Department of Chemistry

Exam Questions for CfE Higher Chemistry

Unit 3 Chemistry in Society

3.1 Getting the Most from Reactants

1. How many moles of oxygen atoms are in 0.5 mol of carbon dioxide?
   A 0.25
   B 0.5
   C 1
   D 2

2. A fullerene molecule consists of 60 carbon atoms.
   Approximately how many such molecules are present in 12 g of this type of carbon?
   A 1.0×10^{22}
   B 1.2×10^{23}
   C 6.0×10^{23}
   D 3.6×10^{25}

3. Which of the following gases would contain the greatest number of molecules in a 100 g
   sample, at room temperature?
   A Fluorine
   B Hydrogen
   C Nitrogen
   D Oxygen

4. A mixture of potassium chloride and potassium carbonate is known to contain
   0·1 mol of chloride ions and 0·1 mol of carbonate ions. How many moles of potassium ions are present?
   A 0·15
   B 0·20
   C 0·25
   D 0·30

5. The mass of 1 mol of sodium is 23 g. What is the approximate mass of one sodium atom?
   A 6×10^{23} g
   B 6×10^{-23} g
   C 3.8×10^{-23} g
   D 3.8×10^{-24} g

6. 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

7. In which of the following pairs do the gases contain the same number of oxygen atoms?
A 1 mol of oxygen and 1 mol of carbon monoxide
B 1 mol of oxygen and 0.5 mol of carbon dioxide
C 0.5 mol of oxygen and 1 mol of carbon dioxide
D 1 mol of oxygen and 1 mol of carbon dioxide

8. The Avogadro Constant is the same as the number of
A molecules in 16 g of oxygen
B ions in 1 litre of sodium chloride solution, concentration 1 mol l-1
C atoms in 24 g of carbon
D molecules in 2 g of hydrogen.

9. Which of the following contains one mole of neutrons?
A 1 g of $^{1}_{1}H$
B 1 g of $^{12}_{6}C$
C 2 g of $^{24}_{12}Mg$
D 2 g of $^{22}_{10}Ne$

10. The Avogadro Constant is the same as the number of
A ions in 1 mol of NaCl
B atoms in 1 mol of hydrogen gas
C electrons in 1 mol of helium gas
D molecules in 1 mol of oxygen gas.

11. The Avogadro Constant is the same as the number of
A molecules in 16 g of oxygen
B electrons in 1 g of hydrogen
C atoms in 24 g of carbon
D ions in 1 litre of sodium chloride solution, concentration 1 mol l^{-1}.

12. Avogadro's Constant is the same as the number of
A molecules in 16.0 g of oxygen
B atoms in 20.2 g of neon
C formula units in 20.0 g of sodium hydroxide
D ions in 58.5 g of sodium chloride.

13. Which of the following has the largest volume under the same conditions of temperature and pressure?
A 1 g hydrogen
B 14 g nitrogen

C 20·2 g neon
D 35·5 g chlorine

14. The equation for the complete combustion of propane is:

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$$

30cm^3 of propane is mixed with 200cm^3 of oxygen and the mixture is ignited. What is the volume of the resulting gas mixture? (All volumes are measured at the same temperature and pressure.)

A 90cm^3
B 120cm^3
C 140cm^3
D 210cm^3

15. 20cm^3 of butane is burned in 150 cm^3 of oxygen.

$$C_4H_{10(g)} + 6O_{2(g)} \rightarrow 4CO2_{(g)} + 5H_2O_{(g)}$$

What is the total volume of gas present after complete combustion of the butane?

A 80cm^3
B 100cm^3
C 180cm^3
D 200cm^3

16. $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$

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

17. $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$

How many litres of nitrogen dioxide gas would be produced in a reaction, starting with

a mixture of 5 litres of nitrogen monoxide gas and 2 litres of oxygen gas? (All volumes are measured under the same conditions of temperature and pressure.)

A 2
B 3
C 4
D 5

18. 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

19. $2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(l)}$
ethyne
What volume of gas would be produced by the complete combustion of 100 cm3 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

20. 20cm3 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 $10cm^3$
B $20cm^3$
C $30cm^3$
D $40cm^3$

21. 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.

22. 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

23. 5 g of copper is added to excess silver nitrate solution. The equation for the reaction that takes place is:

$$Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

After some time, the solid present is filtered off from the solution, washed with water,
dried and weighed. The final mass of the solid will be
A less than 5 g

B 5g
C 10g
D more than 10 g.

24. A pupil added 0·1 mol of zinc to a solution containing 0·05 mol of silver(I) nitrate.

$Zn_{(s)} + 2AgNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + 2Ag_{(s)}$

Which of the following statements about the experiment is correct?

A 0·05 mol of zinc reacts.

B 0·05 mol of silver is displaced.

C Silver nitrate is in excess.

D All of the zinc reacts.

25. 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 cm3 of solution. What is the concentration of $Cu^{2+}{}_{(aq)}$ ions in the solution in mol l^{-1}?

A 0·5

B 1·0

C 2·0

D 4·0

26. 10 g of magnesium is added to 1 litre of 1 mol l^{-1} copper(II) sulphate solution and the

mixture stirred until the reaction is complete. Which of these 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.

27. Ammonia is manufactured from hydrogen and nitrogen by the Haber Process.

$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$

If 80 kg of ammonia is produced from 60 kg of hydrogen, what is the percentage yield?

A $\frac{80}{340} \times 100$

B $\frac{80}{170} \times 100$

C $\frac{30}{80} \times 100$

D $\frac{60}{80} \times 100$

28. Two identical samples of copper(II) carbonate were added to an excess of 1 mol l^{-1}

hydrochloric acid and 1 mol l^{-1} sulphuric acid respectively.

Which of the following would have been different for the two reactions?

A The pH of the final solution

B The volume of gas produced

C The mass of water formed

D The mass of copper(II) carbonate dissolved

29. Which of the following is the best description of a feedstock?
A A consumer product such as a textile, plastic or detergent.
B A complex chemical that has been synthesised from small molecules.
C A mixture of chemicals formed by the cracking of the naphtha fraction from oil.
D A chemical from which other chemicals can be extracted or synthesised.

30. Which of the following compounds is a raw material in the chemical industry?
A Ammonia
B Calcium carbonate
C Hexane
D Nitric acid

31. 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 $\frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g) \rightarrow NH_3(g)$

D $NH_3(g) \rightarrow \frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g)$

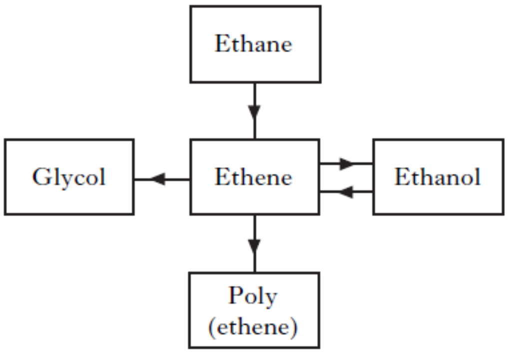
32. Ammonia is made by the Haber Process.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

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

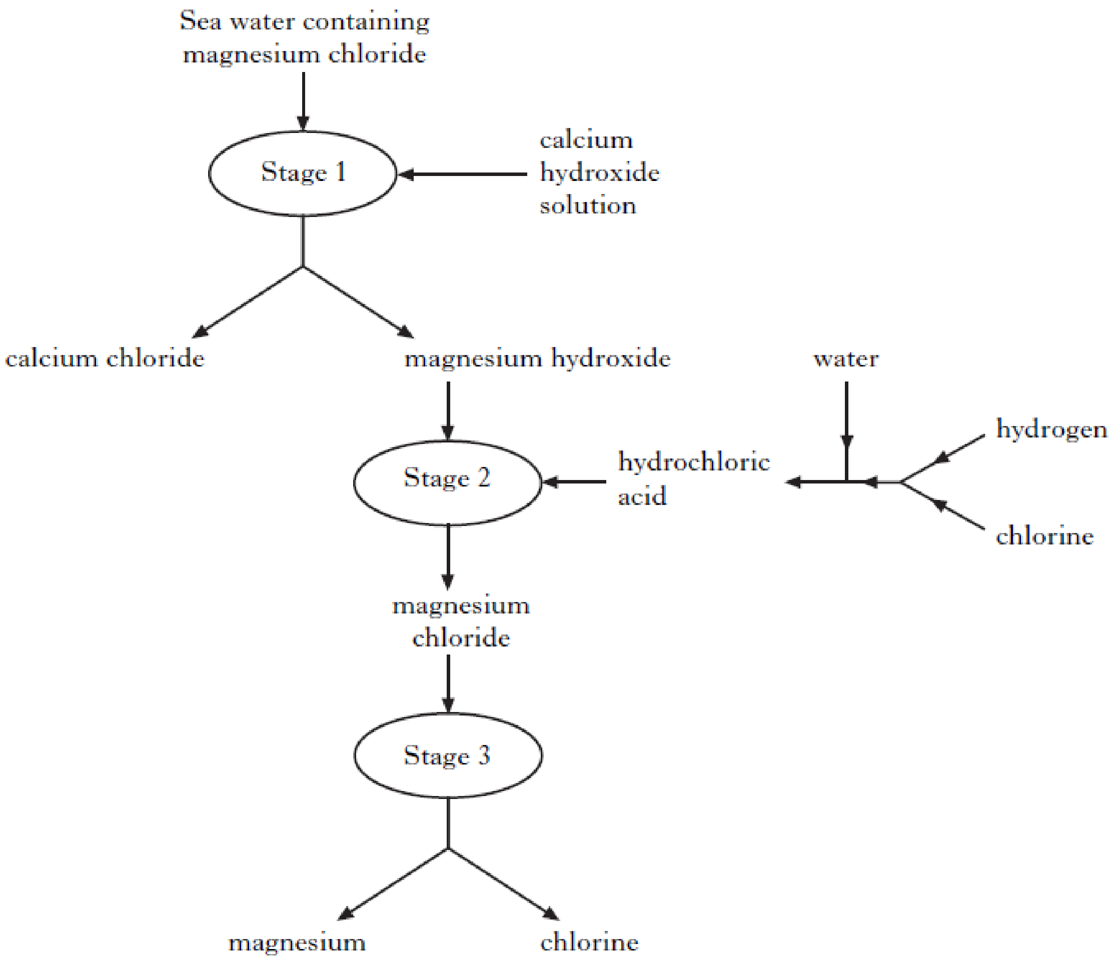
33. The flow chart summarises some industrial processes involving ethene.



The feedstocks for ethene in these processes are
A ethane and glycol
B ethane and ethanol
C glycol and poly(ethene)
D glycol, poly(ethene) and ethanol.

