Kirkcaldy High School

Chemistry

Higher

Unit 3 – Chemistry in Society

TUTORIAL QUESTIONS

(a) Getting the most from reactants

1.

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

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

2.

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

3.

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

4.

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

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

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

5.

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

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.

$20\,cm^3$ of butane is burned in $150\,cm^3$ of oxygen.

$C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$

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

A $80\,cm^3$

B $100\,cm^3$

C $180\,cm^3$

D $200\,cm^3$

8.

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

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

9.

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

10.

Which of the following pairs of gases occupy the same volume?

(Assume all measurements are made under the same conditions of temperature and pressure.)

A 2 g hydrogen and 14 g nitrogen

B 32 g methane and 88 g carbon dioxide

C 7 g carbon monoxide and 16 g oxygen

D 10 g hydrogen chloride and 10 g sulphur dioxide

11.

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.

12.

What volume of oxygen, in litres, is required for the complete combustion of 1 litre of butane gas?

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

A 1

B 4

C 6·5

D 13

13.

A mixture of sodium chloride and sodium sulphate is known to contain 0·6 mol of chloride ions and 0·2 mol of sulphate ions.

How many moles of sodium ions are present?

A 0·4

B 0·5

C 0·8

D 1·0

14.

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(\ell)$
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

15.

Which of the following gases has the same volume as 128·2 g of sulphur dioxide?

A 2·0 g hydrogen

B 8·0 g helium

C 32·0 g oxygen

D 80·8 g of neon.

16.

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

How many moles of sulphate ions are present?

A 1

B 2

C 3

D 4

17.

How many moles of magnesium will react with 20 cm^3 of 2 mol l^{-1} hydrochloric acid?

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

A 0·01

B 0·02

C 0·04

D 0·20

18.

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

What volume of gas, in cm^3, would be obtained by reaction between 100 cm^3 of ammonia gas and excess copper(II) oxide?

(All volumes are measured at atmospheric pressure and 20 °C.)

A 50

B 100

C 200

D 400

19.

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

When 20 cm^3 of ethane was sparked with 100 cm^3 of oxygen, what was the final volume of gases?

All volumes were measured at atmospheric pressure and room temperature.

A 40 cm^3

B 70 cm^3

C 100 cm^3

D 130 cm^3

20.

Calcium carbonate reacts with nitric acid as follows.

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

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.

21.

$CaCO_3(s)$	+	$2HNO_3(aq)$	→	$Ca(NO_3)_2\,(aq)$	+	$CO_2(g)$	+	$H_2O(\ell)$
Mass of 1 mol = 100 g				Mass of 1 mol = 164 g				

2·00 g of calcium carbonate ($CaCO_3$) was reacted with 200 cm^3 of 0·1 mol l^{-1} nitric acid (HNO_3).

Take the volume of 1 mole of carbon dioxide to be 24 litres.

In the reaction

A $CaCO_3$ is the limiting reactant

B an excess of 0·1 mol of nitric acid remains at the end of the reaction

C 1·64 g of calcium nitrate is produced by the reaction

D 480 cm^3 of carbon dioxide is produced by the reaction.

22.

$TiCl_4$	+	2Mg	→	$2MgCl_2$	+	Ti
mass of one mole = 189·9 g		mass of one mole = 24·3 g		mass of one mole = 95·3 g		mass of one mole = 47·9 g

The atom economy for the production of titanium in the above equation is equal to

A $\frac{47{\cdot}9}{189{\cdot}9 + 24{\cdot}3} \times 100$

B $\frac{47{\cdot}9}{189{\cdot}9 + (2 \times 24{\cdot}3)} \times 100$

C $\frac{95{\cdot}3 + 47{\cdot}9}{189{\cdot}9 + 24{\cdot}3} \times 100$

D $\frac{(2 \times 47{\cdot}9)}{189{\cdot}9 + 24{\cdot}3} \times 100$

23.

Iron can be produced from iron(III) oxide.

$2Fe_2O_3(s)$	+	$3C(s)$	→	$4Fe(s)$	+	$3CO_2(g)$
GFM = 159·6 g		GFM = 12·0 g		GFM = 55·8 g		GFM = 44·0 g

The atom economy for the production of iron is

A 69·9%

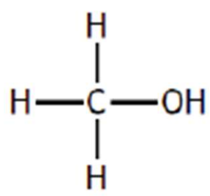
B 62·8%

C 58·2%

D 32·5%.

24.

Methanol can be used as a fuel, in a variety of different ways.



An increasingly common use for methanol is as an additive in petrol.

Methanol has been tested as an additive in petrol at 118 g per litre of fuel.

Calculate the volume of carbon dioxide, in litres, that would be released by combustion of 118 g of methanol.

$$2CH_3OH(\ell) \quad + \quad 3O_2(g) \quad \rightarrow \quad 2CO_2(g) \quad + \quad 4H_2O(\ell)$$

(Take the molar volume of carbon dioxide to be 24 litres mol^{-1}).

25. A student prepared a sample of methyl cinnamate from cinnamic acid and methanol.

cinnamic acid	+	**methanol**	→	**methyl cinnamate**	+	**water**
mass of one mole = 148 g		mass of one mole = 32 g		mass of one mole = 162 g		

6·5 g of cinnamic acid was reacted with 2·0 g of methanol.

(a) Show, by calculation, that cinnamic acid is the limiting reactant.
(One mole of cinnamic acid reacts with one mole of methanol.)

(b) The student obtained 3·7 g of methyl cinnamate from 6·5 g of cinnamic acid.
Calculate the percentage yield.

(c) The student wanted to scale up the experiment to make 100 g of methyl cinnamate.
Cinnamic acid costs £35·00 per 250 g.
Calculate the cost of cinnamic acid needed to produce 100 g of methyl cinnamate.

26.

A chemical explosion is the result of a very rapid reaction that generates a large quantity of heat energy and, usually, a large quantity of gas.

The explosive RDX, $C_3H_6N_6O_6$, is used in the controlled demolition of disused buildings.

During the reaction it decomposes as shown.

$$C_3H_6O_6N_6(s) \rightarrow 3CO(g) + 3H_2O(g) + 3N_2(g)$$

Calculate the volume, in litres, of gas released when 1·0 g of RDX decomposes.

Take the molar volume of the gases to be 24 litres mol^{-1}.

27.

The overall equation for the fermentation of glucose is

$C_6H_{12}O_6$	$\rightarrow$	$2C_2H_5OH$	+	$2CO_2$
mass of one mole = 180 g		mass of one mole = 46 g		

Calculate the percentage yield of ethanol if 445 g of ethanol is produced from 1·0 kg of glucose.

28.

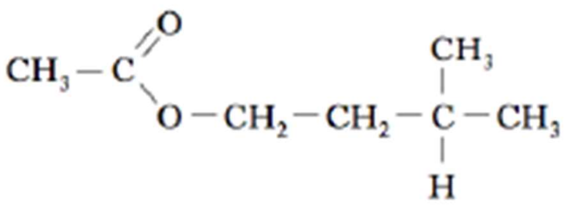
Sodium benzoate is used in the food industry as a preservative. It can be made by reacting benzoic acid with a concentrated solution of sodium carbonate.

$2C_6H_5COOH$	+	Na_2CO_3	$\rightarrow$	$2C_6H_5COONa$	+	CO_2	+	H_2O
mass of 1 mole = 122 g		mass of 1 mole = 106 g		mass of 1 mole = 144 g		mass of 1 mole = 44 g		mass of 1 mole = 18 g

Calculate the atom economy for the production of sodium benzoate.

29.

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 an alcohol with an alkanoic acid.

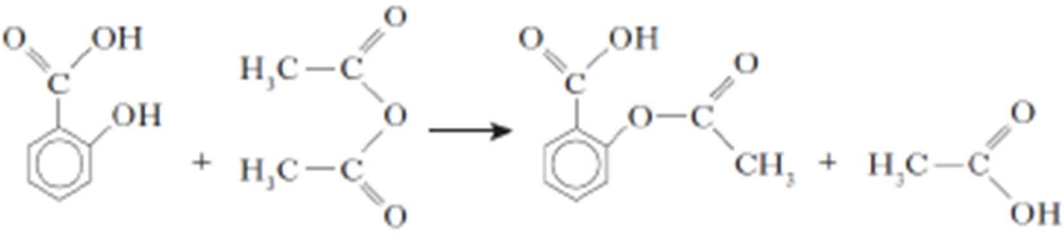
If there is a 65% yield, calculate the mass of ester produced, in grams, when 4·0 g of the alcohol reacts with a slight excess of the acid.

