Taylor High School

Higher Chemistry

Chemistry in Society

Practice Questions

Getting the most from reactants – Section A

1. 0·5 mol of copper(II) chloride and 0·5 mol of copper(II) sulphate are dissolved together in water and made up to 500 cm^3 of solution.

What is the concentration of $Cu2^{+}(aq)$ ions in the solution in mol l^{-1}?

A 0·5

B 1·0

C 2·0

D 4·0

2. 1 mol of hydrogen gas and 1 mol of iodine vapour were mixed and allowed to react. After t seconds, 0·8 mol of hydrogen remained. The number of moles of hydrogen iodide formed at t seconds was

A 0·2

B 0·4

C 0·8

D 1·6.

3. 20 cm^3 of ammonia gas reacted with an excess of heated copper(II) oxide.

$3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Assuming all measurements were made at 200 °C, what would be the volume of gaseous products?

A 10 cm^3

B 20 cm^3

C 30 cm^3

D 40 cm^3

4. 10 g of magnesium is added to 1 litre of 1 mol l^{-1} copper(II) sulphate solution and the mixture stirred until no further reaction occurs.

Which of the following is a result of this reaction?

A All the magnesium reacts.

B 63.5 g of copper is displaced.

C 2 mol of copper is displaced.

D The resulting solution is colourless.

5. Which of the following gas samples has the same volume as 7 g of carbon monoxide?

(All volumes are measured at the same temperature and pressure.)

A 1 g of hydrogen

B 3.5 g of nitrogen

C 10 g of argon

D 35.5 g of chlorine

6. What volume of oxygen (in litres) would be required for the complete combustion of a gaseous mixture containing 1 litre of carbon monoxide and 3 litres of hydrogen?

(All volumes are measured at the same temperature and pressure.)

A 1

B 2

C 3

D 4

7. A mixture of magnesium bromide and magnesium sulfate is known to contain 3 mol of magnesium and 4 mol of bromide ions.

How many moles of sulfate ions are present?

A 1

B 2

C 3

D 4

8. $2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$
Ethyne

What volume of gas would be produced by the complete combustion of 100 cm^3 of ethyne gas?

All volumes were measured at atmospheric pressure and room temperature.

A 200 cm^3

B 300 cm^3

C 400 cm^3

D 800 cm^3

9. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

How many litres of nitrogen dioxide gas could theoretically be obtained in the reaction of 1 litre of nitrogen monoxide gas with 2 litres of oxygen gas?

(All volumes are measured under the same conditions of temperature and pressure.)

A 1

B 2

C 3

D 4

10. Calcium carbonate reacts with nitric acid as follows.

$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

0·05 mol of calcium carbonate was added to a solution containing 0·08 mol of nitric acid.

Which of the following statements is true?

A 0·05 mol of carbon dioxide is produced.

B 0·08 mol of calcium nitrate is produced.

C Calcium carbonate is in excess by 0·01 mol.

D Nitric acid is in excess by 0·03 mol.

11. A mixture of sodium bromide and sodium sulfate is known to contain 5 moles of sodium and 2 moles of bromide ions.

How many moles of sulfate ions are present?

A 1·5

B 2·0

C 2·5

D 3·0

12. In which reaction is the volume of products less than the volume of reactants?

A $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

B $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

C $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

D $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

13. A student obtained a certain volume of carbon dioxide by the reaction of 20 cm3 of 2 mol l-1 hydrochloric acid with excess sodium carbonate.

$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + CO_2(g)$

Which solution of sulfuric acid would give the same final volume of carbon dioxide when added to excess sodium carbonate?

$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na^2SO^4(aq) + CO^2(g)$

A 10 cm^3 of 2 mol l^{-1} sulfuric acid

B 20 cm^3 of 2 mol l^{-1} sulfuric acid

C 10 cm^3 of 4 mol l^{-1} sulfuric acid

D 20 cm^3 of 4 mol l^{-1} sulfuric acid

Getting the most from reactants – Section B

1. A sample of oceanic water was found to contain 0·010 g of dissolved oxygen.

Calculate the number of moles of dissolved oxygen present in the sample.

2. Sulphur trioxide can be prepared in the laboratory by the reaction of sulphur dioxide with oxygen.

$2SO_2(g) + O_2(g)\ 2SO_3(g)$

The sulphur dioxide and oxygen gases are dried by bubbling them through concentrated sulphuric acid. The reaction mixture is passed over heated vanadium(V) oxide.

Sulphur trioxide has a melting point of 17 °C. It is collected as a white crystalline solid.

Under certain conditions, 43·2 tonnes of sulphur trioxide are produced in the reaction of 51·2 tonnes of sulphur dioxide with excess oxygen.

Calculate the percentage yield of sulphur trioxide.

Show your working clearly.

3. A student bubbled 240 cm^3 of carbon dioxide into 400 cm^3 of 0·10 mol l^{-1} lithium hydroxide solution. The equation for the reaction is:

$2LiOH(aq) + CO_2(g) \rightarrow Li_2CO_3(aq) + H_2O(A)$

Calculate the number of moles of lithium hydroxide that would not have reacted. (Take the molar volume of carbon dioxide to be 24 litres mol^{-1}.)

Show your working clearly.

4. Ammonia is produced in industry by the Haber Process.

$N_2(g) + 3H_2(g)\ 2NH_3(g)$

Under certain conditions, 500 kg of nitrogen reacts with excess hydrogen to produce 405 kg of ammonia.
Calculate the percentage yield of ammonia under these conditions.
Show your working clearly.

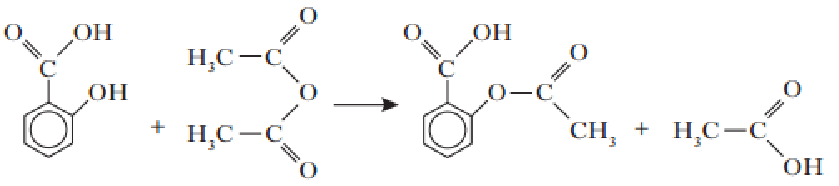
5. Sherbet contains a mixture of sodium hydrogencarbonate and tartaric acid. The fizzing sensation in the mouth is due to the carbon dioxide produced in the following reaction.

