **Uut** (284)	**114** **Uuq** (289)	**115** **Uup** (288)	**116** **Uuh** (293)	**117** **Uus** (294)	**118** **Uuo** (294)

58 **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.4 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.3 Gadolinium	**65** **Tb** 158.9 Terbium	**66** **Dy** 162.5 Dysprosium	**67** **Ho** 164.9 Holmium	**68** **Er** 167.3 Erbium	**69** **Tm** 168.9 Thulium	**70** **Yb** 173.1 Ytterbium	**71** **Lu** 175.0 Lutetium
90 **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237) Neptunium	**94** **Pu** (244) Plutonium	**95** **Am** (243) Americium	**96** **Cm** (247) Curium	**97** **Bk** (247) Berkelium	**98** **Cf** (251) Californium	**99** **Es** (252) Einsteinium	**100** **Fm** (257) Fermium	**101** **Md** (258) Mendelevium	**102** **No** (259) Nobelium	**103** **Lr** (262) Lawrencium

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

2. The electrochemical series

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

3. Physical constants

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

Charge on one electron = -1.60×10^{-19} C

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

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

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

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

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

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

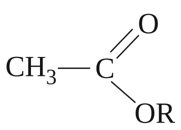
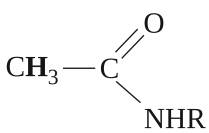
4. SI prefixes, their symbols and values

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

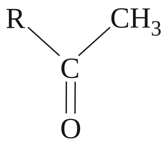
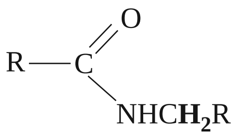
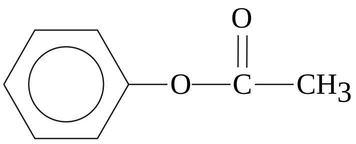
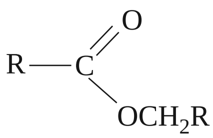
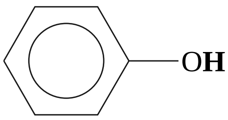
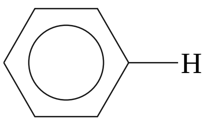
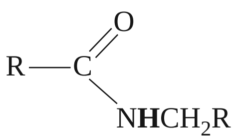
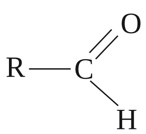
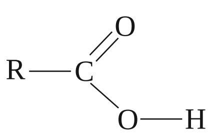
5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

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

Type of proton	Chemical shift (ppm)
$R{-}CH_3$	0.8–1.0
$R{-}CH_2{-}R$	1.2–1.4
RCH = CH–C**H$_3$**	1.6–1.9
$R_3{-}CH$	1.4–1.7
 or 	2.0

TURN OVER

Type of proton	Chemical shift (ppm)
	2.1–2.7
R–CH_2–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H_2**–OH, R_2–C**H**–OH	3.3–4.5
	3.2
R—O—CH_3 or R—O—CH_2R	3.3
	2.3
	4.1
R–O–H	1–6 (varies considerably under different conditions)
R–NH_2	1–5
RHC$=$C**H_2**	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	9–13

6. ^{13}C NMR data

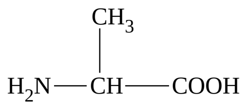
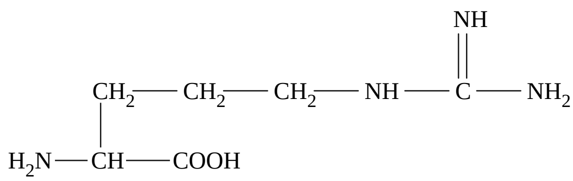
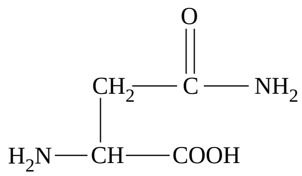
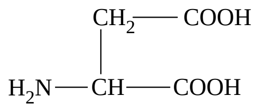
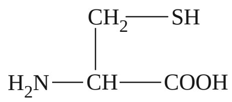
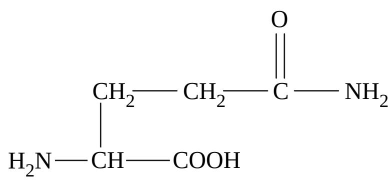
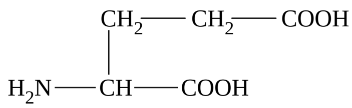
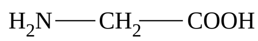
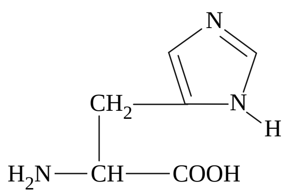
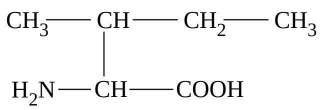
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