(Mass of one mole of the alcohol = 88 g;
mass of one mole of the ester = 130 g)

Show your working clearly.

30.

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.

(*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.

31.

Calcium carbonate reacts with nitric acid as follows.

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

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.

32.

Chlorine gas can be produced by heating calcium hypochlorite, $Ca(OCl)_2$, in dilute hydrochloric acid.

$$Ca(OCl)_2(s) + 2HCl(aq) \rightarrow Ca(OH)_2(aq) + 2Cl_2(g)$$

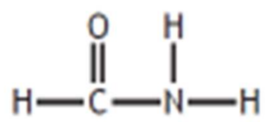
Calculate the mass of calcium hypochlorite that would be needed to produce 0·096 litres of chlorine gas.

(Take the molar volume of chlorine gas to be 24 litres mol^{-1}.)

33.

Methanamide, $HCONH_2$, is widely used in industry to make nitrogen compounds.

It is also used as a solvent as it can dissolve ionic compounds.



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

(a) Calculate the atom economy for the production of methanamide.

(b) 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.

34.

Nitrogen dioxide gas can be prepared in different ways.
In the lab, nitrogen dioxide gas can be prepared by heating copper(II) nitrate.

$$Cu(NO_3)_2(s) \rightarrow CuO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g)$$

Calculate the volume of nitrogen dioxide gas produced when 2·0 g 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.

35.

Hydrogen fluoride, HF, is used to manufacture hydrofluorocarbons.

Hydrofluorocarbons are now used as refrigerants instead of chlorofluorocarbons, CFCs.

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.

36.

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.

37.

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:

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

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.

38.

When copper is added to an acid, what happens depends on the acid and the conditions.

Copper reacts with hot, concentrated sulphuric acid to produce sulphur dioxide.

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$$

Calculate the volume, in litres, of sulphur dioxide gas that would be produced when 10 g of copper reacts with excess concentrated sulphuric acid.

(Take the molar volume of sulphur dioxide to be 24 litres mol^{-1}.)

Show your working clearly.

39.

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.

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

40.

Nitrogen and compounds containing nitrogen are widely used in industry.

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

$$HCOOH + NH_3 \rightleftharpoons HCONH_2 + H_2O$$

methanoic acid   methanamide

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.

41.

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.

42.

A mixture of sodium chloride and sodium sulphate is known to contain 0·6 mol of chloride ions and 0·2 mol of sulphate ions.

How many moles of sodium ions are present?

A 0·4

B 0·5

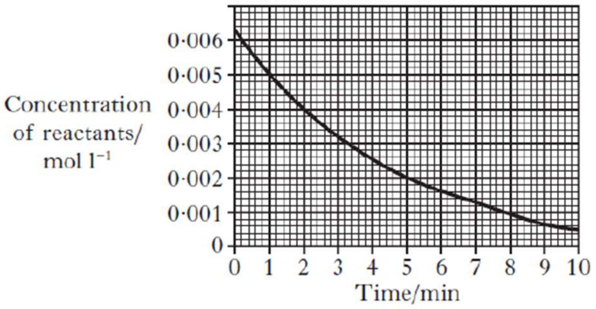
C 0·8

D 1·0

(b) Controlling the rate

1.

The following graph represents a reaction between sodium hydroxide and ethyl ethanoate.



What is the average rate of the reaction over the first 5 minutes, in mol l^{-1} min^{-1}?

A $3{\cdot}6 \times 10^{-4}$

B $8{\cdot}4 \times 10^{-3}$

C $8{\cdot}4 \times 10^{-4}$

D $1{\cdot}2 \times 10^{-3}$

2.

In which of the following will **both** changes result in an increase in the rate of a chemical reaction?

A A decrease in activation energy and an increase in the frequency of collisions.

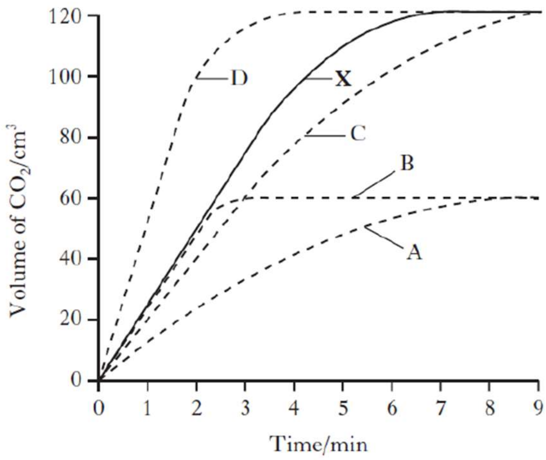
B An increase in activation energy and a decrease in particle size.

C An increase in temperature and an increase in the particle size.

D An increase in concentration and a decrease in the surface area of the reactant particles.

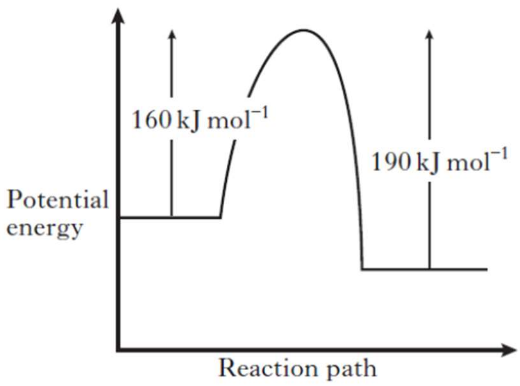
3.

Graph **X** was obtained when 1 g of calcium carbonate powder reacted with excess dilute hydrochloric acid at 20 °C.



Which curve would best represent the reaction of 0·5 g lump calcium carbonate with excess of the same dilute hydrochloric acid?

4.



When a catalyst is used, the activation energy of the forward reaction is reduced to 35 kJ mol^{-1}.

What is the activation energy of the catalysed reverse reaction?

A 30 kJ mol^{-1}

B 35 kJ mol^{-1}

C 65 kJ mol^{-1}

D 190 kJ mol^{-1}

5.

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

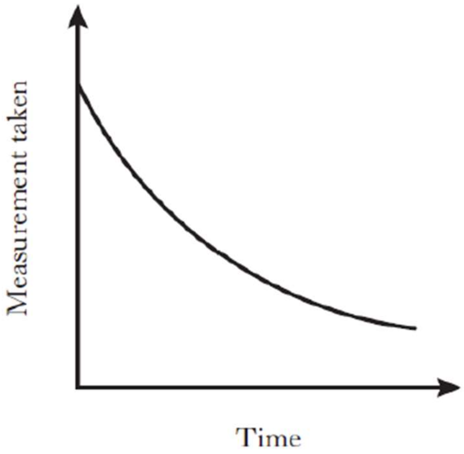
A 50 cm^3 beaker

B 50 cm^3 burette

C 50 cm^3 pipette

D 50 cm^3 measuring cylinder.

6.



Which of the following measurements, taken at regular intervals and plotted against time, would give the graph shown above?

A Temperature

B Volume of gas produced

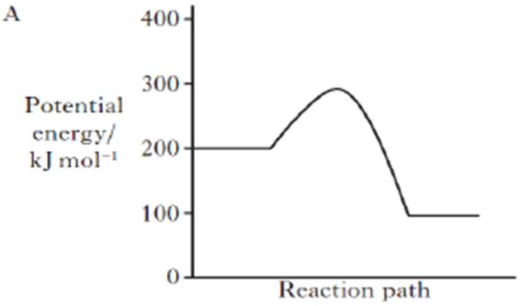
C pH of solution

D Mass of the beaker and contents

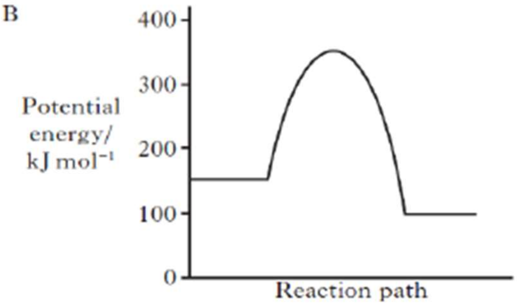
7.