$2NaHCO_3$	+	$C_4H_6O_6$	$\rightarrow$	$Na_2(C_4H_4O_6)$ +	$2H_2O$ +	$2CO_2$
sodium hydrogencarbonate		tartaric acid		sodium tartrate		

In an experiment, a student found that adding water to 20 sherbet sweets produced 105 cm^3 of carbon dioxide. Assuming that sodium hydrogencarbonate is in excess, calculate the average mass of tartaric acid, in grams, in one sweet.
(Take the molar volume of carbon dioxide to be 24 litre mol^{-1}.)

Show your working clearly.

6. Aspirin, a common pain-killer, can be made by the reaction of salicylic acid with ethanoic anhydride.



$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

(a) Calculate the atom economy for the formation of aspirin using this method.
Show your working clearly.

(b) In a laboratory preparation of aspirin, 5·02 g of salicylic acid produced 2·62 g of aspirin. Calculate the percentage yield of aspirin.
Show your working clearly.

7. Hydrogen sulfide is a toxic gas with the smell of rotten eggs.
Hydrogen sulfide gas can be prepared by the reaction of iron(II) sulfide with excess dilute hydrochloric acid:

$FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$

Calculate the mass, in g, of iron(II) sulfide required to produce 79 cm^3 of hydrogen sulfide gas. (Take the molar volume of hydrogen sulfide to be 24 litres mol^{-1}.)
Show your working clearly.

8. Dark blue compounds can be made by reacting ammonia with copper ions. To determine the number of ammonia molecules that react with each copper ion, a student prepared the following mixtures and measured their colour intensity.

Mixture	A	B	C	D	E	F
Volume of 0·1 mol l^{-1} Cu^{2+} solution, cm^3	7·5	5·0	2·5	2·0	1·5	1·0
Volume of 0·1 mol l^{-1} NH_3 solution, cm^3	2·5	5·0	7·5	8·0	8·5	
Colour intensity	0·61	1·23	1·83	1·96	1·47	0·98

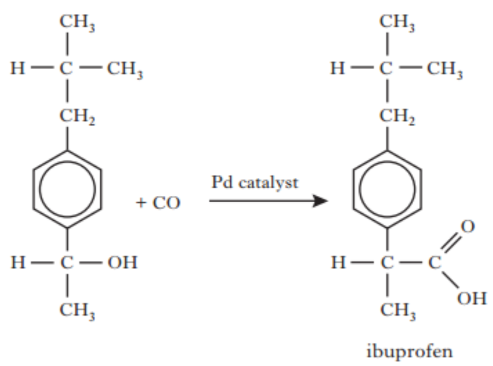
(An additional table, if required, can be found on Page thirty-four.)

(a) Complete the table to show the volume of NH_3 solution required for the final experiment.

(b) The number of ammonia molecules that react with each copper ion can be found from the mixture with the greatest colour intensity.

How many ammonia molecules react with each copper ion?

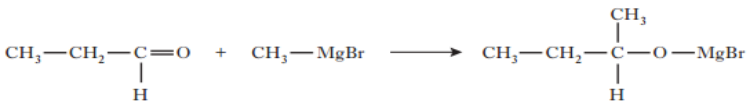
9. From the 1990s, ibuprofen has been synthesised by a three step process. The equation below shows the final step of the synthesis.



(a) What is the atom economy of this step?

10. A chemist tested whether it would be possible to make money by producing butan-2-ol from propanal using a two-step process.

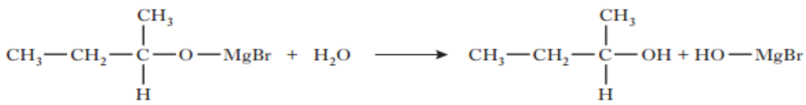
Step One
Methyl magnesium bromide reacts with propanal.



propanal
GFM 58

methyl magnesium bromide

Step Two
The product from step one reacts with water to produce butan-2-ol.



butan-2-ol
GFM 74

The chemist managed to make 5·75 g of butan-2-ol using 5·01 g of propanal and 20·0 g of methyl magnesium bromide.

(a) Calculate the percentage yield obtained in this experiment assuming that the CH_3MgBr is in excess.

11. An experiment was carried out to measure the concentration of hypochlorite ions in a sample of bleach. In this experiment, the bleach sample reacted with excess hydrogen peroxide.

$H_2O_2(aq) + ClO^-(aq) \rightarrow H_2O() + Cl^-(aq) + O_2(g)$

By measuring the volume of oxygen given off, the concentration of bleach can be calculated.

(i) 80 cm^3 of oxygen gas was produced from 5·0 cm^3 of bleach.
Calculate the concentration of the hypochlorite ions in the bleach.
(Take the molecular volume of oxygen to be 24 litre mol^{-1}.)

12. A student carried out an investigation to measure the nitrite level in the school water supply. A compound, which reacts with the nitrite ions to form a product that absorbs light, is added to water samples. The higher the concentration of nitrite ions present in a water sample, the greater the amount of light absorbed.

(a) The student prepared potassium nitrite solutions of known concentration by diluting samples from a stock solution.

Calculate the mass, in mg, of potassium nitrite, KNO_2, needed to make 1 litre of stock solution with a nitrite ion concentration of 250 mg l^{-1}.

Equilibria – Section A

1. In which of the following reactions would an Increase in pressure cause the equilibrium position to move to the left?

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

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

C $Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$

D $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

2. If ammonia is added to a solution containing copper(II) ions an equilibrium is set up.

$Cu^{2+}(aq) + 2OH^-(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4(OH)_2(aq)$
(deep blue)

If acid is added to this equilibrium system

A the intensity of the deep blue colour will increase

B the equilibrium position will move to the right

C the concentration of Cu^{2+} (aq) ions will increase

D the equilibrium position will not be affected.

3. A catalyst is added to a reaction at equilibrium. Which of the following does not apply?

A The rate of the forward reaction increases.

B The rate of the reverse reaction increases.

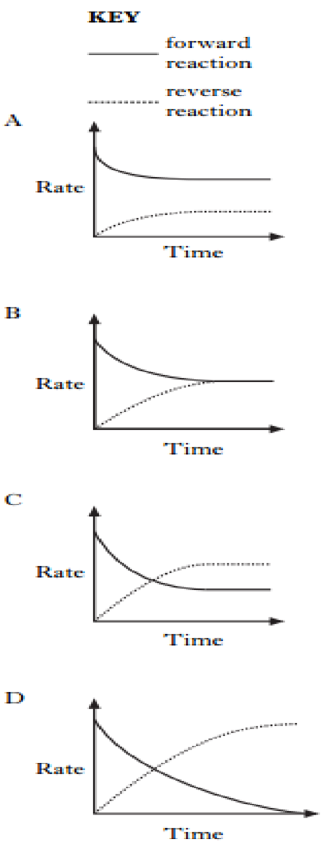
C The position of equilibrium remains unchanged.