34. Polylactic acid is used to make a biodegradable polymer. Polylactic acid can be manufactured by either a batch or a continuous process. What is meant by a batch process? (1)

35. Magnesium metal can be extracted from sea water.
An outline of the reactions involved is shown in the flow diagram.

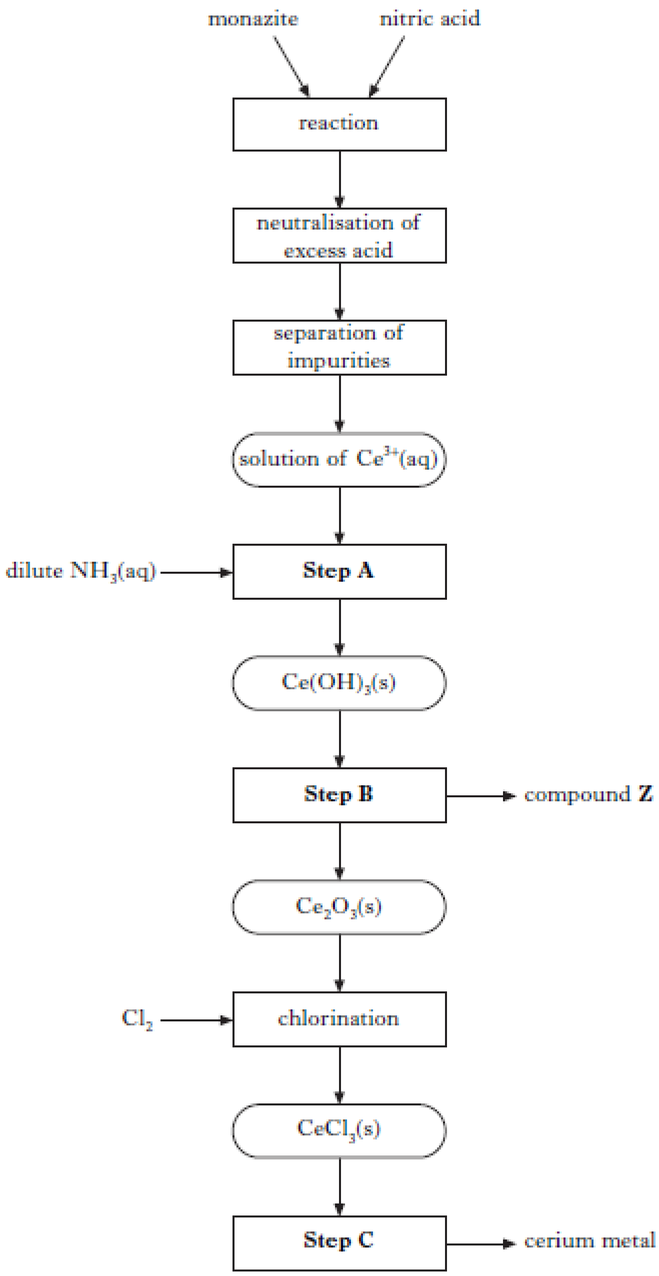


(a) Why can the magnesium hydroxide be easily separated from the calcium chloride at Stage 1? (1)

(b) Name the type of chemical reaction taking place at Stage 2. (1)

(c) Give two different features of this process that make it economical. (2)

36. Cerium metal is extracted from the mineral monazite.
The flow diagram for the extraction of cerium from the mineral is shown below.



(a) Name the type of chemical reaction taking place in Step A. (1)

(b) In Step B, cerium hydroxide is heated to form cerium oxide, Ce_2O_3, and compound Z. Name compound Z. (1)

(c) In Step C, cerium metal is obtained by electrolysis. What feature of the electrolysis can be used to reduce the cost of cerium production? (1)

37. Ozone can be produced in the laboratory by electrical discharge.

$3O_{2(g)} \rightarrow 2O_{3(g)}$

Calculate the approximate number of $O_{3(g)}$ molecules produced from one mole of $O_{2(g)}$ molecules. (1)

38. Chlorine gas can be produced by heating calcium hypochlorite, Ca(OCl)2, in dilute
hydrochloric acid.

$Ca(OCl)_{2(s)} + 2HCl_{(aq)} \rightarrow Ca(OH)_{2(aq)} + 2Cl_{2(g)}$

Calculate the mass of calcium hypochlorite that would be needed to produce 0·096 litres of chlorine gas. (Take the molar volume of chlorine gas to be 24 litres mol^{-1}.)
Show your working clearly. (2)

39. A student bubbled 240 cm^3 of carbon dioxide into 400cm^3 of 0.10 mol l^{-1} lithium hydroxide solution.
The equation for the reaction is:

$2LiOH_{(aq)} + CO_{2(g)} \rightarrow Li_2CO_{3(aq)} + H_2O_{(l)}$

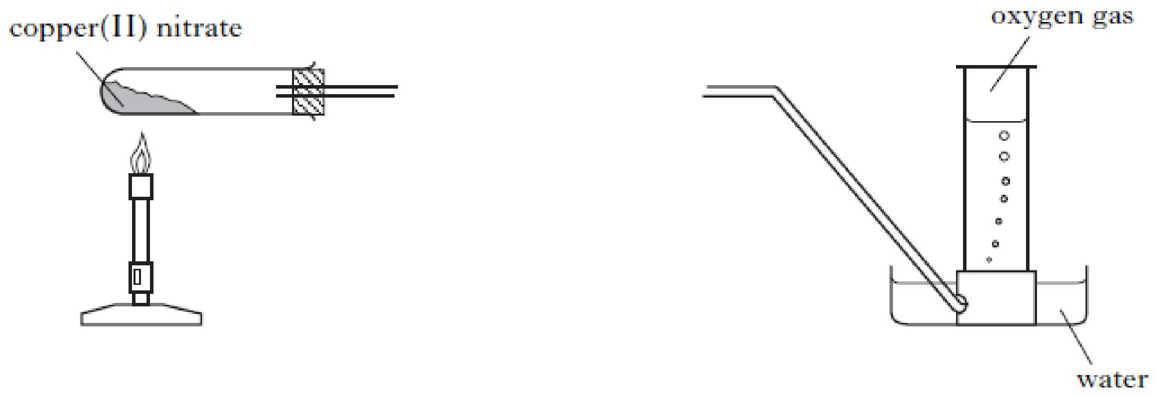
Calculate the number of moles of lithium hydroxide that would not have reacted.
(Take the molar volume of carbon dioxide to be 24 litres mol^{-1}.)
Show your working clearly. (2)

40. (a) In the lab, nitrogen dioxide gas can be prepared by heating copper(II) nitrate.

$Cu(NO_3)_{2(s)} \rightarrow CuO_{(s)} + 2NO_{2(g)} + ½ O_{2(g)}$

Calculate the volume of nitrogen dioxide gas produced when 2.0g of copper(II) nitrate is completely decomposed on heating. (Take the molar volume of nitrogen dioxide to be 24 litres mol^{-1}.) Show your working clearly. (2)

(b) Nitrogen dioxide has a boiling point of 22 °C. Complete the diagram to show how nitrogen dioxide can be separated and collected. (1)



41. 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.

$$2NaHCO_3 + C_4H_6O_6 \rightarrow Na_2(C_4H_4O_6) + 2H_2O + 2CO_2$$

$2NaHCO_3$	+	$C_4H_6O_6$	$\rightarrow$	$Na_2(C_4H_4O_6)$	+	$2H_2O$	+	$2CO_2$
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. (2)

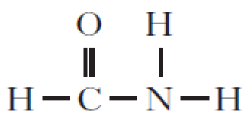
42. The nutritional information states that 100 g of margarine contains 0.70 g of sodium. The sodium is present as sodium chloride (NaCl). Calculate the mass of sodium chloride, in g, present in every 100 g of margarine. (1)

43. Hydrogen fluoride gas is manufactured by reacting calcium fluoride with concentrated sulphuric acid.

$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$

What volume of hydrogen fluoride gas is produced when 1.0 kg of calcium fluoride reacts completely with concentrated sulphuric acid?
(Take the molar volume of hydrogen fluoride gas to be 24 litres mol-1.)
Show your working clearly. (2)

44. Methanamide, HCONH2, is widely used in industry to make nitrogen compounds. It is also used as a solvent as it can dissolve ionic compounds.



(a) Why is methanamide a suitable solvent for ionic compounds? (1)

(b) In industry, methanamide is produced by the reaction of an ester with ammonia.

$HCOOCH_3$	+	NH_3	$\rightarrow$	$HCONH_2$	+	CH_3OH
mass of one mole = 60·0 g		mass of one mole = 17·0 g		mass of one mole = 45·0 g		mass of one mole = 32·0 g

(i) Name the ester used in the industrial manufacture of methanamide. (1)

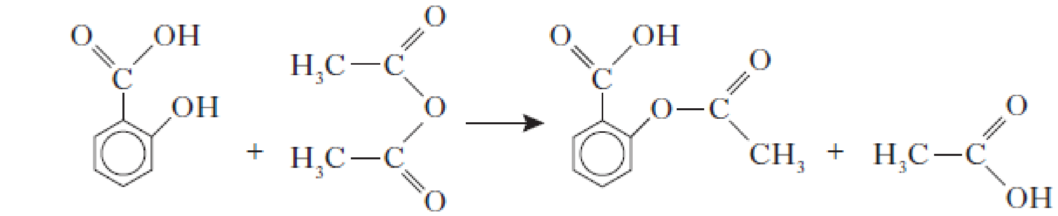
(ii) Calculate the atom economy for the production of methanamide. (1)

(c) In the lab, methanamide can be prepared by the reaction of methanoic acid with ammonia.