Which of the following potential energy diagrams represents the most exothermic reaction?

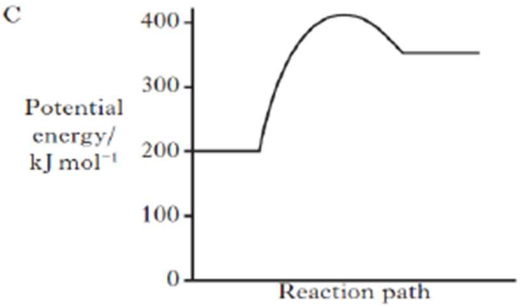
A



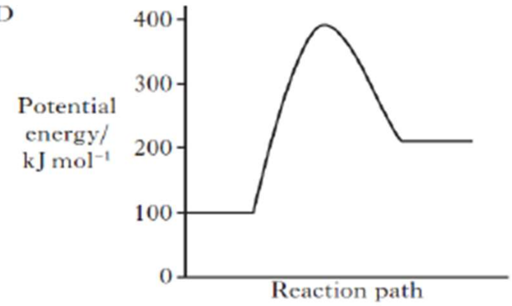
B



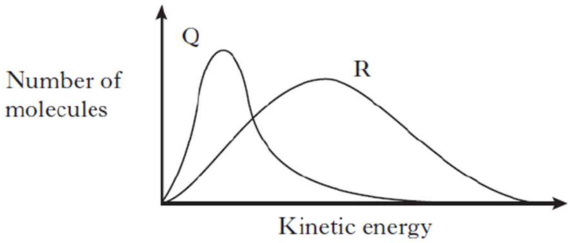
C



D



8.

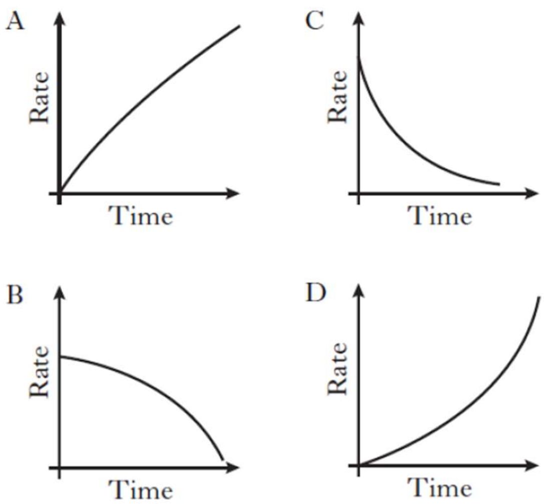


Which line in the table is correct for curves **Q** and **R** in the above graph?

	Curve Q	Curve R
A	1 mol of O_2 at 50 °C	2 mol of O_2 at 100 °C
B	1 mol of O_2 at 100 °C	2 mol of O_2 at 100 °C
C	2 mol of O_2 at 50 °C	1 mol of O_2 at 100 °C
D	2 mol of O_2 at 100 °C	1 mol of O_2 at 100 °C

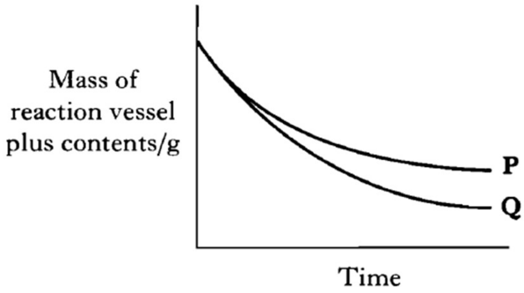
9.

Which of the following graphs could represent the change in the rate of reaction when magnesium ribbon reacts with dilute hydrochloric acid?



10.

When copper carbonate reacts with excess acid, carbon dioxide is produced. The curves shown were obtained under different conditions.



The change from **P** to **Q** could be brought about by

A increasing the concentration of the acid

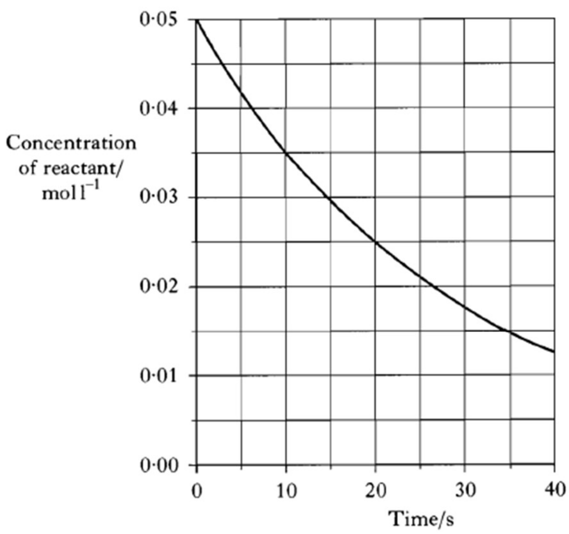
B increasing the mass of copper carbonate

C decreasing the particle size of the copper carbonate

D adding a catalyst.

11.

The graph below shows the change in the concentration of a reactant with time for a given chemical reaction.



What is the average rate of this reaction, in mol l^{-1} s^{-1}, between 10 and 20 s?

A $1{\cdot}0 \times 10^{-2}$

B $1{\cdot}0 \times 10^{-3}$

C $1{\cdot}5 \times 10^{-2}$

D $1{\cdot}5 \times 10^{-3}$

12.

In a reaction involving gases, an increase in temperature results in

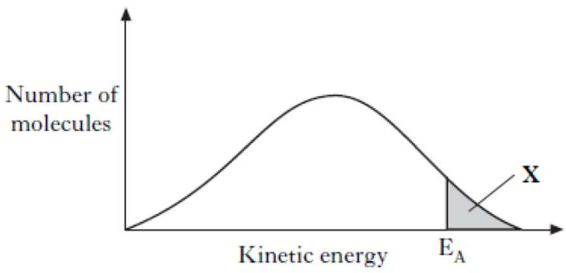
A an increase in activation energy

B an increase in the enthalpy change

C a decrease in the activation energy

D more molecules per second forming an activated complex.

13.



In area **X**

A molecules always form an activated complex

B no molecules have the energy to form an activated complex

C collisions between molecules are always successful in forming products

D all molecules have the energy to form an activated complex.

14.

The following results were obtained in the reaction between marble chips and dilute hydrochloric acid.

Time/minutes	0	2	4	6	8	10
Total volume of carbon dioxide produced/cm^3	0	52	68	78	82	84

What is the average rate of production of carbon dioxide, in $cm^3\ min^{-1}$, between 2 and 8 minutes?

A 5

B 26

C 30

D 41

15.

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

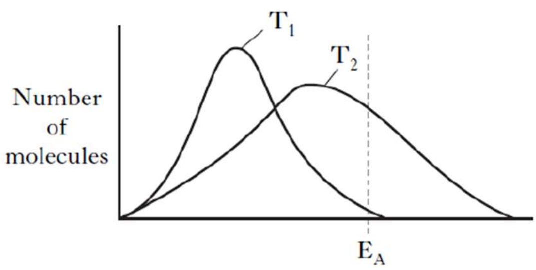
A 0·2

B 0·4

C 0·8

D 1·6.

16.

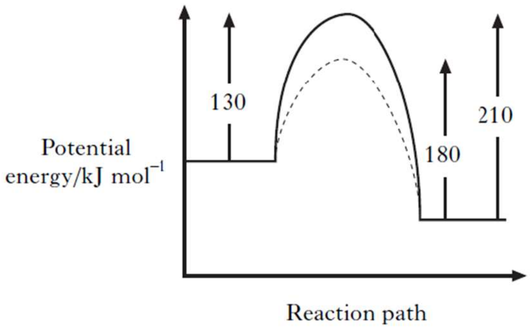


Which line in the table is correct for a reaction as the temperature **decreases** from T_2 to T_1?

	Activation energy (E_A)	**Number of successful collisions**
A	remains the same	increases
B	decreases	decreases
C	decreases	increases
D	remains the same	decreases

17.