D The position of equilibrium shifts to the right.

4. Steam and carbon monoxide react to form an equilibrium mixture.

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

Which of the following graphs shows how the rates of the forward and reverse reactions change when carbon monoxide and steam are mixed?



5. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

The equation represents a mixture at equilibrium.

Which line in the table is true for the mixture after a further 2 hours of reaction?

	Rate of forward reaction	Rate of back reaction
A	decreases	decreases
B	increases	increases
C	unchanged	decreases
D	unchanged	unchanged

6. In which of the following would an increase in pressure result in the equilibrium position being moved to the left?

A $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

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

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

D $Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$

7. Ammonia is made by the Haber Process.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The equilibrium position lies to the left.

Which line in the table is correct?

	Atom Economy	Percentage Yield
A	high	high
B	high	low
C	low	high
D	low	low

8. A few drops of concentrated sulphuric acid were added to a mixture of 0·1 mol of methanol and 0·2 mol of ethanoic acid. Even after a considerable time, the reaction mixture was found to contain some of each reactant.

Which of the following is the best explanation for the incomplete reaction?

A The temperature was too low.

B An equilibrium mixture was formed.

C Insufficient methanol was used.

D Insufficient ethanoic acid was used.

9. In a reversible reaction, equilibrium is reached when

A molecules of reactants cease to change into molecules of products

B the concentrations of reactants and products are equal

C the concentrations of reactants and products are constant

D the activation energy of the forward reaction is equal to that of the reverse reaction.

10. Ethanol is manufactured by reacting ethane with steam.

$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$

$\Delta H = -46 \text{ kJ mol}^{-1}$

Which set of conditions would give the best yield of ethanol at equilibrium?

A High temperature, low pressure

B High temperature, high pressure

C Low temperature, high pressure

D Low temperature, low pressure

Equilibria – Section B

1. Atmospheric oxygen, $O_2(g)$, dissolves in the Earth's oceans forming dissolved oxygen, $O_2(aq)$, which is essential for aquatic life.

   An equilibrium is established.

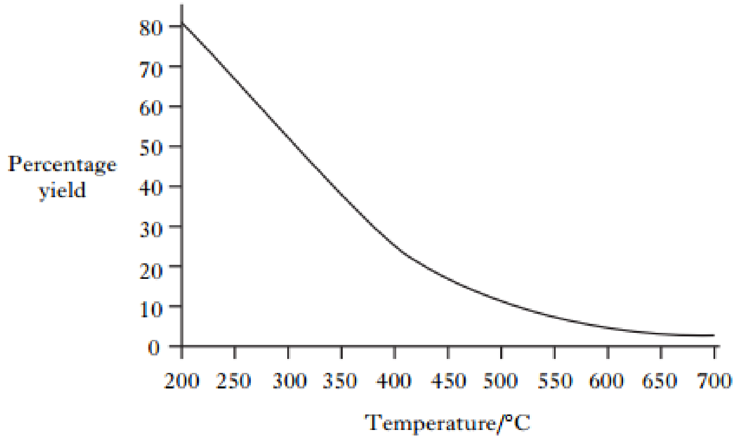
   $O_2(g) + (aq) \rightleftharpoons O_2(aq)$ $\Delta H = -12{\cdot}1$ kJ mol^{-1}

   (a) What is meant by a reaction at "equilibrium"?

2. Ammonia is produced in industry by the Haber Process.

   $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

   The graph shows how the percentage yield of ammonia changes with temperature at a pressure of 100 atmospheres.



   (i) A student correctly concludes from the graph that the production of ammonia is an exothermic process.
   What is the reasoning that leads to this conclusion?

   (ii) Explain clearly why the industrial manufacture of ammonia is carried out at a pressure greater than 100 atmospheres.

3. Mobile phones are being developed that can be powered by methanol. Methanol can be made by a two-stage process.

In the second stage, the carbon monoxide and hydrogen react to produce methanol.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91$ kJ mol^{-1}

Circle the correct words in the table to show the changes to temperature and pressure that would favour the production of methanol.

temperature	decrease / keep the same / increase
pressure	decrease / keep the same / increase

4. Ethanol, for use in industrial processes, can be produced by reacting ethane gas with steam.

$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$

(i) What name is given to this type of chemical reaction?

(ii) What would happen to the equilibrium position if a catalyst was used?

Chemical Energy – Section A

1. Given the equations

$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

$\Delta H = a\ J\ mol^{-1}$

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

$\Delta H = b\ J\ mol^{-1}$

$Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$

$\Delta H = c\ J\ mol^{-1}$

then, according to Hess's Law

A c = a – b

B c = a + b

C c = b – a

D c = – b – a.

2. Ethanol (C_2H_5OH) has a different enthalpy of combustion from dimethyl ether (CH_3OCH_3).

This is because the compounds have different

A boiling points

B molecular masses

C products of combustion

D bonds within the molecules.

3. $S(s) + H_2(g) \rightarrow H_2S(g)$ ΔH = a

$H_2(g) + O_2(g) \rightarrow H_2O(A)$ ΔH = b

$S(s) + O_2(g) \rightarrow SO_2(g)$ ΔH = c

$H_2S(g) + O_2(g) \rightarrow H_2O(A) + SO_2(g)$ ΔH = d

What is the relationship between a, b, c and d?

A a = b + c – d

B a = d – b – c

C a = b – c – d

D a = d + c – b

4. The enthalpy of combustion of methanol is

–727 kJ mol^{-1}.

What mass of methanol has to be burned to produce 72·7 kJ?

A 3·2 g

B 32·0 g

C 72·7 g

D 727·0 g

5. $C(s) + H_2(g) + O_2(g) \rightarrow HCOOH(l)$ ΔH = a

$HCOOH(l) + ½O_2(g) \rightarrow CO_2(g) + H_2O(l)$ ΔH = b

$C(s) + O_2(g) \rightarrow CO_2(g)$ ΔH = c

$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ ΔH = d

What is the relationship between a, b, c and d?

A a = c + d − b

B a = b − c − d

C a = −b − c − d

D a = c + b + d

6.