$HCOOH$	+	NH_3	$\rightleftharpoons$	$HCONH_2$	+	H_2O
mass of one mole = 46·0 g		mass of one mole = 17·0 g		mass of one mole = 45·0 g		mass of one mole = 18·0 g

When 1·38 g of methanoic acid was reacted with excess ammonia, 0·945 g of methanamide was produced. Calculate the percentage yield of methanamide. Show your working clearly. (2)

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

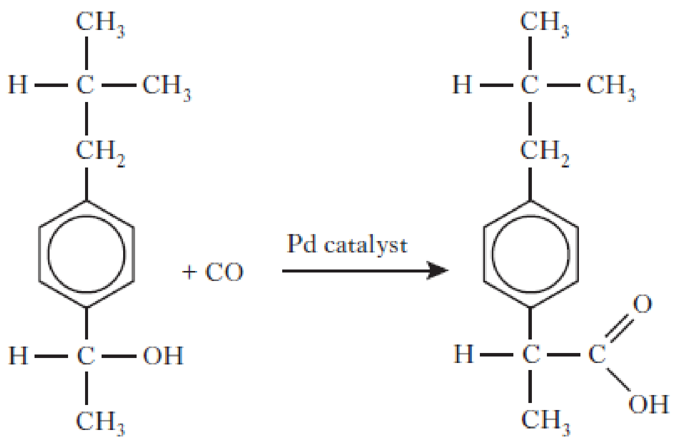


$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

(a) Calculate the atom economy for the formation of aspirin using this method. Show your working clearly. (2)

(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. (2)

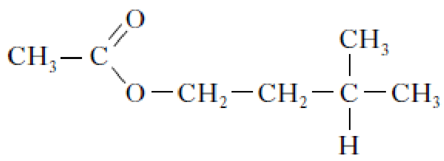
46. From the 1990s, ibuprofen has been synthesised by a three step process. The equation below shows the final step of the synthesis.



ibuprofen

What is the atom economy of this step? (1)

47. One of the chemicals released in a bee sting is an ester that has the structure shown.



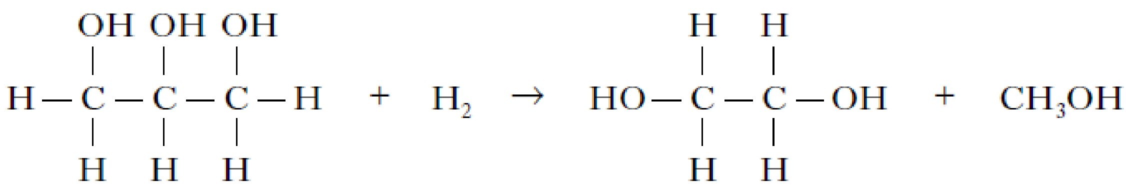
This ester can be produced by the reaction of 2-methylbutan-1-ol with ethanoic acid.
If there is a 65% yield, calculate the mass of ester produced, in grams, when 4.0 g of the alcohol reacts with a slight excess of the acid.
(Mass of one mole of the alcohol = 88 g; mass of one mole of the ester = 130 g)
Show your working clearly. (2)

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

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

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. (2)

49. Ethane-1,2-diol is produced in industry by reacting glycerol with hydrogen.



glycerol ethane-1,2-diol

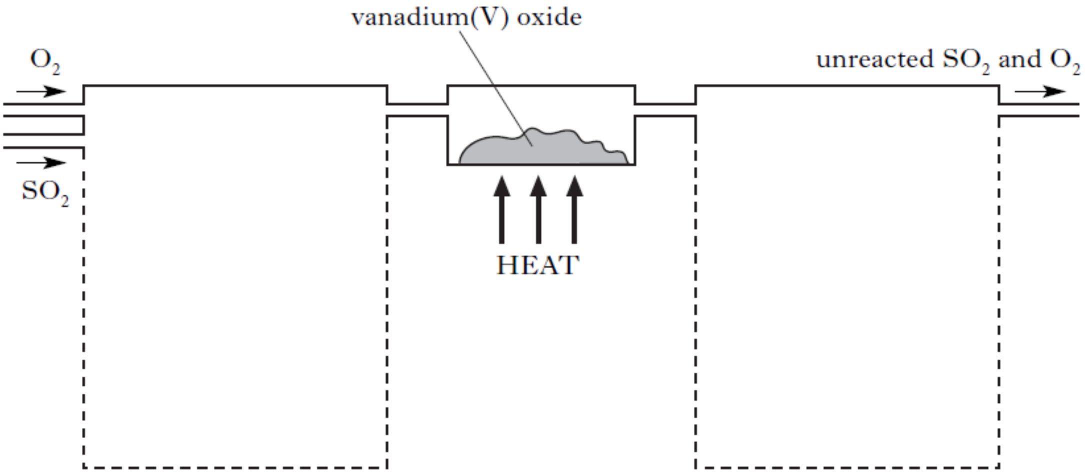
Excess hydrogen reacts with 27·6 kg of glycerol to produce 13·4 kg of ethane-1,2-diol.
Calculate the percentage yield of ethane-1,2-diol. Show your working clearly. (2)

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

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

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.

(a) Complete the diagram to show how the reactant gases are dried and the product is collected. (2)



(b) 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. (2)

3.2 Equilibria

1. A catalyst is used in the Haber Process.

   $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

   Which of the following best describes the action of the catalyst?
   A Increases the rate of the forward reaction only
   B Increases the rate of the reverse reaction only
   C Increases the rate of both the forward and reverse reactions
   D Changes the position of the equilibrium of the reaction

2. In which of the following systems will the equilibrium be unaffected by a change in
   pressure?
   A $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$
   B $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
   C $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$
   D $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$

3. 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.

4. Which line in the table shows the effect of a catalyst on the reaction rates and position of equilibrium in a reversible reaction?

	Rate of forward reaction	Rate of reverse reaction	Position of equilibrium
A	increased	unchanged	moves right
B	increased	increased	unchanged
C	increased	decreased	moves right
D	unchanged	unchanged	unchanged

5. The following equilibrium exists in bromine water.

$$\underset{\text{(red)}}{Br_2(aq)} + H_2O(\ell) \rightleftharpoons \underset{\text{(colourless)}}{Br^-(aq)} + 2H^+(aq) + \underset{\text{(colourless)}}{OBr^-(aq)}$$

The red colour of bromine water would fade on adding a few drops of a concentrated
solution of

A HCl
B KBr
C AgNO3
D NaOBr.

6. 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.

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

8. 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)

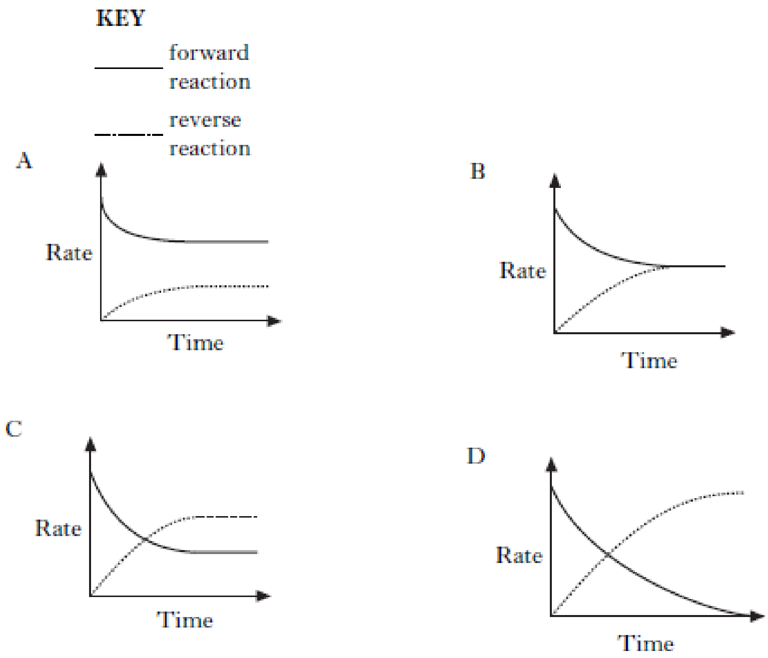
If acid is added to this equilibrium system

A the intensity of the deep blue colour will increase
B the equilibrium position will move to the right
C the concentration of Cu2+(aq) ions will increase
D the equilibrium position will not be affected.

9. 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?



10. $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$
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

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

12. Nitrogen dioxide gas can be prepared in different ways. It is manufactured industrially as part of the Ostwald process. In the first stage of the process,

nitrogen monoxide is produced by passing ammonia and oxygen over a platinum catalyst.

$$NH_{3(g)} + O_{2(g)} \rightarrow NO_{(g)} + H_2O_{(g)}$$

(a) Balance the above equation. (1)

(b) Platinum metal is a heterogeneous catalyst for this reaction. What is meant by a heterogeneous catalyst? (1)

(c) The nitrogen monoxide then combines with oxygen in an exothermic reaction to form nitrogen dioxide.

$$2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$$

What happens to the yield of nitrogen dioxide gas if the reaction mixture is cooled? (1)

13. 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.

$$O_{2(g)} + (aq) \rightleftharpoons O_{2(aq)} \qquad \Delta H = -12{\cdot}1 \text{ kJ mol-1}$$

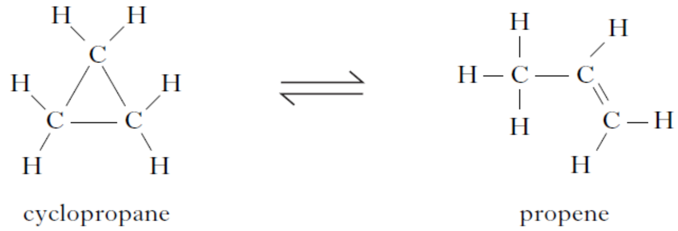
(a) (i) What is meant by a reaction at "equilibrium"?

(ii) What would happen to the concentration of dissolved oxygen if the temperature of the Earth's oceans increased?

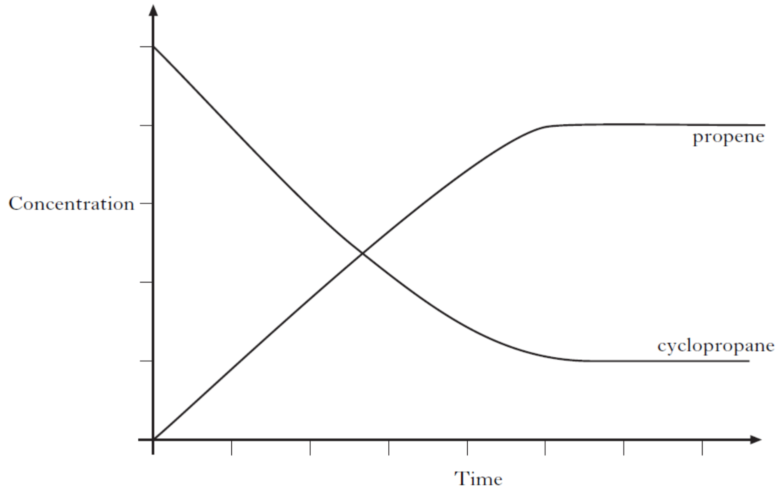
(b) A sample of oceanic water was found to contain 0·010 g of dissolved oxygen.

Calculate the number of moles of dissolved oxygen present in the sample. (1)

14. When cyclopropane gas is heated over a catalyst, it isomerises to form propene gas and an equilibrium is obtained.



The graph shows the concentrations of cyclopropane and propene as equilibrium is established in the reaction.