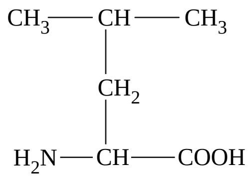
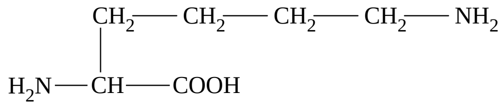
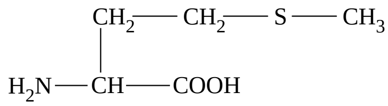
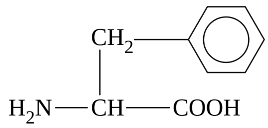
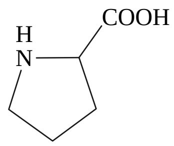
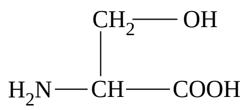
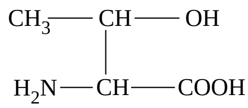
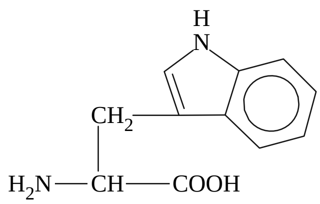
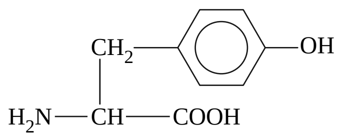
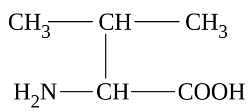
7. Infrared absorption data

Characteristic range for infrared absorption

Bond	Wave number (cm^{-1})
C–Cl	700–800
C–C	750–1100
C–O	1000–1300
C=C	1610–1680
C=O	1670–1750
O–H (acids)	2500–3300
C–H	2850–3300
O–H (alcohols)	3200–3550
N–H (primary amines)	3350–3500

8. 2-amino acids (α-amino acids)

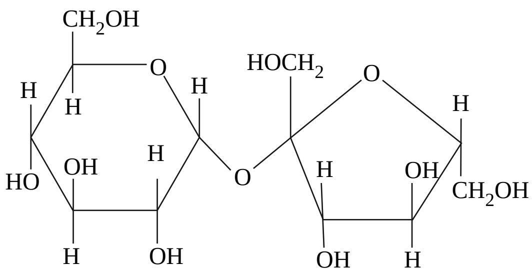
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

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

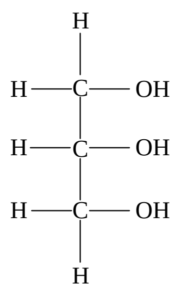
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

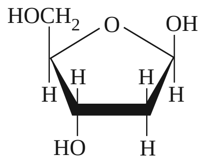
10. Structural formulas of some important biomolecules



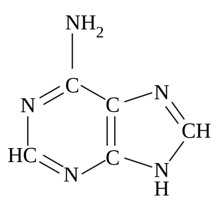
sucrose



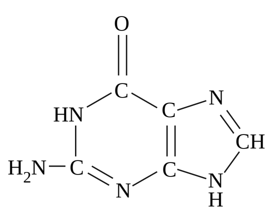
glycerol



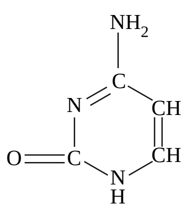
deoxyribose



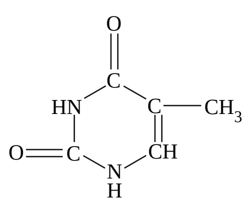
adenine



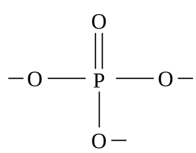
guanine



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