$5N_2O_4(l) + 4CH_3NHNH_2(l) \rightarrow 4CO_2(g) + 12H_2O(l) + 9N_2(g)$

ΔH = −5116 kJ

The energy released when 2 moles of each reactant are mixed and ignited is

A 2046 kJ

B 2558 kJ

C 4093 kJ

D 5116 kJ.

7. Aluminium reacts with oxygen to form aluminium oxide.

$2Al(s) + 1½O_2(g) \rightarrow Al_2O_3(s)$

$\Delta H = -1670$ kJ mol^{-1}

What is the enthalpy of combustion of aluminium in kJ mol−1?

A −835

B −1113

C −1670

D +1670

8. In the presence of bright light, hydrogen and chlorine react explosively. One step in the reaction is shown below.

$H_2(g) + Cl(g) \rightarrow HCl(g) + H(g)$

The enthalpy change for this step can be represented as

A (H-H bond enthalpy) + (Cl-Cl bond enthalpy)

B (H-H bond enthalpy) – (Cl-Cl bond enthalpy)

C (H-H bond enthalpy) + (H-Cl bond enthalpy)

D (H-H bond enthalpy) – (H-Cl bond enthalpy)

9. Which of the following equations represents an enthalpy of combustion?

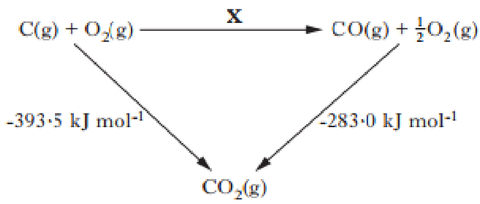
A $C_2H_6(g) + 3\ ½\ O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

B $C_2H_5OH() + O_2(g) \rightarrow CH_3COOH(l) + H_2O(l)$

C $CH_3CHO(l) + ½\ O_2(g) \rightarrow CH_3COOH(l)$

D $CH_4(g) + 1\ ½\ O_2(g) \rightarrow CO(g) + 2H_2O(l)$

10. Consider the reaction pathways shown below.



According to Hess's law, the enthalpy change for reaction X is

A –676·5 kJ mol^{-1}

B –110·5 kJ mol^{-1}

C +110·5 kJ mol^{-1}

D +676·5 kJ mol^{-1}.

11. The mean bond enthalpy of the N−H bond is equal to one third of the value of ΔH for which change?

A $N(g) + 3H(g) \rightarrow NH_3(g)$

B $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

C $½N_2(g) + 1½\ H_2(g) \rightarrow NH_3(g)$

D $NH_3(g) \rightarrow ½N_2(g) + 1½H_2(g)$

Chemical Energy – Section B

1. The enthalpy of formation of glycerol is the enthalpy change for the reaction:

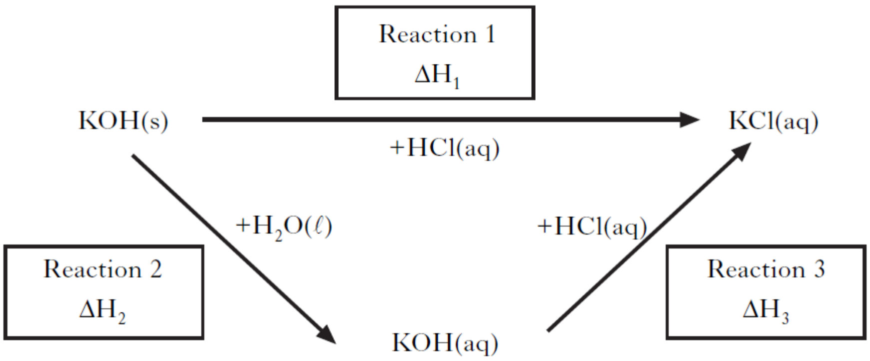
$3C(s) + 4H_2(g) + 1½O_2(g) \rightarrow C_3H_8O_3(l)$
(graphite)

Calculate the enthalpy of formation of glycerol, in kJ mol^{-1}, using information from the data booklet and the following data.

$C_3H_8O_3(l) + 3½O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ ΔH = –1654 kJ mol^{-1}

Show your working clearly.

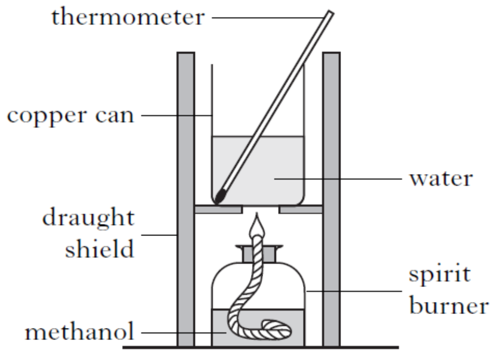
2. Hess's Law can be verified using the reactions summarised below.



A student found that 1·08kJ of energy was **released** when 1·2 g of potassium hydroxide was dissolved completely in water.

Calculate the enthalpy of solution of potassium hydroxide.

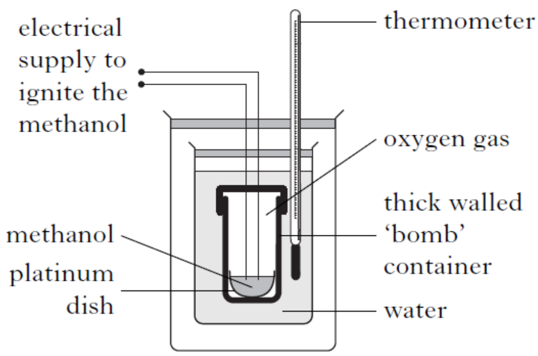
3. A student used the simple laboratory apparatus shown to determine the enthalpy of combustion of methanol.



(a) (i) What measurements are needed to calculate the energy released by the burning methanol?

(ii) The student found that burning 0.370 g of methanol produces 3.86 kJ of energy.
Use this result to calculate the enthalpy of combustion of methanol.

(b) A more accurate value can be obtained using a bomb calorimeter.



One reason for the more accurate value is that less heat is lost to the surroundings than in the simple laboratory method.

Give **one** other reason for the value being more accurate in the bomb calorimeter method.

4. Silane, silicon hydride, is formed in the reaction of silicon with hydrogen.

$Si(s) + 2H_2(g) \rightarrow SiH_4(g)$
silane

The enthalpy change for this reaction is called the enthalpy of formation of silane.
The combustion of silane gives silicon dioxide and water.