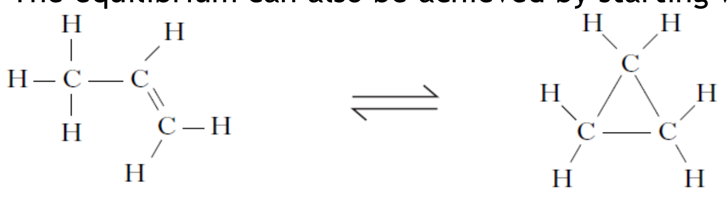


(a) Mark clearly on the graph the point at which equilibrium has just been reached. (1)

(b) Why does increasing the pressure have no effect on the position of this equilibrium?

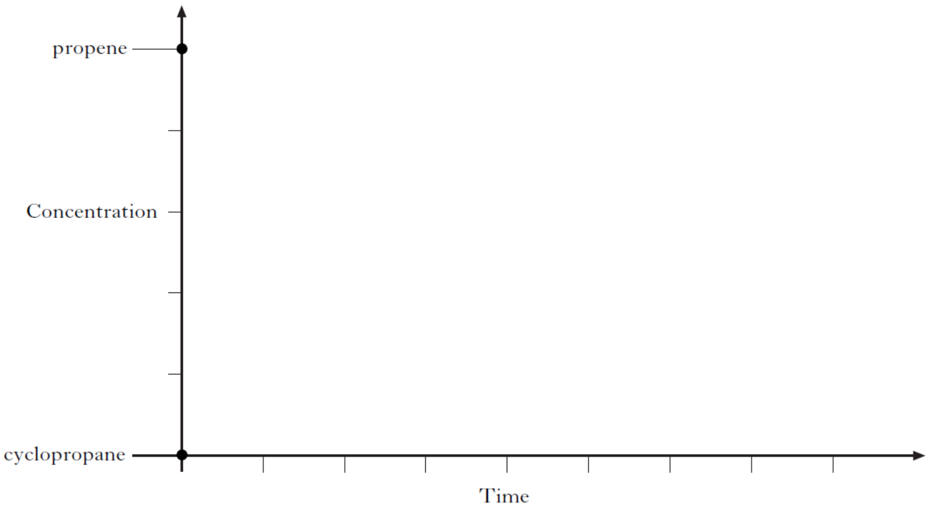
(1)

(c) The equilibrium can also be achieved by starting with propene.



propene cyclopropane

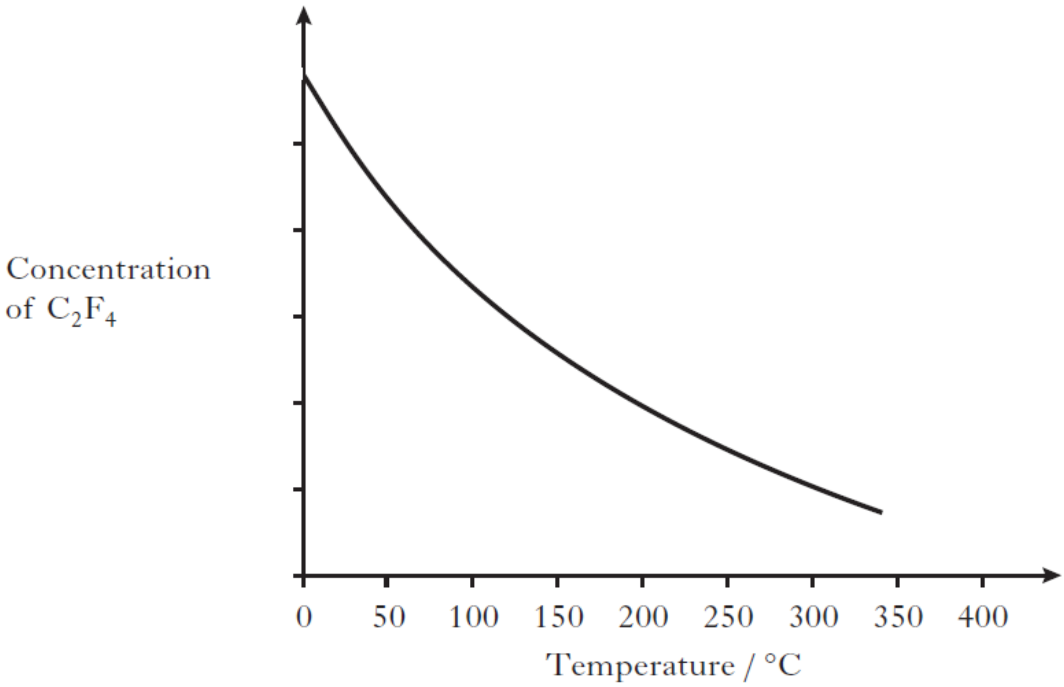
Using the initial concentrations shown, sketch a graph to show how the concentrations of propene and cyclopropane change as equilibrium is reached for the reverse reaction (1)



15. Tetrafluoroethene, C_2F_4, is produced in industry by a series of reactions. The final reaction in its manufacture is shown below.

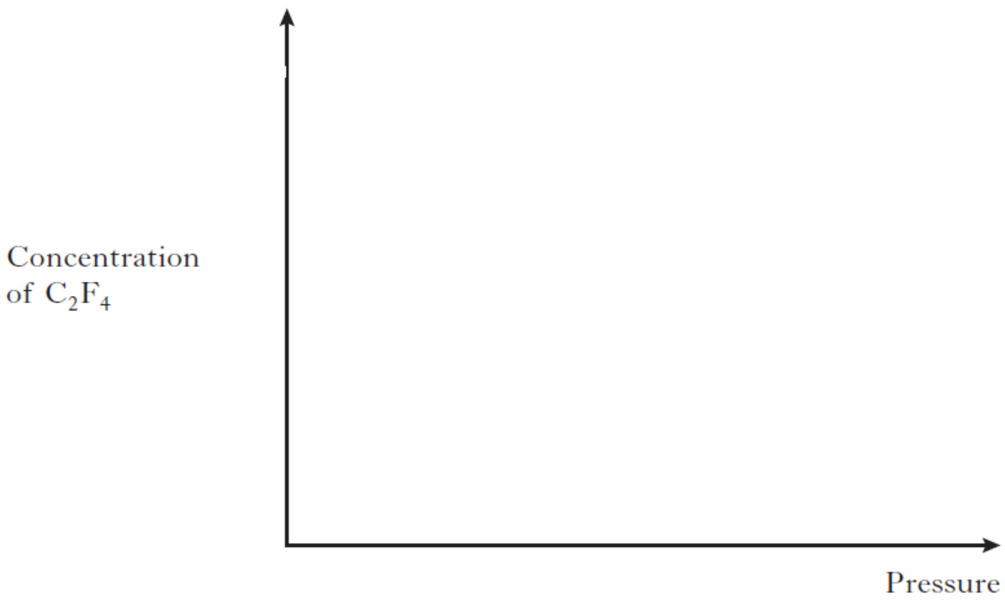
$$2CHClF_{2(g)} \rightleftharpoons C_2F_{4(g)} + 2HCl_{(g)}$$

The graph shows the variation in concentration of C_2F_4 formed as temperature is increased.



(a) What conclusion can be drawn about the enthalpy change for the formation of tetrafluoroethene? (1)

(b) Sketch a graph to show how the concentration of tetrafluoroethene formed would vary with increasing pressure. (1)

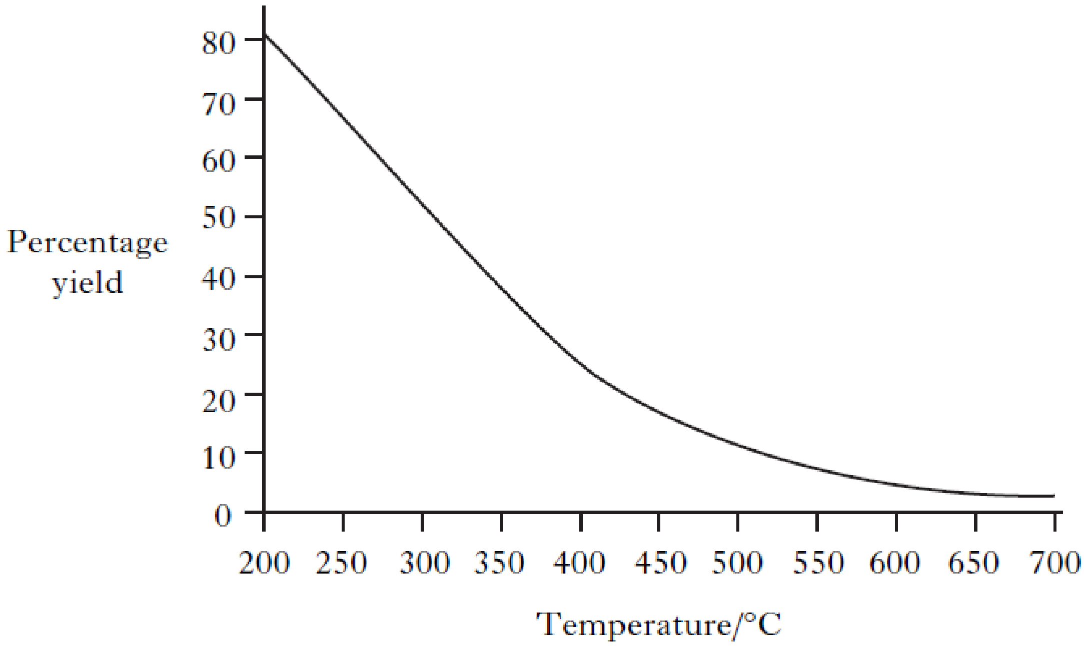


16. Ammonia is produced in industry by the Haber Process.

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(a) State whether the industrial manufacture of ammonia is likely to be a batch or a continuous process. (1)

(b) 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? (1)

(ii) Explain clearly why the industrial manufacture of ammonia is carried out at a pressure greater than 100 atmospheres. (2)

17. Rivers and drains are carefully monitored to ensure that they remain uncontaminated by potentially harmful substances from nearby industries. Chromate ions, CrO42-, are particularly hazardous.
When chromate ions dissolve in water the following equilibrium is established.