The following potential diagram is for a reaction carried out with and without a catalyst.



The activation energy for the catalysed reaction is

A 30 kJ mol^{-1}

B 80 kJ mol^{-1}

C 100 kJ mol^{-1}

D 130 kJ mol^{-1}.

18.

For any chemical, its temperature is a measure of

A the average kinetic energy of the particles that react

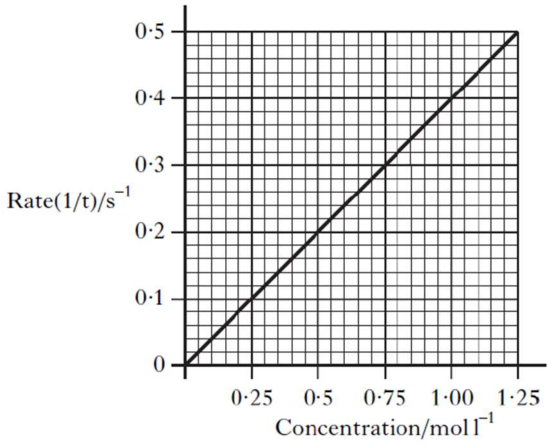
B the average kinetic energy of all the particles

C the activation energy

D the minimum kinetic energy required before reaction occurs.

19.

The graph shows how the rate of a reaction varies with the concentration of one of the reactants.



What was the reaction time, in seconds, when the concentration of the reactant was 0·50 mol l^{-1}?

A 0·2

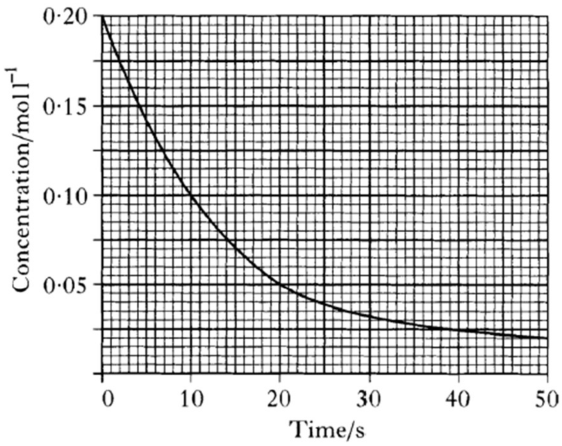
B 0·5

C 2·0

D 5·0

20.

The graph shows the variation of concentration of a reactant with time as a reaction proceeds.



What is the average reaction rate during the first 20 s?

A 0·0025 mol l^{-1} s^{-1}

B 0·0050 mol l^{-1} s^{-1}

C 0·0075 mol l^{-1} s^{-1}

D 0·0150 mol l^{-1} s^{-1}

21.

A potential energy diagram can be used to show the activation energy (E_A) and the enthalpy change (ΔH) for a reaction.

Which of the following combinations of E_A and ΔH could **never** be obtained for a reaction?

A $E_A = 50\,kJ\,mol^{-1}$ and $\Delta H = -100\,kJ\,mol^{-1}$

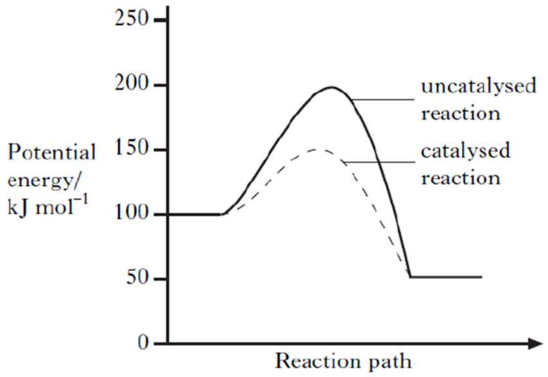
B $E_A = 50\,kJ\,mol^{-1}$ and $\Delta H = +100\,kJ\,mol^{-1}$

C $E_A = 100\,kJ\,mol^{-1}$ and $\Delta H = +50\,kJ\,mol^{-1}$

D $E_A = 100\,kJ\,mol^{-1}$ and $\Delta H = -50\,kJ\,mol^{-1}$

22.

A reaction was carried out with and without a catalyst as shown in the energy diagram.



What is the enthalpy change, in $kJ\,mol^{-1}$, for the catalysed reaction?

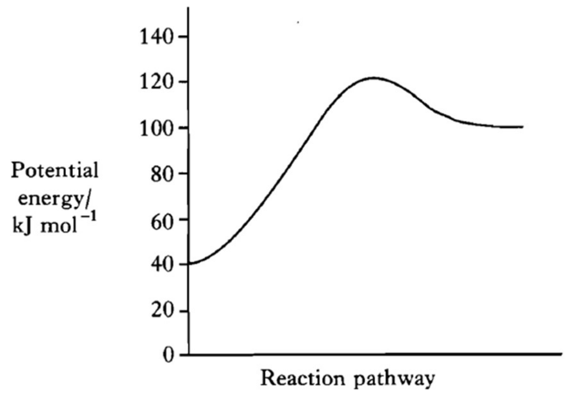
A −100

B −50

C +50

D +100

23.



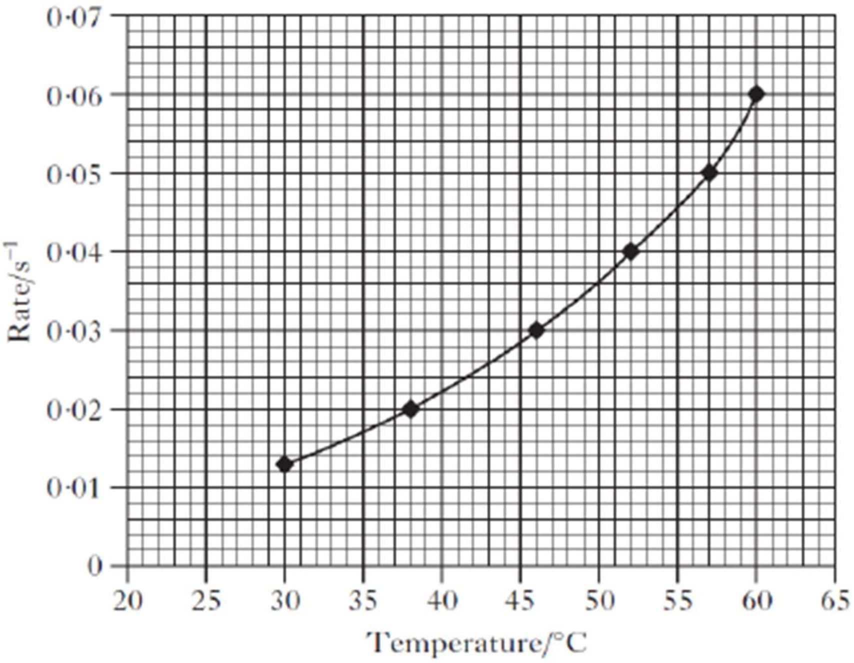
Which set of data applies to the above reaction?

	Enthalpy change	Activation energy/ $kJ\,mol^{-1}$
A	Exothermic	60
B	Exothermic	80
C	Endothermic	60
D	Endothermic	80

24.

A student investigated the effect of changing temperature on the rate of chemical reaction.

The results from the investigation are shown in the graph below.



(*a*) Use the graph to determine the temperature rise required to double the rate of reaction.

(*b*) Collision theory can be used to explain reaction rates.

Collision theory states that for two molecules to react, they must first collide with one another.