$SiH_4(g) + 2O_2(g) \rightarrow SiO_2(s) + 2H_2O(l)$ $\Delta H = -1517$ kJ mol^{-1}

The enthalpy of combustion of silicon is –911 kJ mol^{-1}.

Use this information and the enthalpy of combustion of hydrogen in the data booklet to calculate the enthalpy of formation of silane, in kJ mol^{-1}.
Show your working clearly.

5. Chloromethane can be produced by the reaction of methane with chlorine.

$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$

Using bond enthalpies from the data booklet, calculate the enthalpy change, in kJ mol^{-1}, for this reaction.

6. Mobile phones are being developed that can be powered by methanol.
Methanol can be made by a two-stage process.

(*a*) In the first stage, methane is reacted with steam to produce a mixture of carbon monoxide and hydrogen.

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

Use the data below to calculate the enthalpy change, in kJ mol^{-1}, for the forward reaction.

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$ $\Delta H = -283$ kJ mol^{-1}

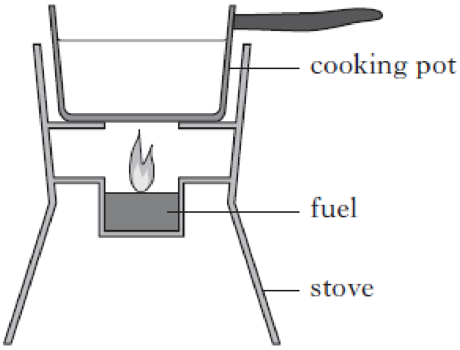
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\Delta H = -242$ kJ mol^{-1}

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta H = -803$ kJ mol^{-1}

Show your working clearly.

7. Different fuels are used for different purposes.

(*a*) Ethanol, C_2H_5OH, can be used as a fuel in some camping stoves.



The enthalpy of combustion of ethanol given in the data booklet is −1367 kJ mol^{-1}.

(i) Using this value, calculate the mass of ethanol, in g, required to raise the temperature of 500 g of water from 18 °C to 100 °C.
Show your working clearly.

(ii) Suggest **two** reasons why less energy is obtained from burning ethanol in the camping stove than is predicted from its enthalpy of combustion.

(*b*) Petrol is a fuel used in cars.

Energy released when 1·00 g of petrol burned/kJ	48·0
Volume of 1·00 g of petrol/cm^3	1·45

A car has a 50·0 litre petrol tank.
Calculate the energy, in kJ, released by the complete combustion of one tank of petrol.

8. The compound diborane (B_2H_6) is used as a rocket fuel.

(i) It can be prepared as shown.

$BF_3 + NaBH_4 \rightarrow B_2H_6 + NaBF_4$

Balance this equation.

(ii) The equation for the combustion of diborane is shown below.
$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(l)$

Calculate the enthalpy of combustion of diborane (B2H6) in kJ mol−1, using the following data.

$2B(s) + 3H_2(g) \rightarrow B_2H_6(g)$ $\Delta H = 36$ kJ mol^{-1}

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H = -286$ kJ mol^{-1}

$2B(s) + 1\frac{1}{2}O_2(g) \rightarrow B_2O_3(s)$ $\Delta H = -1274$ kJ mol^{-1}

9. The production of hydrogen chloride from hydrogen and chlorine is exothermic.

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Using bond enthalpy values, calculate the enthalpy change, in kJ mol^{-1}, for this reaction.

10. The industrial method currently used to produce butan-2-ol is the hydration of but-2-ene.
$C_4H_8(g) + H_2O(g) \rightarrow C_4H_{10}O(g)$

The enthalpy values for the following reactions are:

$4C(s) + 4H_2(g) \rightarrow C_4H_8(g)$ $\Delta H = -7{\cdot}1$ kJ mol^{-1}

$4C(s) + 5H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_4H_{10}O(g)$ $\Delta H = -292{\cdot}8$ kJ mol^{-1}

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H = -483{\cdot}6$ kJ mol^{-1}

Using the data above, calculate the enthalpy change, in kJ mol^{-1}, for the production of butan-2-ol by hydration of but-2-ene.

11. 2-Methylpropan-1-ol may be used as an alternative to ethanol as a fuel.

(i) Ethanol releases 29·7 kJ of energy for every gram of fuel burned.

Using the information from the table below, show by calculation that 2-methylpropan-1-ol releases more energy than the same mass of ethanol when burnt.

	2-methylpropan-1-ol
Mass of one mole/g	74
Enthalpy of combustion/kJ mol^{-1}	–2669

Oxidising or Reducing Agents – Section A

1. In which reaction is hydrogen gas acting as an oxidising agent?

A $H_2 + CuO \rightarrow H_2O + Cu$

B $H_2 + C_2H_4 \rightarrow C_2H_6$

C $H_2 + Cl_2 \rightarrow 2HCl$

D H2 + 2Na → 2NaH

2. In which of the following reactions is a positive ion reduced?

A Iodide → iodine

B Nickel(II) → nickel(III)

C Cobalt(III) → cobalt(II)

D Sulphate→ sulphite

3. Iodide ions can be oxidised using acidified potassium permanganate solution.

The equations are:

$2I^-(aq) \rightarrow$ I2(aq) + $2e^-$

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

How many moles of iodide ions are oxidised by one mole of permanganate ions?

A 1.0

B 2.0

C 2.5

D 5.0

4. Which of the following elements is the strongest reducing agent?

A Lithium

B Bromine

C Fluorine

D Aluminium

5. One of the reactions taking place within a carbon monoxide sensor is

$2CO + 2H_2O \rightarrow 2CO_2 + 4H^+ + 4e^-$

This reaction is an example of

A reduction

B redox

C oxidation

D hydration.

6. During a redox process in acid solution, iodate ions, $IO_3^-(aq)$, are converted into iodine, $I_2(aq)$.

$IO_3^-(aq) \rightarrow I_2(aq)$

The numbers of $H^+(aq)$ and $H_2O(l)$ required to balance the ion-electron equation for the formation of 1 mol of $I_2(aq)$ are, respectively

A 3 and 6

B 6 and 3

C 6 and 12

D 12 and 6.

7. Which of the following elements is the strongest reducing agent?

A Fluorine

B Hydrogen

C Potassium

D Magnesium

Oxidising or Reducing Agents – Section B

1. A major problem for the developed world is the pollution of rivers and streams by nitrite and nitrate ions.

The concentration of nitrite ions, $NO_2^-(aq)$, in water can be determined by titrating samples against acidified permanganate solution.