$2CrO4^{2-}{}_{(aq)} + 2H^{+}(aq) \rightleftharpoons Cr_2O_7\ 2^{-}{}_{(aq)} + H_2O_{(l)}$

yellow　　　　　　　orange

Explain fully the colour change that would be observed when solid sodium hydroxide is added to the solution. (2)

3.3 Chemical Energy

1. Which of the following represents an exothermic process?

A $Cl_{2(g)} \rightarrow 2Cl_{(g)}$

B $Na_{(s)} \rightarrow Na_{(g)}$

C $Na_{(g)} \rightarrow Na^{+}_{(g)} + e^{-}$

D $Na^{+}_{(g)} + Cl^{-}_{(g)} \rightarrow Na^{+}Cl^{-}_{(s)}$

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

A $C_2H_6(g) + 3\frac{1}{2}O_2(g) \downarrow 2CO_2(g) + 3H_2O(\ell)$

$$C_2H_6(g) + 3\tfrac{1}{2}O_2(g) \\ \downarrow \\ 2CO_2(g) + 3H_2O(\ell)$$

B
$$C_2H_5OH(\ell) + O_2(g) \\ \downarrow \\ CH_3COOH(\ell) + H_2O(\ell)$$

C
$$CH_3CHO(\ell) + \tfrac{1}{2}O_2(g) \\ \downarrow \\ CH_3COOH(\ell)$$

D
$$CH_4(g) + 1\tfrac{1}{2}O_2(g) \\ \downarrow \\ CO(g) + 2H_2O(\ell)$$

3. 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

4. $5N_2O_{4(l)} + 4CH_3NHNH_{2(l)} \rightarrow 4CO_{2(g)} + 12H_2O_{(l)} + 9N_{2(g)}$ $\Delta H = -5116$ 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.

5. Aluminium reacts with oxygen to form aluminium oxide.

$2Al_{(s)} + 1\frac{1}{2}O_{2(g)} \rightarrow Al_2O_{3(s)}$ $\Delta H = -1670$ kJ mol−1

What is the enthalpy of combustion of aluminium in kJ mol^{-1}?

A −835
B −1113
C −1670
D +1670

6.
$$S(s) + H_2(g) \rightarrow H_2S(g) \quad \Delta H = a$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = b$$
$$S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = c$$
$$H_2S(g) + 1\tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) + SO_2(g) \quad \Delta H = d$$

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

7. Given the equations
$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g) \quad \Delta H = a\ J\ mol^{-1}$$
$$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g) \quad \Delta H = b\ J\ mol^{-1}$$
$$Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s) \quad \Delta H = c\ J\ mol^{-1}$$
then, according to Hess's Law
A c = a - b
B c = a + b
C c = b - a
D c = - b - a.

8.
$$C(s) + H_2(g) + O_2(g) \rightarrow HCOOH(\ell) \quad \Delta H = a$$
$$HCOOH(\ell) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + H_2O(\ell) \quad \Delta H = b$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = c$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = d$$
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

9. 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).

10. The energy changes taking place during chemical reactions have many everyday uses.

(a) Some portable cold packs make use of the temperature drop that takes place when the chemicals in the pack dissolve in water.
Name the type of reaction that results in a fall in temperature. (1)

(b) Flameless heaters are used by mountain climbers to heat food and drinks. The chemical reaction in a flameless heater releases 45 kJ of energy. If 200 g of water is heated using this heater, calculate the rise in temperature of the water, in °C. (1)

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

(a) It can be prepared as shown.

$BF_3 + NaBH_4 \rightarrow B_2H_6 + NaBF_4$

Balance this equation. (1)

(b) 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. (2)

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

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = -286\,\text{kJ mol}^{-1}$$

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

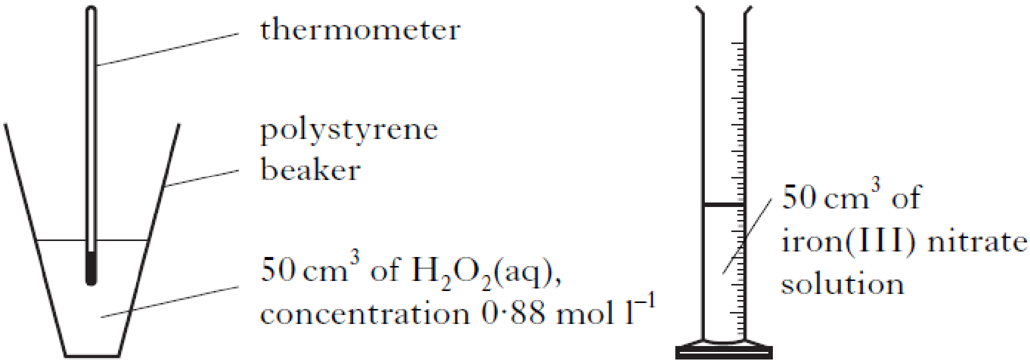
12. Hydrogen peroxide decomposes as shown:

$H_2O_{2(aq)} \rightarrow H_2O_{(l)} + \tfrac{1}{2}\,O_{2(g)}$

The reaction can be catalysed by iron(III) nitrate solution.

(a) What type of catalyst is iron(III) nitrate solution in this reaction? (1)

(b) In order to calculate the enthalpy change for the decomposition of hydrogen peroxide, a student added iron(III) nitrate solution to hydrogen peroxide solution.

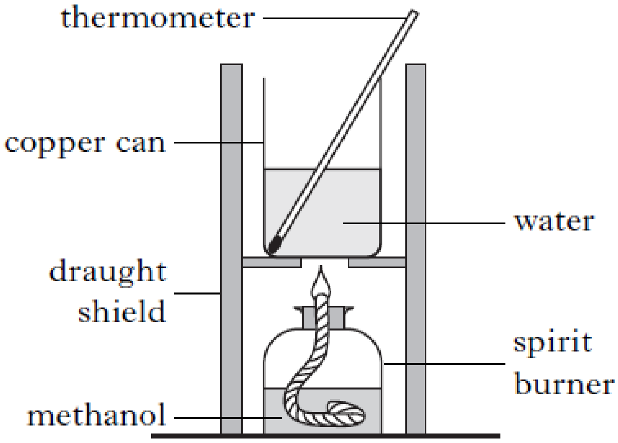


As a result of the reaction, the temperature of the solution in the polystyrene beaker
increased by 16 °C.

(i) What is the effect of the catalyst on the enthalpy change (ΔH) for the reaction? (1)

(ii) Use the experimental data to calculate the enthalpy change, in kJ mol-1, for the decomposition of hydrogen peroxide. Show your working clearly. (3)

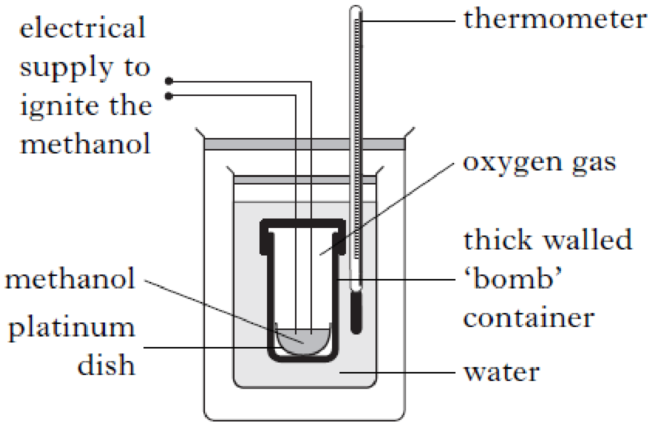
13. A student used the simple laboratory apparatus shown to determine the enthalpy of combustion of methanol.



(a) (i) What measurements are needed to calculate the energy released by the burning methanol? (1)

(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. (1)

(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. (1)

14. Mobile phones are being developed that can be powered by methanol. Methanol can be made by a two-stage process.
In the first stage, methane is reacted with steam to produce a mixture of carbon monoxide and hydrogen.

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$$

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

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

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

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

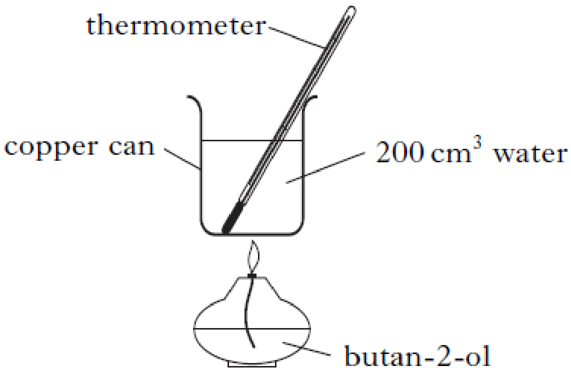
Show your working clearly. (2)

15. The enthalpies of combustion of some alcohols are shown in the table.

Name of alcohol	**Enthalpy of combustion/kJ mol^{-1}**
methanol	–727
ethanol	–1367
propan-1-ol	–2020

(a) Using this data, predict the enthalpy of combustion of butan-1-ol, in kJ mol–1. (1)

(b) A value for the enthalpy of combustion of butan-2-ol, C_4H_9OH, can be determined experimentally using the apparatus shown.



Mass of butan-2-ol burned = 1·0 g

Temperature rise of water = 40 °C

Use these results to calculate the enthalpy of combustion of butan-2-ol, in kJ mol^{-1}.

(2)

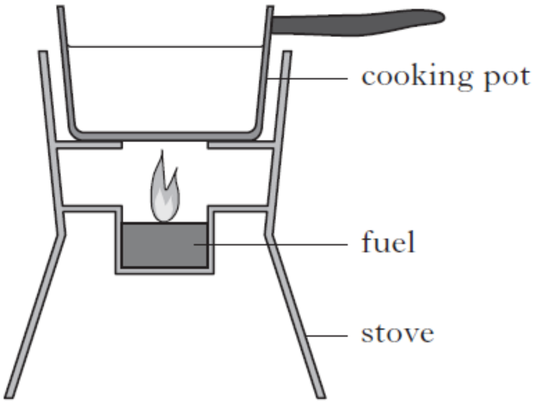
(c) Enthalpy changes can also be calculated using Hess's Law. The enthalpy of formation for pentan-1-ol is shown below.

$$5C_{(s)} + 6H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow C_5H_{11}OH_{(l)} \qquad \Delta H = -354 \text{ kJ mol}^{-1}$$

Using this value, and the enthalpies of combustion of carbon and hydrogen from the data booklet, calculate the enthalpy of combustion of pentan-1-ol, in kJ mol^{-1}. (2)

16. Different fuels are used for different purposes.

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



(i) The enthalpy of combustion of ethanol given in the data booklet is −1367 kJ mol^{-1}. 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. (3)

(ii) Suggest two reasons why less energy is obtained from burning ethanol in the camping stove than is predicted from its enthalpy of combustion. (2)

(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. (2)

17. Hydrogen has been named as a ‘fuel for the future’. In a recent article researchers
reported success in making hydrogen from glycerol:

$C_3H_8O_{3(l)} \rightarrow CO_{2(g)} + CH_{4(g)} + H_{2(g)}$

(a) Balance this equation. (1)

(b) The enthalpy of formation of glycerol is the enthalpy change for the reaction:

$3C_{(s)}$ + $4H_{2(g)}$ + $1\frac{1}{2}O_{2(g)}$ $\rightarrow$ $C_3H_8O_{3(l)}$
(graphite)

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

$C_3H_8O_{3(l)} + 3\frac{1}{2}O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$ $\Delta H = -1654$ kJ mol^{-1}

Show your working clearly. (2)

18. The equation for the enthalpy of formation of ethyne is:

$2C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$

Use the enthalpies of combustion of carbon, hydrogen and ethyne given in the data booklet to calculate the enthalpy of formation of ethyne, in kJ mol^{-1}. Show your working clearly. (2)

19. 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. (2)

20. 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. (2)

21. When in danger, bombardier beetles can fire a hot, toxic mixture of chemicals at the attacker. This mixture contains quinone, $C_6H_4O_2$, a compound that is formed by the reaction of hydroquinone, $C_6H_4(OH)_2$, with hydrogen peroxide, H_2O_2. The reaction is catalysed by an enzyme called catalase.