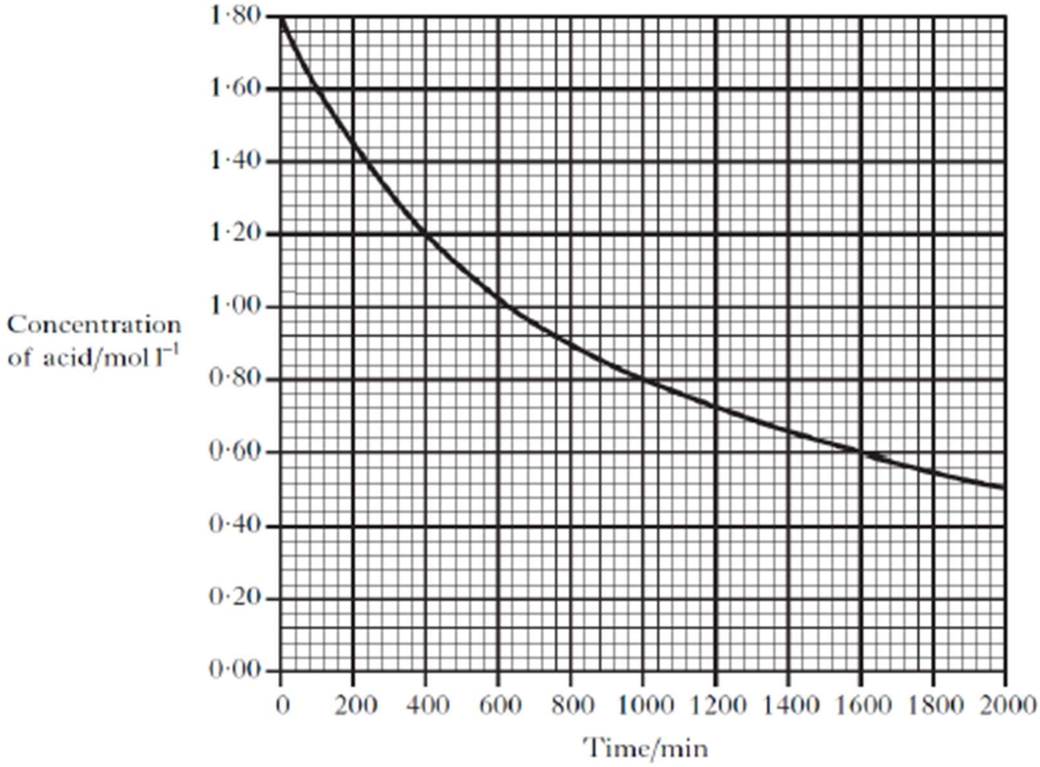
State **two** conditions necessary for the collisions to result in the formation of products.

25. Chloromethane, CH_3Cl, can be produced by reacting methanol solution with dilute hydrochloric acid using a solution of zinc chloride as a catalyst

$$CH_3OH(aq) + HCl \rightarrow CH_3Cl(aq) + H_2O(l)$$

(a) Explain how a catalyst can bring about an increase in the rate of reaction

The graph shows how the concentration of the hydrochloric acid changed over a period of time when the reaction was carried out at 20 °C.

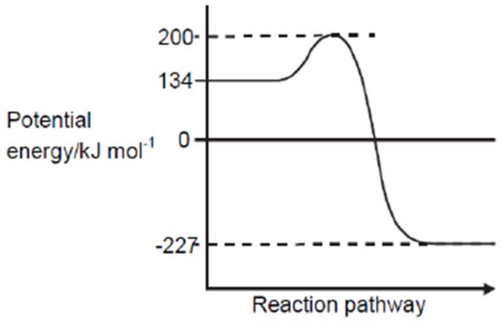


(b) Calculate the average rate in $p^{-1}min^{-1}$ in the first 400 minutes.

(c) On the graph above, sketch a curve to show how the concentration of hydrochloric acid would change over time if the reaction was repeated at 30 °C.

26.

The potential energy diagram for a chemical reaction is shown below:



What is the enthalpy change, in kJ mol^{-1}, for the reaction?

A -66

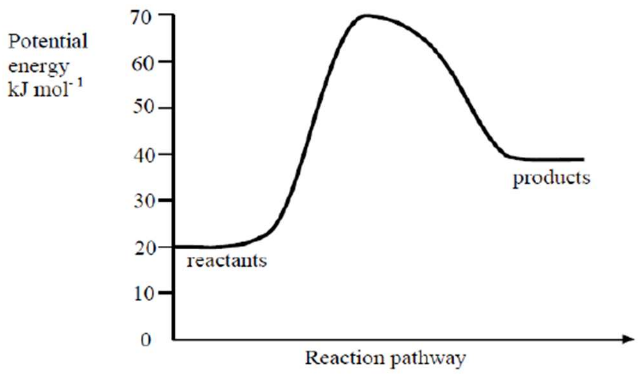
B -227

C -361

D -427

27.

The potential energy diagram represents the energy changes in a chemical reaction.



The value of the enthalpy change, in kJ mol^{-1}, for the reaction is

A - 30

B - 20

C +20

D +50

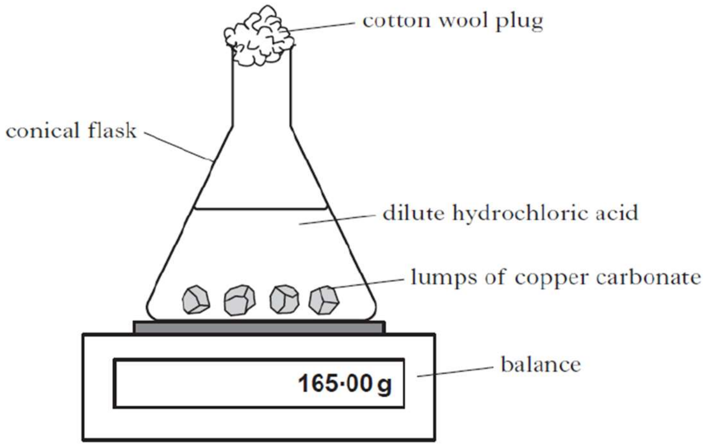
28. The following incorrect answer was taken from an examination paper. Give the correct explanation

Question	As a rough guide, the rate of a reaction tends to double for every 10 °C rise in temperature. Why does a small increase in temperature produce a large increase in reaction rate?
Student answer	Because rising temperature increases the activation energy which increases the number of collisions which speeds up the reaction greatly.

29. Copper(II) carbonate reacts with dilute hydrochloric acid as shown.

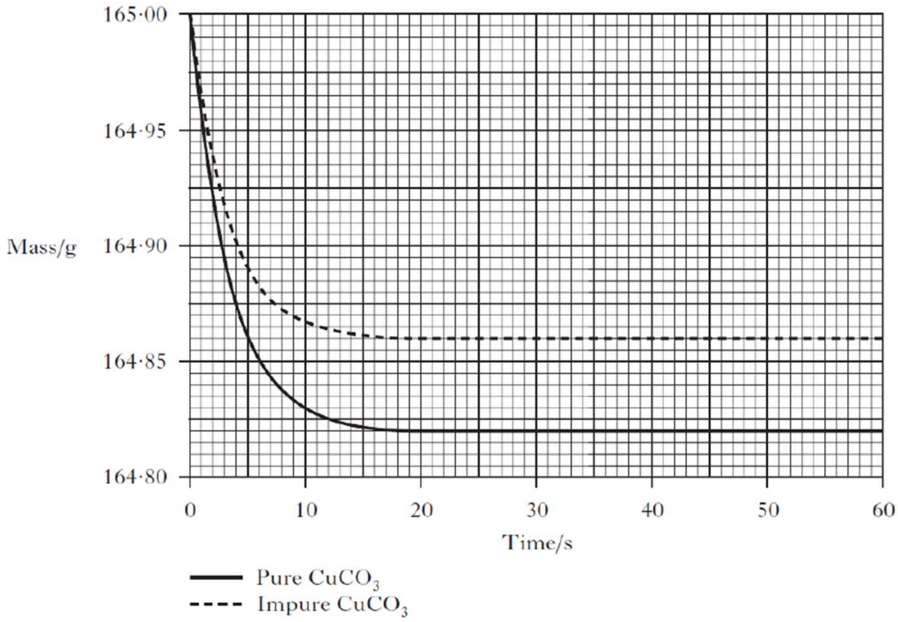
$$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$$

A student used the apparatus shown below to follow the progress of the reaction.



(a) Suggest why a cotton wool plug is placed in the mouth of the conical flask.

The experiment was carried out using 0.50 g samples of both pure and impure copper(II) carbonate. The graph below shows the results obtained.



(b) For the sample of pure copper(II) carbonate, calculate the average reaction rate in gs^{-1} over the first 10 seconds.

(c) Calculate the average rate of reaction for the impure copper(II) carbonate over the first 10 seconds.