During the reaction the nitrite ion is oxidised to the nitrate ion.

Complete the ion-electron equation for the oxidation of the nitrite ions.

$NO_2^-(aq) \rightarrow NO_3^-(aq)$

2. The number of moles of carbon monoxide in a sample of air can be measured as follows.

Step 1 The carbon monoxide reacts with iodine(V) oxide, producing iodine.

$5CO(g) + I_2O_5(s) \rightarrow I_2(s) + 5CO_2(g)$

Step 2 The iodine is then dissolved in potassium iodide solution and titrated against sodium thiosulphate solution.

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

(a) Write the ion-electron equation for the oxidation reaction in **Step 2**.

3. Suncreams contain antioxidants.

One antioxidant used in skin care products is vitamin C, $C_6H_8O_6$.

Complete the ion-electron equation for the oxidation of vitamin C.

$C_6H_8O_6(aq) \qquad \rightarrow \qquad C_6H_6O_6(aq)$

4. Solutions containing iodine are used to treat foot rot in sheep.

The concentration of iodine in a solution can be determined by titrating with a solution of thiosulfate ions.

$I_2 \quad + \quad 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

thiosulfate ions

(a) Write an ion-electron equation for the reaction of the oxidising agent in the titration.

5. The Periodic Table allows chemists to make predictions about the properties of elements.

Li	Be	B	C	N	O	F	Ne

(*a*) The elements lithium to neon make up the second period of the Periodic Table.

Which element in the second period is the strongest reducing agent?

6. The ion-electron equations for the reduction and oxidation reactions occurring in the cell are shown below.

$O2 + 4H^+ + 4e^- \rightarrow 2H_2O$

$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$

Write the overall redox equation for the reaction taking place.

7. Fluorine is an extremely reactive element. Its compounds are found in a range of products.

(*a*) Iodine can be extracted from iodide salts by reacting them with acidified permanganate solution.

$10I^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 5I_2(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$

Why can fluorine not be produced from fluoride salts using acidified permanganate?

8. Hydrogen and chlorine gases are used in an experiment to demonstrate a free radical reaction. The chlorine used in the experiment is made in a redox reaction between permanganate ions and chloride ions.

The ion-electron equations for the oxidation and reduction reactions are shown below.

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

Write a balanced equation for the reaction of permanganate ions with chloride ions to produce chlorine gas.

9. In many bathroom cleaning products, the bleaching agent is the hypochlorite ion, $ClO^-(aq)$.

(a) Hypochlorite bleaches can be made by reacting sodium hydroxide with chlorine. Sodium hypochlorite, sodium chloride and water are formed.

Write a balanced equation for the reaction.

(b) When $ClO^-(aq)$ acts as a bleach, it is reduced to produce the $Cl^-(aq)$ ion.

$ClO^-(aq) \rightarrow Cl^-(aq)$

Complete the above to form the ion-electron equation for the reduction reaction.

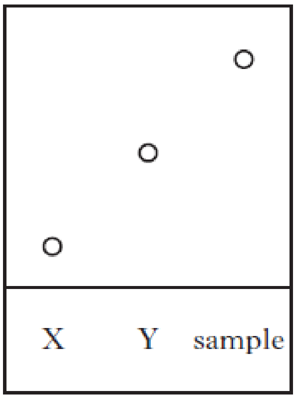
Chemical Analysis – Section A

1. An organic chemist is attempting to synthesise a fragrance compound by the following chemical reaction.
compound **X** + compound **Y** → fragrance compound

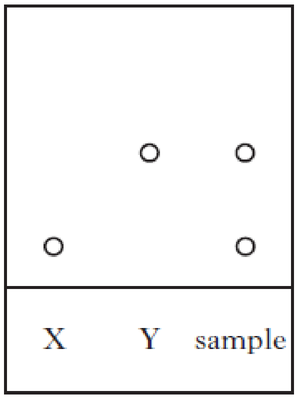
After one hour, a sample is removed and compared with pure samples of compounds **X** and **Y** using thin-layer chromatography.

Which of the following chromatograms shows that the reaction has produced a pure sample of the fragrance compound?

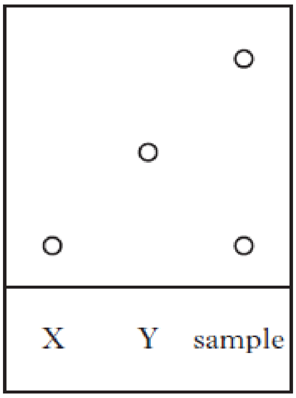
A



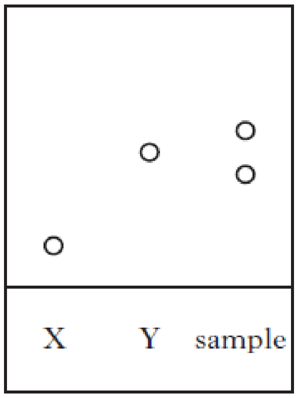
B



C



D



Chemical Analysis – Section B

1. A major problem for the developed world is the pollution of rivers and streams by nitrite and nitrate ions. The concentration of nitrite ions, $NO2^{-}$(aq), in water can be determined by titrating samples against acidified permanganate solution.

(a) Suggest **two** points of good practice that should be followed to ensure that an accurate end-point is achieved in a titration.

(b) An average of 21·6cm3 of 0·0150 mol l–1 acidified permanganate solution was required to react completely with the nitrite ions in a 25·0 cm3 sample of river water.