(a) Most enzymes can catalyse only specific reactions, eg catalase cannot catalyse the hydrolysis of starch. Give a reason for this. (1)

(b) The equation for the overall reaction is:

$C_6H_4(OH)_{2(aq)} + H_2O_{2(aq)} \rightarrow C_6H_4O_{2(aq)} + 2H_2O(l)$

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

$C_6H_4(OH)_{2(aq)} \rightarrow C_6H_4O_{2(aq)} + H_{2(g)}$ $\Delta H = +177.4$ kJ mol^{-1}

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{2(aq)}$ $\Delta H = -191.2$ kJ mol^{-1}

$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -241.8$ kJ mol^{-1}

$H_2O_{(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -43.8$ kJ mol^{-1}

Show your working clearly. (2)

22. (a) Methane is produced in the reaction of aluminium carbide with water.

$Al_4C_3 + H_2O \rightarrow Al(OH)_3 + CH_4$

Balance the above equation. (1)

(b) Silane, silicon hydride, is formed in the reaction of silicon with hydrogen.

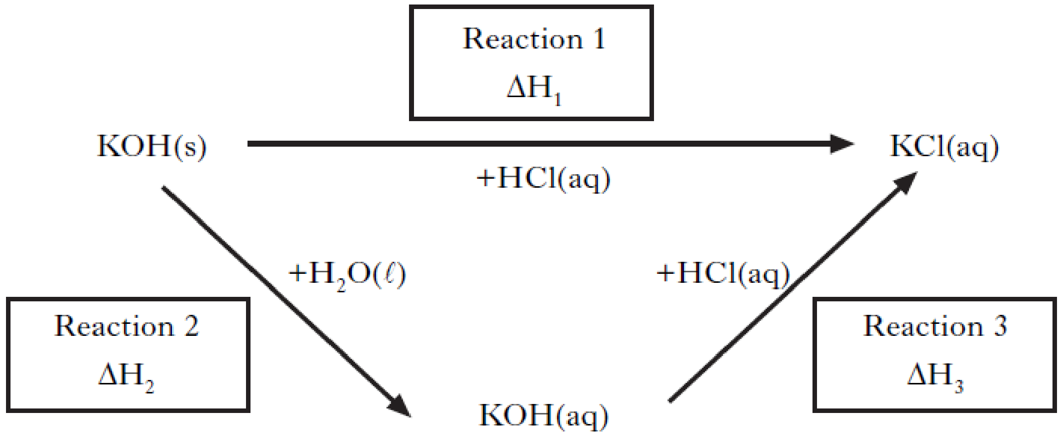
$Si_{(s)} + 2H_{2(g)} \rightarrow \underset{\text{silane}}{SiH_{4(g)}}$

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

$$SiH_{4(g)} + 2O_{2(g)} \rightarrow SiO_{2(s)} + 2H_2O_{(l)} \qquad \Delta H = -1517 \text{ kJ mol}^{-1}$$

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. (2)

23. (a) Hess's Law can be verified using the reactions summarised below.



(i) Complete the list of measurements that would have to be carried out in order to determine the enthalpy change for Reaction 2. (1)

Reaction 2

1. Using a measuring cylinder, measure out 25 cm^3 of water into a polystyrene cup.

2.

3. Weigh out accurately about 1·2 g of potassium hydroxide and add it to the water, with stirring, until all the solid dissolves.

4.

(ii) Why was the reaction carried out in a polystyrene cup? (1)

(iii) 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. (1)

(b) A student wrote the following incorrect statement.

The enthalpy of neutralisation for hydrochloric acid reacting with potassium hydroxide is less than that for sulphuric acid reacting with potassium hydroxide because fewer moles of water are formed as shown in these equations.

$HCl + KOH \rightarrow KCl + H_2O$

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

Explain the mistake in the student's statement. (1)

3.4 Oxidising or Reducing Agents

1. The iodate ion, $IO3^-$, can be converted to iodine.
Which is the correct ion-electron equation for the reaction?
A $2IO3^-_{(aq)} + 12H^+_{(aq)} + 12e^- \rightarrow 2I^-_{(aq)} + 6H_2O_{(l)}$
B $IO3^-_{(aq)} + 6H^+_{(aq)} + 7e^- \rightarrow I^-_{(aq)} + 3H_2O_{(l)}$
C $2IO3^-_{(aq)} + 12H^+_{(aq)} + 11e^- \rightarrow I_{2(aq)} + 6H_2O_{(l)}$
D $2IO3^-_{(aq)} + 12H^+_{(aq)} + 10e^- \rightarrow I_{2(aq)} + 6H_2O_{(l)}$

2. Which of the following is a redox reaction?
A $Mg + 2HCl \rightarrow MgCl_2 + H_2$
B $MgO + 2HCl \rightarrow MgC_{l2} + H_2O$
C $MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$
D $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

3. The ion-electron equations for a redox reaction are:

$$2I^-(aq) \rightarrow I_2(aq) + 2e^-$$

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

How many moles of iodide ions are oxidized by one mole of permanganate ions?
A 0.2
B 0.4
C 2
D 5

4. In which of the following reactions is the hydrogen ion acting as an oxidising agent?
A $Mg + 2HCl \rightarrow MgCl_2 + H_2$
B $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$
C $CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2$
D $CH_3COONa + HCl \rightarrow NaCl + CH_3COOH$

5. 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.

6. 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

7. 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 $H_2 + 2Na \rightarrow 2NaH$

8. Iodide ions can be oxidised using acidified potassium permanganate solution.
The equations are:

$$2I^-(aq) \rightarrow I_2(aq) + 2e^-$$

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

How many moles of iodide ions are oxidized by one mole of permanganate ions?
A 1.0
B 2.0
C 2.5
D 5.0

9. During a redox process in acid solution, iodate ions are converted into iodine.

$$2IO_3^-{}_{(aq)} + 12H^+{}_{(aq)} + xe^- \rightarrow I_{2(aq)} + 6H_2O_{(l)}$$

To balance the equation, what is the value of x?
A 2
B 6
C 10
D 12

10. The following reactions take place when nitric acid is added to zinc.

$$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(\ell)$$

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

How many moles of $NO3^-{}_{(aq)}$ are reduced by one mole of zinc?

A $\frac{2}{3}$

B 1

C $\frac{3}{2}$

D 2

11. 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

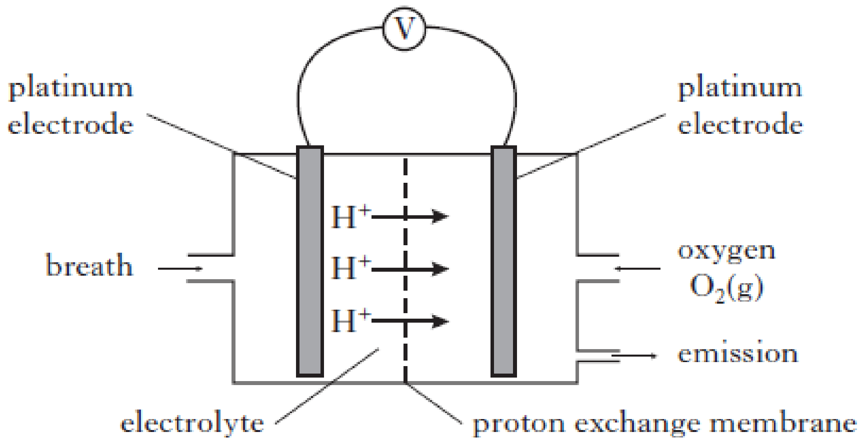
A reduction

B redox

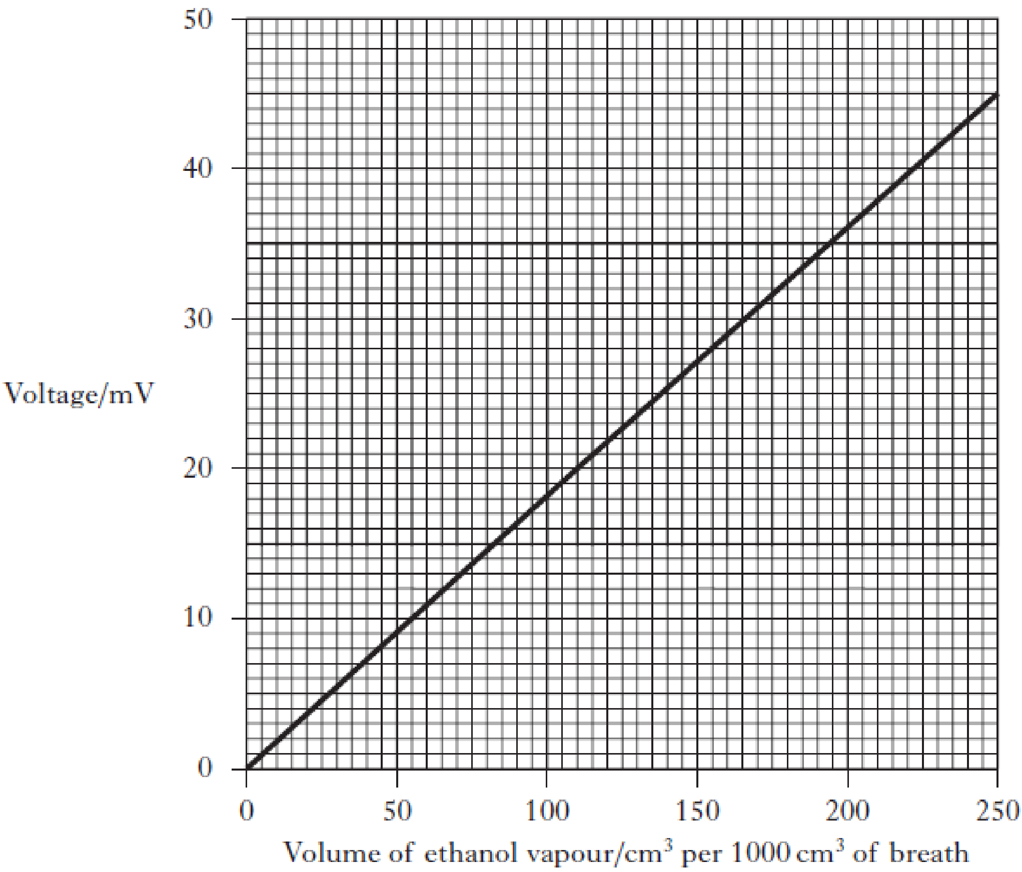
C oxidation

D hydration.