(d) Explain, in terms of collision theory, the difference between the average rate for the pure and impure $CuCO_3$.

30. A student was asked to prepare a plan to investigate the effect of concentration on the rate of reaction. The plan is below.

Aim

To find the effect of changing the concentration of iodide ions on the rate of reaction between hydrogen peroxide and an acidified solution of potassium iodide.

Procedure

1. Using 100 cm^3 measuring cylinders, measure out 10 cm^3 of sulphuric acid, 10 cm^3 of sodium thiosulphate solution, 1 cm^3 of starch solution and 25 cm^3 of potassium iodide solution. Pour these into a dry 100 cm^3 glass beaker and place the beaker on the bench.
2. Measure out 5 cm^3 of hydrogen peroxide solution and start the timer.
3. Add the hydrogen peroxide solution to the beaker. When the blue/black colour just appears, stop the timer and record the time (in seconds).
4. Repeat this procedure four times but each time use a different concentration of potassium iodide solution.

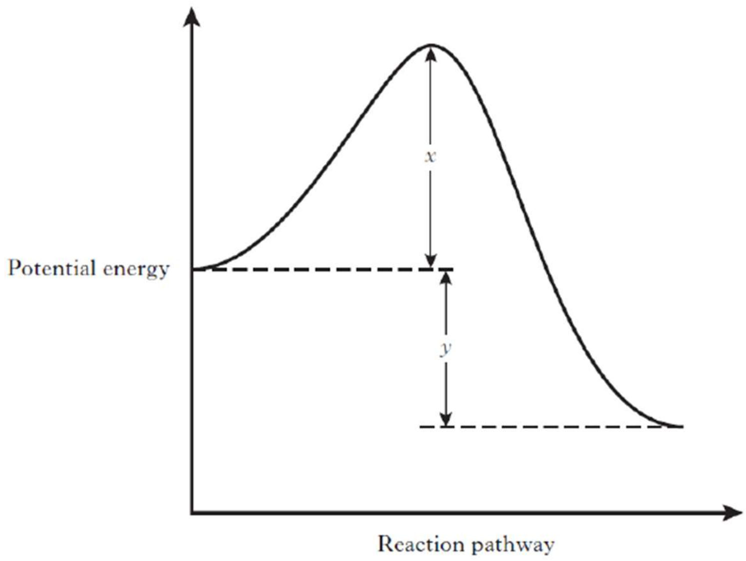
(a) In step 4 of the procedure, what should be done to obtain potassium iodide solutions of different concentrations?

(b) State **two** improvements that could be made to the student's planned procedure.

(c) Collision theory can be used to explain reaction rates. Collision theory states that for two molecules to react, they must first collide with one another.

State a condition necessary for the collisions to result in the formation of products.

31.



The enthalpy change for the forward reaction can be represented by

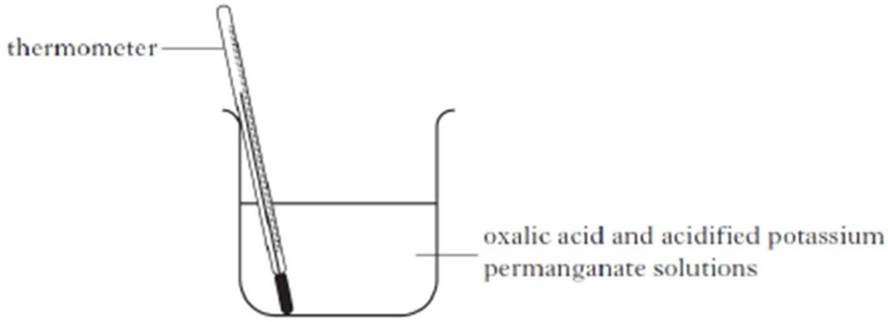
A x

B y

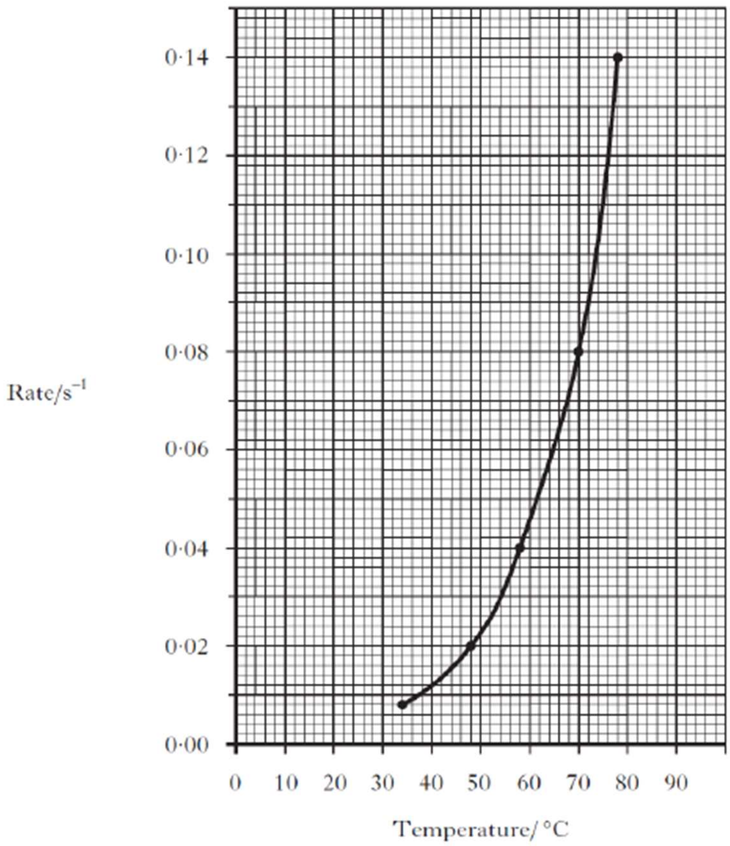
C $x + y$

D $x - y$.

32. A student carries out an experiment to determine the effect of temperature on the rate of reaction between oxalic acid and acidified potassium permanganate solution. They record the time taken for the solution to turn from purple to colourless.



The student's results are shown on the graph below.



The reaction time recorded in one experiment was 25 s.

(a) Use the graph to determine the temperature, in °C of this reaction.

(b) Why is it difficult to obtain an accurate reaction time when the experiment is carried out below 30 °C?

(c) A small increase in temperature can cause a large increase in reaction rate. As temperature is increased, collisions occur more frequently.
What other reason is there for the large increase in reaction rate observed when the temperature is increased?

33.

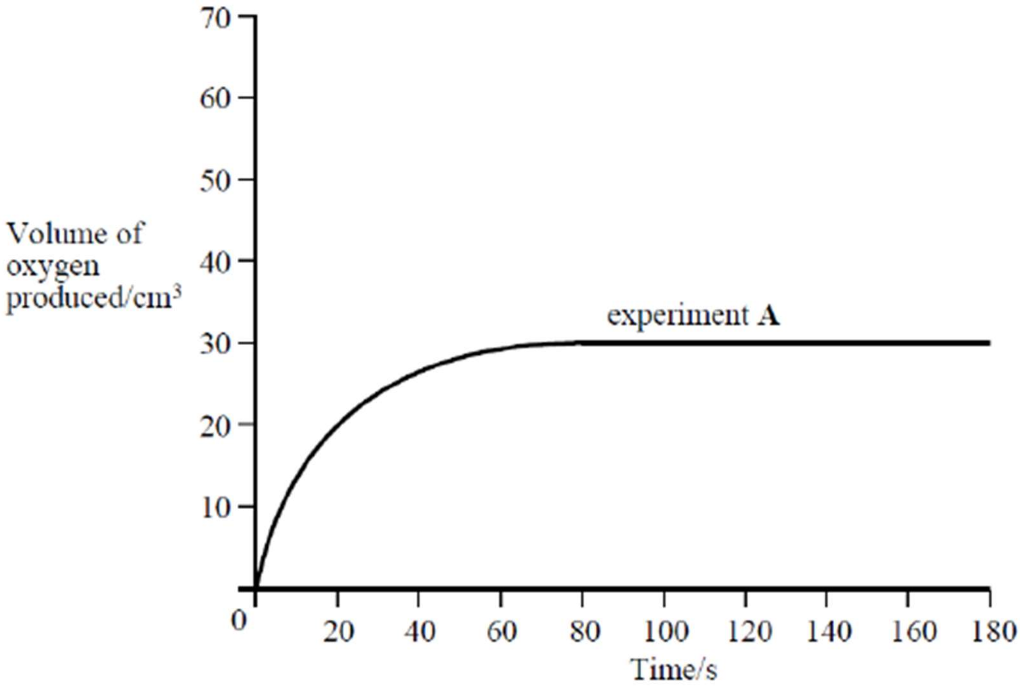
Hydrogen peroxide decomposes to form water and oxygen. This process can be catalysed by adding solid potassium permanganate.