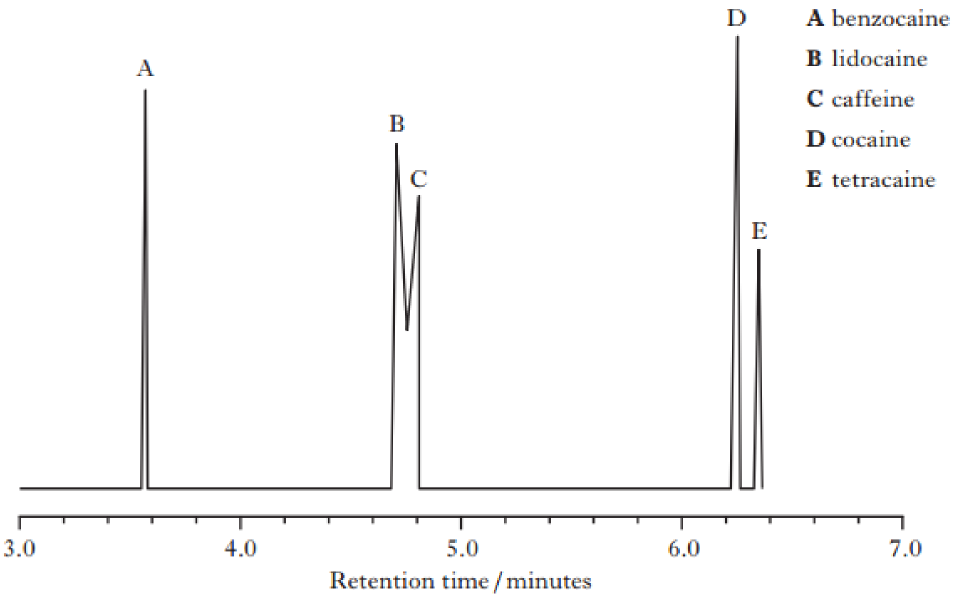
The equation for the reaction taking place is:

$2MnO_4^-(aq) + 5NO_2^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5NO_3^-(aq) + 3H_2O(l)$

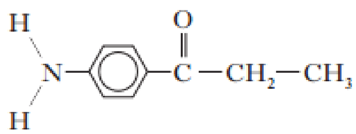
(i) Calculate the nitrite ion concentration, in mol l^{-1}, in the river water.
Show your working clearly.

2. When forensic scientists analyse illegal drugs, anaesthetics such as lidocaine are sometimes found to be present.

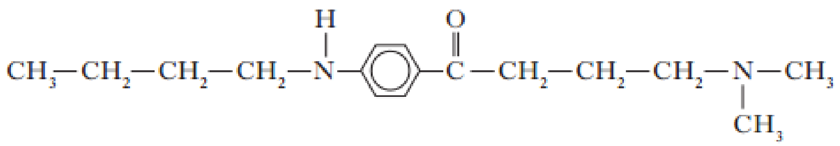
The gas chromatogram below is from an illegal drug.



(i) The structures of benzocaine and tetracaine are shown below.



benzocaine

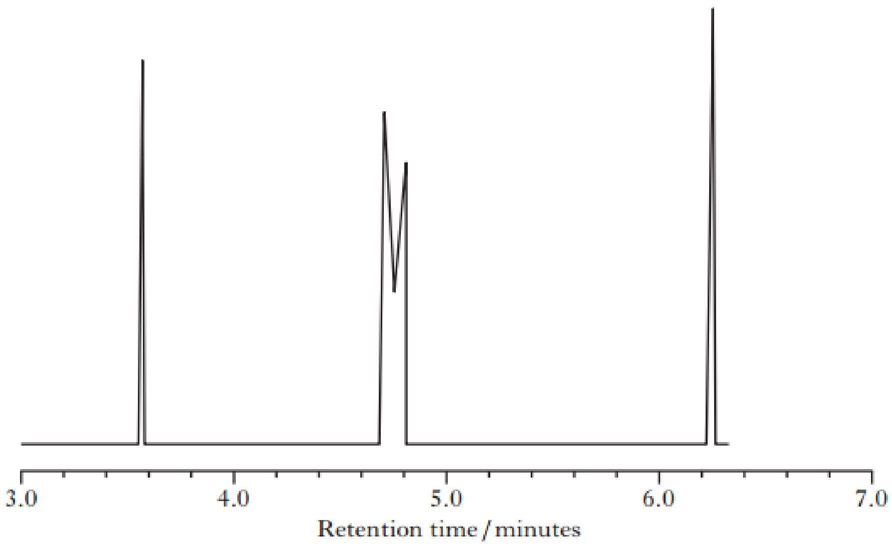


tetracaine

Suggest why benzocaine has a shorter retention time than tetracaine.

(ii) Why is it difficult to obtain accurate values for the amount of lidocaine present in a sample containing large amounts of caffeine?

(iii) Add a peak to the diagram below to complete the chromatogram for a second sample that only contains half the amount of tetracaine compared to the first.



3. Three 20·0 cm^3 samples of a sheep treatment solution were titrated with 0·10 mol l^{-1} thiosulfate solution.

The results are shown below.

Sample	Volume of thiosulfate/cm^3
1	18·60
2	18·10
3	18·20

(i) Why is the volume of sodium thiosulfate used in the calculation taken to be 18·15 cm^3, although this is not the average of the three titres in the table?

(ii) Calculate the concentration of iodine, in mol l^{-1}, in the foot rot treatment solution.
Show your working clearly

(iii) Describe how to prepare 250 cm^3 of a 0·10 mol l^{-1} standard solution of sodium thiosulfate, $Na_2S_2O_3$.

Your answer should include the mass, in g, of sodium thiosulfate required.

4. Hydrogen sulfide, H_2S, can cause an unpleasant smell in water supplies.

The concentration of hydrogen sulfide can be measured by titrating with a chlorine standard solution.

The equation for the reaction taking place is

$4Cl_2(aq) + H_2S(aq) + 4H_2O(l) \rightarrow SO_4^{2-}(aq) + 10H^+(aq) + 8Cl^-(aq)$

50·0 cm^3 samples of water were titrated using a 0·010 mol l^{-1} chlorine solution.

(i) Name an appropriate piece of apparatus which could be used to measure out the water samples.

(ii) What is meant by the term standard solution?

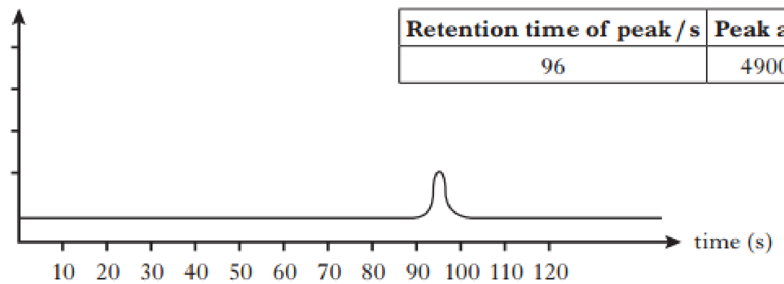
(iii) An average of 29·4 cm^3 of 0·010 mol l^{-1} chlorine solution was required to react completely with a 50·0 cm^3 sample of water.