12. The concentration of ethanol in a person's breath can be determined by measuring the voltage produced in an electrochemical cell.



Different ethanol vapour concentrations produce different voltages as is shown in
the graph below.



(a) Calculate the mass of ethanol, in g, in 1000 cm3 of breath when a voltage of 20 mV was recorded. (Take the molar volume of ethanol, C_2H_5OH, vapour to be
24 litres mol^{-1}.) Show your working clearly. (3)

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

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

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

Write the overall redox equation for the reaction taking place. (1)

13. Oxalic acid is found in rhubarb. The number of moles of oxalic acid in a carton of rhubarb juice can be found by titrating samples of the juice with a solution of potassium permanganate, a powerful oxidising agent.
The equation for the overall reaction is:

$5(COOH)_{2(aq)} + 6H^+_{(aq)} + 2MnO_4{}^-_{(aq)} \rightarrow 2Mn^{2+}{}_{(aq)} + 10CO2(aq) + 8H_2O_{(l)}$

(a) Write the ion-electron equation for the reduction reaction. (1)

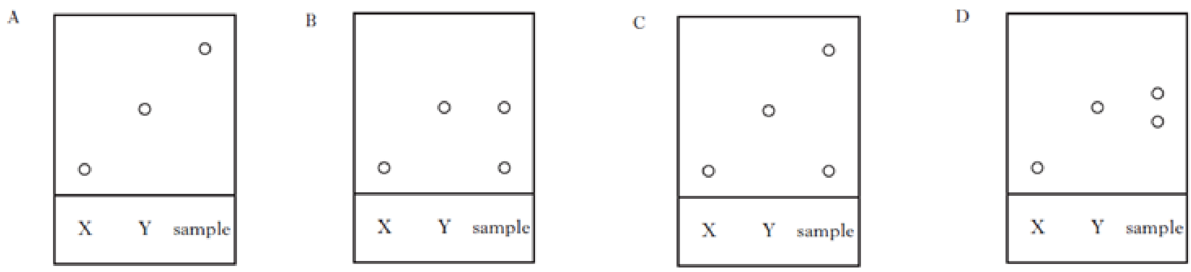
(b) Why is an indicator not required to detect the end-point of the titration? (1)

3.5 Chemical Analysis

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?



2. The alcohol content of wine was analysed by four students. Each student carried out the experiment three times.

	Experiment 1 (%)	Experiment 2 (%)	Experiment 3 (%)
Student A	10·0	9·0	8·0
Student B	6·4	6·6	6·8
Student C	6·5	6·6	6·6
Student D	9·0	8·5	9·6

The most reproducible results were obtained by

A Student A

B Student B

C Student C

D Student D

3. 45 cm^3 of a solution could be most accurately measured out using a

A 50 cm^3 beaker

B 50 cm^3 burette

C 50 cm^3 pipette

D 50 cm^3 measuring cylinder.

4. Aluminium carbonate can be produced by the following reaction.

$$2AlCl_{3(aq)} + 3K_2CO_{3(aq)} \rightarrow Al_2(CO_3)_{3(s)} + 6KCl_{(aq)}$$

The most suitable method for obtaining a sample of the aluminium carbonate is

A collection over water
B distillation
C evaporation
D filtration.

5. Seaweeds are a rich source of iodine in the form of iodide ions. The mass of iodine in a seaweed can be found using the procedure outlined below.

(a) Step 1
The seaweed is dried in an oven and ground into a fine powder. Hydrogen peroxide solution is then added to oxidise the iodide ions to iodine molecules.
The ion-electron equation for the reduction reaction is shown.
$H_2O_{2(aq)} + 2H^+_{(aq)} + 2e^- \rightarrow 2H_2O_{(l)}$
Write a balanced redox equation for the reaction of hydrogen peroxide with iodide ions. (1)

(b) Step 2
Using starch solution as an indicator, the iodine solution is then titrated with sodium thiosulphate solution to find the mass of iodine in the sample.
The balanced equation for the reaction is shown.
$2Na_2S_2O_{3(aq)} + I_{2(aq)} \rightarrow 2NaI_{(aq)} + Na_2S_4O_{6(aq)}$
In an analysis of seaweed, 14.9cm^3 of 0.00500 mol l^{-1} sodium thiosulphate solution was required to reach the end-point. Calculate the mass of iodine present in the seaweed sample. Show your working clearly. (3)

6. Oxalic acid is found in rhubarb. The number of moles of oxalic acid in a carton of rhubarb juice can be found by titrating samples of the juice with a solution of potassium permanganate, a powerful oxidising agent.
The equation for the overall reaction is:
$5(COOH)_{2(aq)} + 6H^+_{(aq)} + 2MnO_4{}^-_{(aq)} \rightarrow 2Mn^{2+}{}_{(aq)} + 10CO2(aq) + 8H_2O_{(l)}$

(a) Write the ion-electron equation for the reduction reaction. (1)

(b) Why is an indicator not required to detect the end-point of the titration? (1)

(c) In an investigation using a 500 cm^3 carton of rhubarb juice, separate 25.0cm^3 samples were measured out. Three samples were then titrated with 0.040 mol l^{-1} potassium permanganate solution, giving the following results.

Titration	Volume of potassium permanganate solution used/cm^3
1	27·7
2	26·8
3	27·0

Average volume of potassium permanganate solution used = 26.9cm^3.

(i) Why was the first titration result not included in calculating the average volume of potassium permanganate solution used? (1)

(ii) Calculate the number of moles of oxalic acid in the 500 cm^3 carton of rhubarb juice.
Show your working clearly. (2)

7. 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. (1)

(b) Name a chemical that can be used to indicate when all of the iodine has been
removed in the reaction taking place in Step 2. (1)

(c) If 50.4cm^3 of 0.10 mol l^{-1} sodium thiosulphate solution was used in a titration,
calculate the number of moles of carbon monoxide in the sample of air.
Show your working clearly. (2)

8. 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.

(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 21·6cm^3 of 0·0150 mol l^{-1} acidified permanganate solution was required to react completely with the nitrite ions in a 25·0 cm^3 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)

(ii) During the reaction the nitrite ion is oxidised to the nitrate ion. Complete the ion-electron equation for the oxidation of the nitrite ions.

$NO_2^-{}_{(aq)} \rightarrow NO_3^-{}_{(aq)}$ (1)

9. (a) The concentration of chromate ions in water can be measured by titrating with a solution of iron(II) sulphate solution. To prepare the iron(II) sulphate solution used in this titration, iron(II) sulphate crystals were weighed accurately into a dry beaker. Describe how these crystals should be

dissolved and then transferred to a standard flask in order to produce a solution of accurately known concentration. (2)

(b) A 50·0cm^3 sample of contaminated water containing chromate ions was titrated and found to require 27·4 cm^3 of 0·0200 mol l^{-1} iron(II) sulphate solution to reach the end-point. The redox equation for the reaction is:

$$3Fe^{2+}_{(aq)} + CrO_4^{2-}{}_{(aq)} + 8H^+_{(aq)} \rightarrow 3Fe^{3+}_{(aq)} + Cr^{3+}_{(aq)} + 4H_2O_{(l)}$$

Calculate the chromate ion concentration, in mol l^{-1}, present in the sample of water. Show your working clearly. (2)

10. 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.

(a) Name an appropriate piece of apparatus which could be used to measure out the water samples. (1)

(b) What is meant by the term standard solution? (1)

(c) 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. (3)

11. Zinc is an essential element for the body and is found in a variety of foods.
(a) The mass of zinc in four 100 g samples taken from a cheese spread was measured.

Sample	Mass of Zn/mg
1	4·0
2	21·7
3	3·9
4	4·1

Calculate the average mass of Zn, in mg, in 100 g of this cheese spread. (1)

(b) The recommended daily allowance of zinc is 9·5 mg for an adult male. 100 g of peanuts contains 3·3 mg of zinc. Calculate the mass of peanuts which would provide the recommended daily allowance of zinc. (2)

12. 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.

$$I_2 \quad + \quad \underset{\text{thiosulfate ions}}{2S_2O_3^{2-}} \quad \rightarrow \quad 2I^- \quad + \quad S_4O_6^{2-}$$

(a) Write an ion-electron equation for the reaction of the oxidising agent in the titration. (1)

(b) 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? (1)

(ii) Calculate the concentration of iodine, in mol l^{-1}, in the foot rot treatment solution. Show your working clearly. (3)

(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. (3)

13. 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.

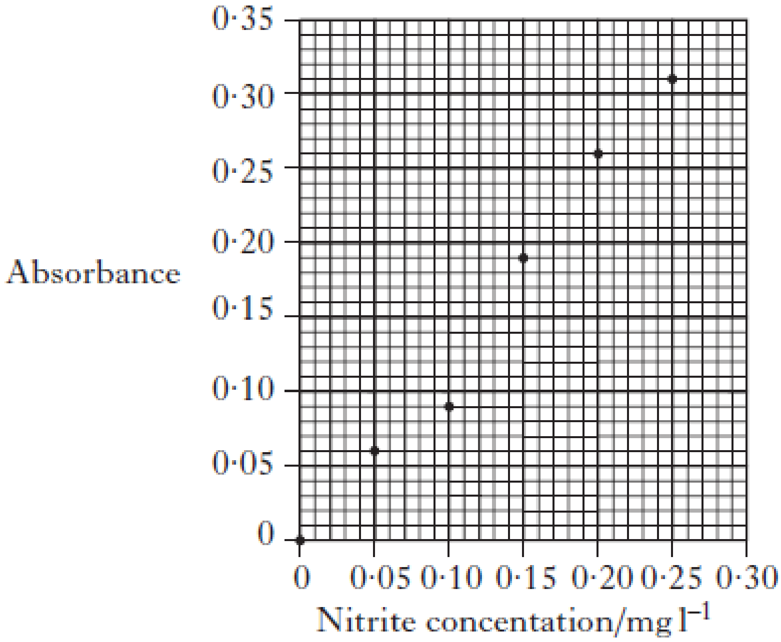
(i) Calculate the mass, in mg, of potassium nitrite, KNO_2, needed to make 1 litre of stock solution with a nitrite ion concentration of 250 mg l^{-1}. (2)

(ii) Describe how the weighed potassium nitrate is dissolved to prepare the stock solution to ensure that its concentration is accurately known. (2)

(iii) Why should the student use distilled or deionised water rather than tap water when dissolving the potassium nitrite? (1)

(iv) To prepare a solution with a nitrite ion concentration of 0·05 mg l^{-1} the student dilutes the stock solution. Why is this method more accurate than preparing a solution by weighing out potassium nitrite? (1)

(b) The graph below shows results for five solutions of potassium nitrite and a sample of distilled water.