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

The volume of oxygen produced over time was measured in two experiments using the same volume of hydrogen peroxide each time.

Experiment	Concentration of H_2O_2/mol l^{-1}
A	0·5
B	1·0

The curve obtained from experiment **A** is shown.



(a) Sketch the above graph onto your answer paper and add a curve to show the initial rate and final volume of oxygen produced in experiment **B**.

(b) Draw a labelled diagram of the assembled laboratory apparatus which could be used to **collect** and **measure** the volume of oxygen produced in these experiments.

(c) Why are both experiments carried out at the same temperature?

34.

A student carried out the Prescribed Practical Activity (PPA) to find the effect of concentration on the rate of the reaction between hydrogen peroxide solution and an acidified solution of iodide ions.

$$H_2O_2(aq) \quad + \quad 2H^+(aq) \quad + \quad 2I^-(aq) \quad \rightarrow \quad 2H_2O(\ell) \quad + \quad I_2(aq)$$

During the investigation, only the concentration of the iodide ions was changed.

Part of the student's results sheet for this PPA is shown.

Results

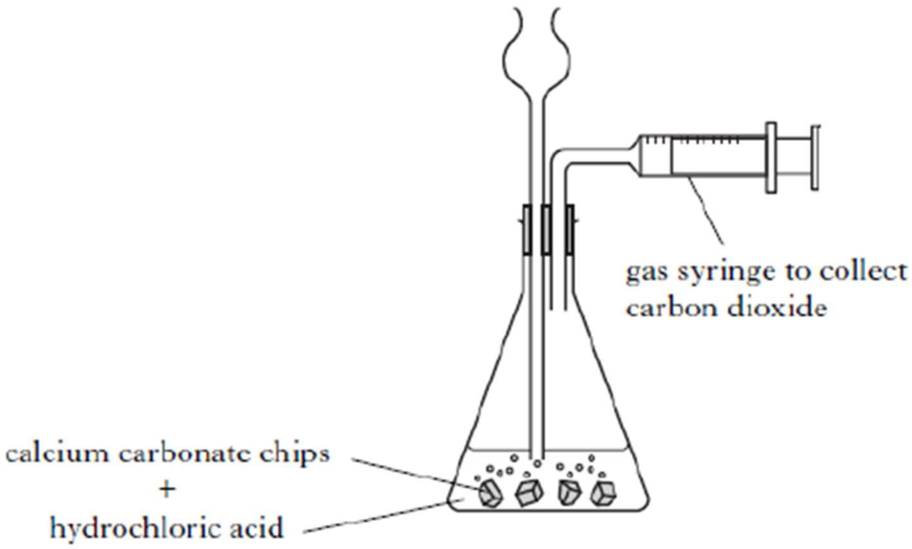
Experiment	Volume of KI(aq) /cm^3	Volume of H_2O /cm^3	Volume of H_2O_2(aq) /cm^3	Volume of H_2SO_4(aq) /cm^3	Volume of $Na_2S_2O_3$(aq) /cm^3	Rate /s^{-1}
1	25	0	5	10	10	0.043
2						
3						

(*a*) Describe how the concentration of the potassium iodide solution was changed during this series of experiments.

(*b*) Calculate the reaction time, in seconds, for the first experiment.

35.

An experiment was carried out to determine the rate of the reaction between hydrochloric acid and calcium carbonate chips. The rate of this reaction was followed by measuring the volume of gas released over a certain time.



(*a*) Describe a different way of measuring volume in order to follow the rate of this reaction.

(*b*) What other variable could be measured to follow the rate of this reaction?

(c) Chemical Energy

1.

$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g) \quad \Delta H = +88\,kJ$

$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g) \quad \Delta H = +10\,kJ$

The enthalpy change for the reaction

$$2NO_2(g) \rightarrow N_2O_4(g)$$

will be

A +98 kJ

B +78 kJ

C −78 kJ

D −98 kJ.

2.

$S(s) + H_2(g) \rightarrow H_2S(g) \quad \Delta H = a$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = b$

$S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = c$

$H_2S(g) + 1\frac{1}{2}O_2(g) \rightarrow H_2O(\ell) + SO_2(g) \quad \Delta H = d$

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 $a = d + c - b$

3.

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 $c = -b - a$.

4.

$C(s) + H_2(g) + O_2(g) \rightarrow HCOOH(\ell) \quad \Delta H = a$

$HCOOH(\ell) + {}^1/_2O_2(g) \rightarrow CO_2(g) + H_2O(\ell) \quad \Delta H = b$

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = c$

$H_2(g) + {}^1/_2O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = d$

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 $a = c + b + d$

5.

Excess iron was added to 100 cm^3 of 1·0 mol l^{-1} copper(II) sulphate solution releasing 3·1 kJ of energy.

$Fe(s) + CuSO_4(aq) \rightarrow Cu(s) + FeSO_4(aq)$

What is the enthalpy change, in kJ mol^{-1} for the above reaction?

A −0·31

B −3·1

C −31

D −310

6.

$C(graphite) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -394\ kJ\ mol^{-1}$

$C(diamond) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395\ kJ\ mol^{-1}$

What is the enthalpy change, in $kJ\ mol^{-1}$, for the conversion of one mole of graphite into one mole of diamond?

A −789

B −1

C +1

D +789

7.

When 3·6 g of butanal (relative formula mass = 72) was burned, 134 kJ of energy was released.

From this result, what is the enthalpy of combustion, in $kJ\ mol^{-1}$?

A −6·7

B +6·7

C −2680

D +2680

8.

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(\ell) \quad \Delta H_1$

$CH_3CHO(\ell) + 2\tfrac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 2H_2O(\ell) \quad \Delta H_2$

$2O_3(g) \rightarrow 3O_2(g) \quad \Delta H_3$

The enthalpy change equal to $\Delta H_1 - \Delta H_2 + \tfrac{1}{2}\Delta H_3$ is associated with the reaction

A $C_2H_4(g) + \tfrac{1}{2}O_2(g) \rightarrow CH_3CHO(\ell)$

B $C_2H_4(g) + O_3(g) \rightarrow CH_3CHO(\ell) + O_2(g)$

C $C_2H_4(g) + 2O_3(g) \rightarrow CH_3CHO(\ell) + 2\tfrac{1}{2}O_2(g)$

D $C_2H_4(g) + 2\tfrac{1}{2}O_2(g) + CH_3CHO(\ell) + O_3(g) \rightarrow 4CO_2(g) + 4H_2O(\ell)$

9.

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 g

C 72·7 g

D 727 g

10. The enthalpy change for $K(s) \rightarrow K(g)$ is 88 $kJmol^{-1}$

Using the above information and information from the data booklet (page 11), the enthalpy change for $K(s) \rightarrow K^{2+}(g) + 2e^-$ is

A. 513 $kJmol^{-1}$

B. 3052 $kJmol^{-1}$

C. 3471 $kJmol^{-1}$

D. 3559 $kJmol^{-1}$

11.

$5N_2O_4(\ell) + 4CH_3NHNH_2(\ell) \rightarrow 4CO_2(g) + 12H_2O(\ell) + 9N_2(g) \quad \Delta H = -5116\,kJ$

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.

12.

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)

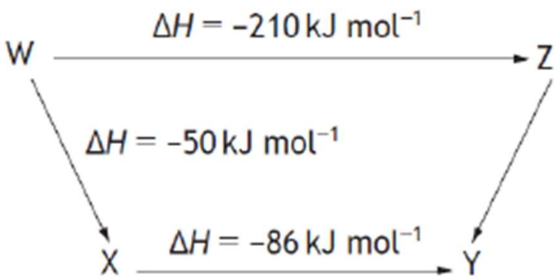
B (H-H bond enthalpy) − (Cl-Cl bond enthalpy)

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

D (H-H bond enthalpy) − (H-Cl bond enthalpy).