Calculate the hydrogen sulfide concentration, in mol l^{-1}, present in the water sample.
Show your working clearly.

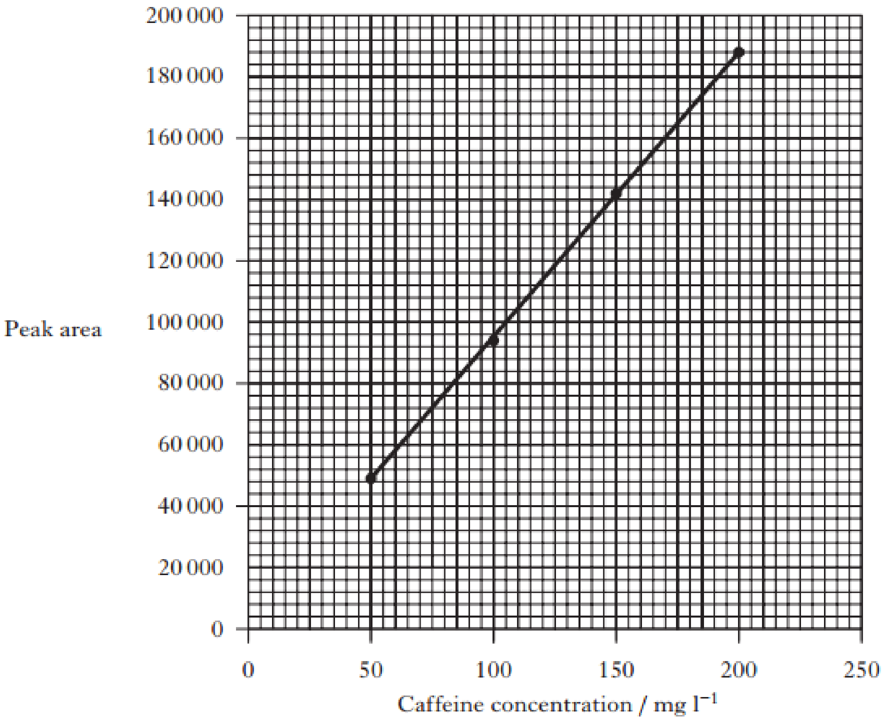
5. Caffeine is also added to some soft drinks. The concentration of caffeine can be found using chromatography.

A chromatogram for a standard solution containing 50 mg l^{-1} of caffeine is shown below.

Retention time of peak / s	Peak area
96	49000

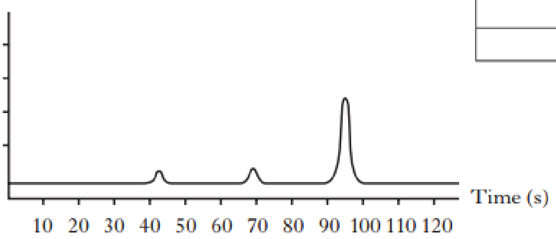


Results from four caffeine standard solutions were used to produce the calibration graph below.



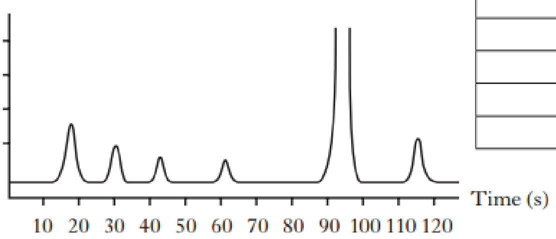
Chromatograms for two soft drinks are shown below.

Soft drink **X**



Retention time of peak / s	Peak area
42	1000
69	1350
96	68000

Soft drink **Y**



Retention time of peak / s	Peak area
17	7000
30	4600
43	3000
62	2500
96	----
115	5000

(i) What is the caffeine content, in mg l^{-1} of soft drink X?

(ii) The caffeine content of the soft drink Y cannot be determined from its chromatogram. What should be done to the sample of soft drink Y so that the caffeine content could be reliably calculated?

6. A student carried out an investigation to measure the nitrite level in the school water supply.

A compound, which reacts with the nitrite ions to form a product that absorbs light, is added to water samples. The higher the concentration of nitrite ions present in a water sample, the greater the amount of light absorbed.

(a) The student prepared potassium nitrite solutions of known concentration by diluting samples from a stock solution.

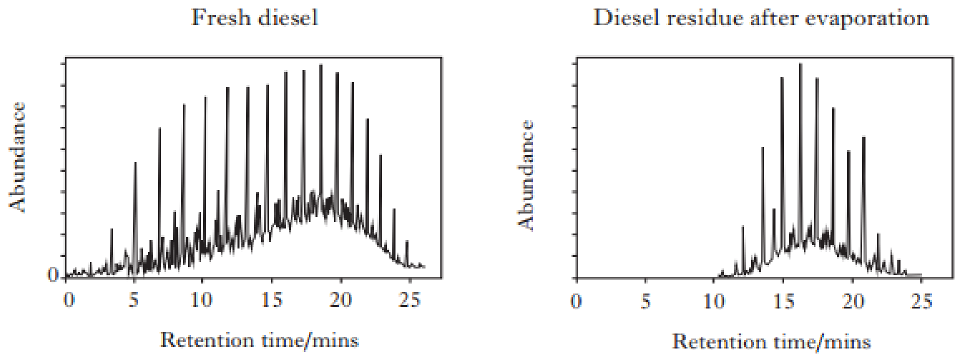
(i) Describe how the weighed potassium nitrate is dissolved to prepare the stock solution to ensure that its concentration is accurately known.

(ii) Why should the student use distilled or deionised water rather than tap water when dissolving the potassium nitrite?

7. When a fire has been started deliberately, gas liquid chromatography (GLC) can be used to identify the tiny amounts of fuel or flammable liquid used to help start the fire.

(a) Diesel contains a mixture of non-polar molecules of different sizes.

Below are the chromatograms recorded using a normal sample of diesel and a sample of diesel that has been heated until around 90% of the diesel had evaporated.



Explain how these chromatograms show that large molecules have longer retention times than small molecules in this type of chromatography.

(b) A suspicious house fire was found to have started in a chair.

An almost empty bottle of paint thinner was found in a suspect's car.

In the house there were two cans of furniture polish which might have been used to clean the chair at some time.

The chromatograms obtained from the remains of the chair, the paint thinner and the furniture polishes are shown opposite.

Which of the substances tested were present on the armchair?