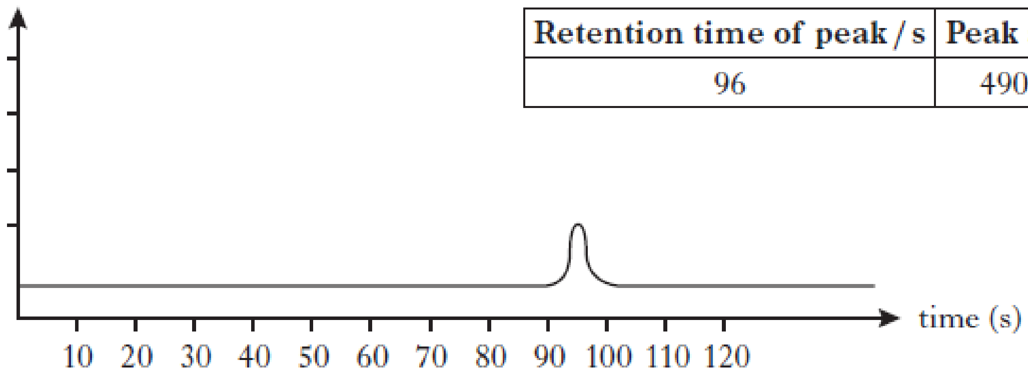
The results for four tap water samples are shown below.

	Absorbance
Sample One	0·09
Sample Two	0·09
Sample Three	0·33
Sample Four	0·09

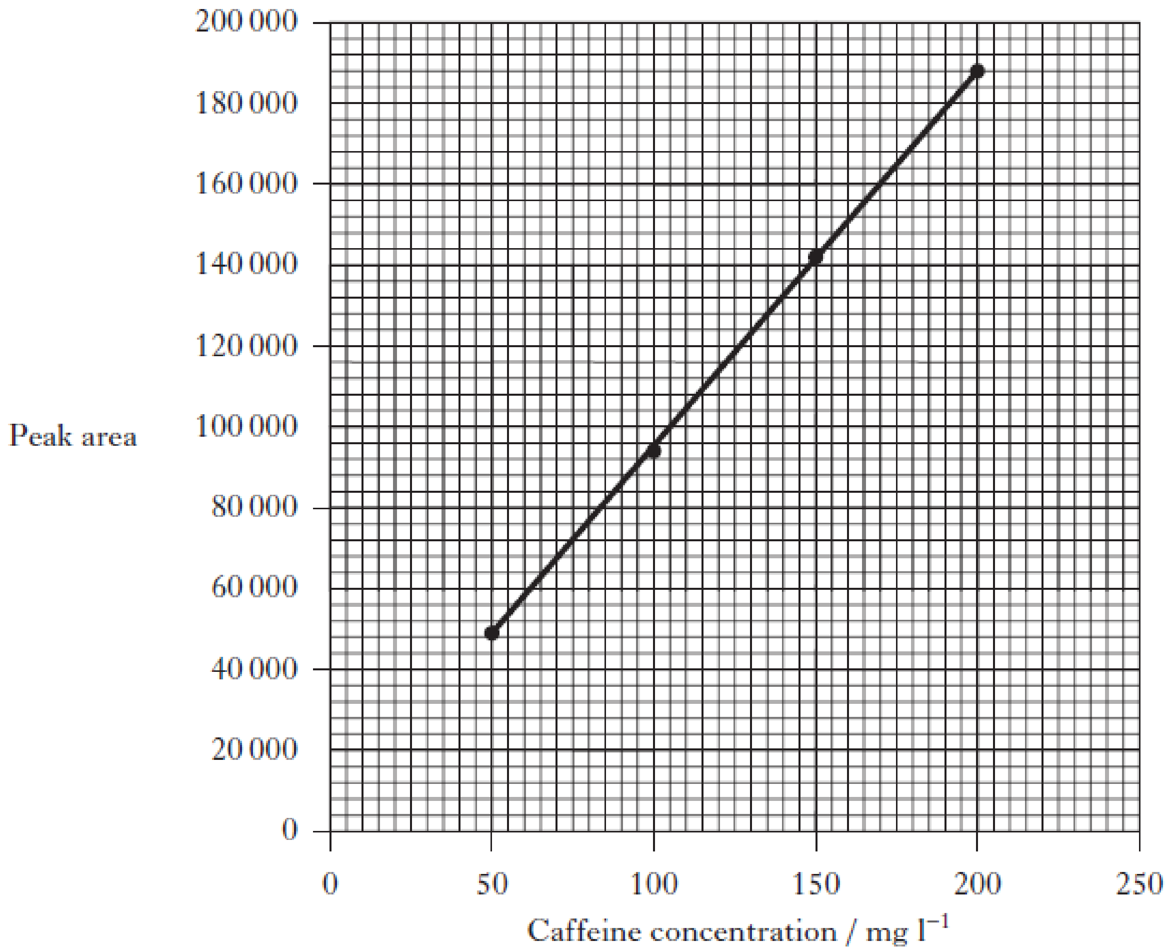
What is the concentration of nitrite ions, in mg l^{-1}, in the tap water? (2)

14. Soft drinks contain many ingredients. Caffeine is 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.

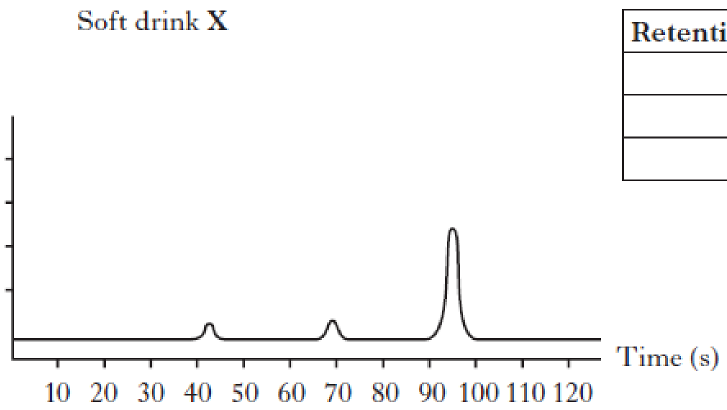
Retention time of peak / s	Peak area
96	49000



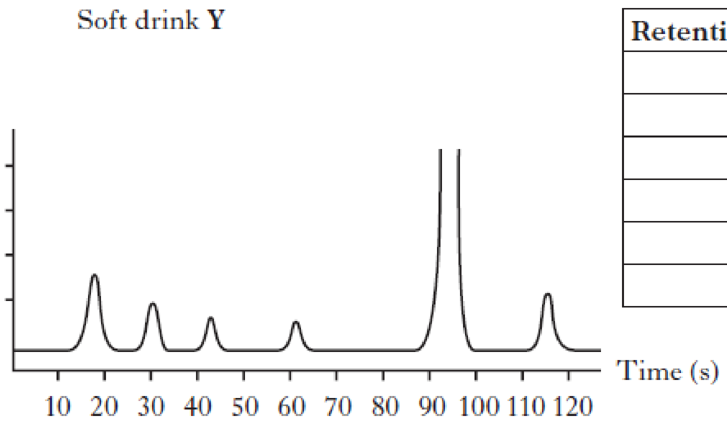
Results from four caffeine standard solutions were used to produce the calibration graph below.



Chromatograms for two soft drinks are shown below.



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

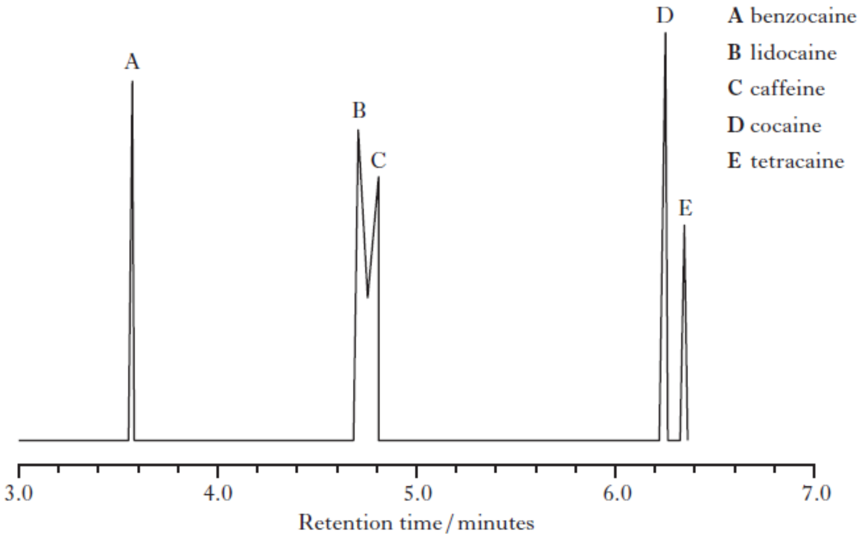


Retention time of peak / s	Peak area
17	7000
30	4600
43	3000
62	2500
96	----
115	5000

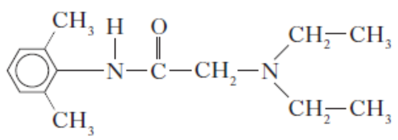
(a) What is the caffeine content, in mg l−1 of soft drink X? (1)

(b) 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? (1)

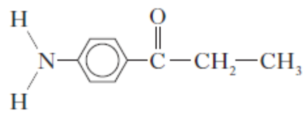
15. When forensic scientists analyse illegal drugs, anaesthetics such as lidocaine, benzocaine and tetracaine are sometimes found to be present. The gas chromatogram below is from an illegal drug.



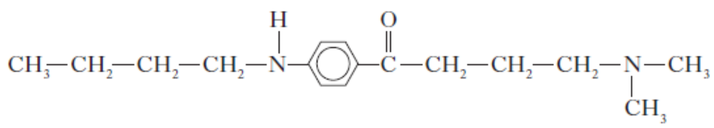
(a) The structures of lidocaine, benzocaine and tetracaine are shown below.



lidocaine



benzocaine



tetracaine

Suggest why benzocaine has a shorter retention time than tetracaine. (1)

(b) Why is it difficult to obtain accurate values for the amount of lidocaine present in a sample containing large amounts of caffeine? (1)

(c) 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. (1)