13.

Consider the reaction pathway shown below.



According to Hess's Law, the ΔH value, in kJ mol^{-1}, for reaction Z to Y is

A +74

B −74

C +346

D −346.

36.

14.

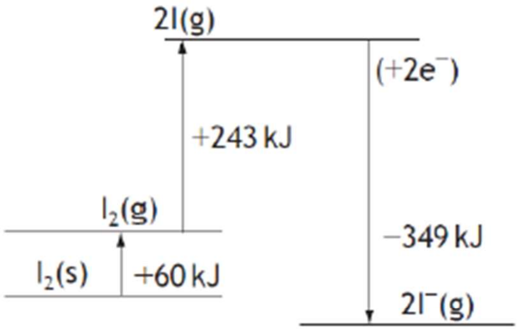
$I_2(s) \rightarrow I_2(g)$ $\Delta H = +60\,kJ\,mol^{-1}$

$I_2(g) \rightarrow 2I(g)$ $\Delta H = +243\,kJ\,mol^{-1}$

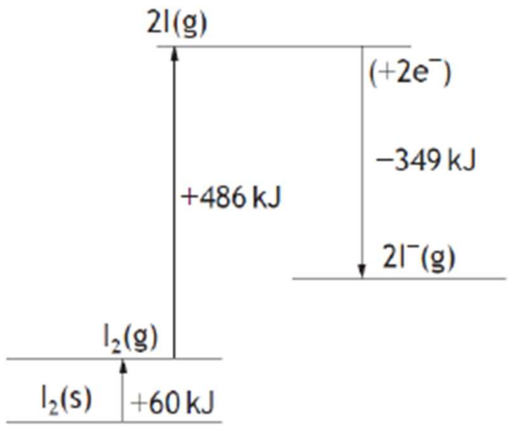
$I(g) + e^- \rightarrow I^-(g)$ $\Delta H = -349\,kJ\,mol^{-1}$

Which of the following would show the energy diagram for $I_2(s) + 2e^- \rightarrow 2I^-(g)$?

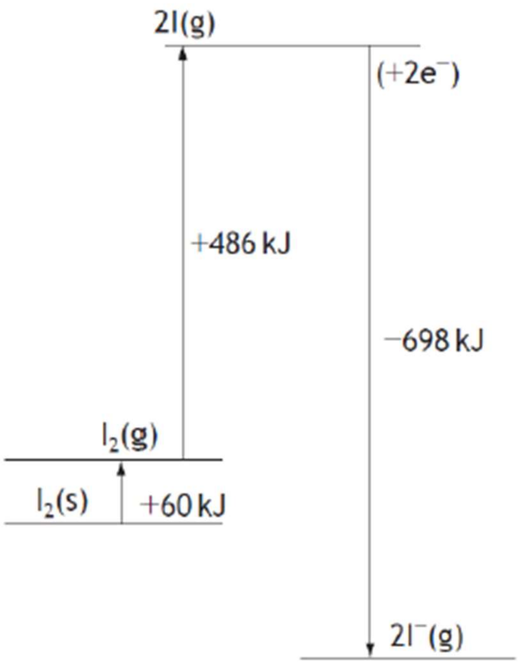
A



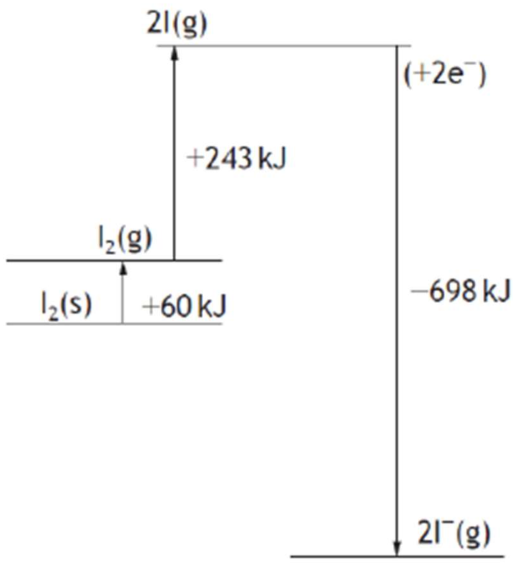
B



C



D



15.

The bond enthalpy of a gaseous diatomic molecule is the energy required to break one mole of the covalent bonds. It is also the energy released in the formation of one mole of the bonds from the atoms involved.

Bond	Bond enthalpy/kJ mol^{-1}
H — H	432
I — I	149
H — I	295

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

What is the enthalpy change, in kJ mol^{-1}, for the above reaction?

A +9

B −9

C +286

D −286

16.

What is the relationship between enthalpies p, q, r and s?

$S(s) + H_2(g) \rightarrow H_2S(g)$ $\Delta H = p$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$ $\Delta H = q$

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H = r$

$H_2S(g) + 1\frac{1}{2}O_2(g) \rightarrow H_2O(\ell) + SO_2(g)$ $\Delta H = s$

A $p = q + r - s$

B $p = s - q - r$

C $p = q - r - s$

D $p = s + r - q$

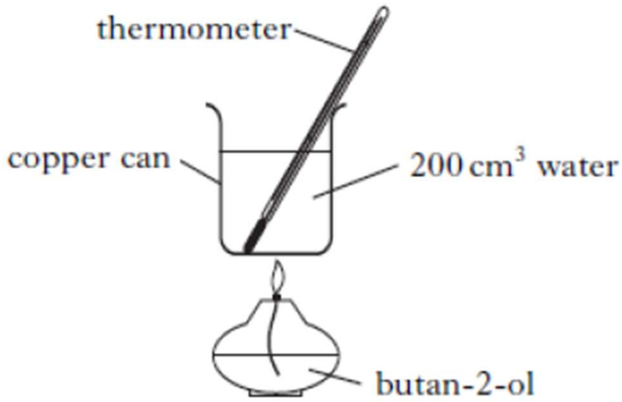
17.

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}.

(*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}.

(*c*) Enthalpy changes can also be calculated using Hess's Law.

The enthalpy of formation for pentan-1-ol is shown below.

$$5C(s) + 6H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_5H_{11}OH(\ell) \qquad \Delta H = -354\ \text{kJ mol}^{-1}$$

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}.

18.

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.

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$	$\Delta H = -283\ kJ\ mol^{-1}$
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$	$\Delta H = -242\ kJ\ mol^{-1}$
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	$\Delta H = -803\ kJ\ mol^{-1}$

Show your working clearly.

19.

Hydrogen and fluorine can react explosively to form hydrogen fluoride gas.

The equation for the reaction is shown.

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

Using bond enthalpy values from the data booklet, calculate the enthalpy change for this reaction.

20.

Tetrafluoroethene, C_2F_4, is produced in industry by a series of reactions.

The first reaction involves reacting chloromethane with hydrogen fluoride.

Use bond enthalpies from the Data Booklet to calculate the enthalpy change, in kJ, for the reaction.

21.

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.

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

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.

22.

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

$$\underset{\text{(graphite)}}{3C(s)} + 4H_2(g) + 1\tfrac{1}{2}O_2(g) \rightarrow C_3H_8O_3(\ell)$$

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

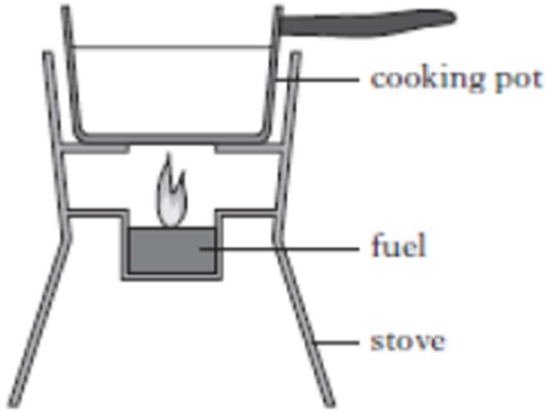
$$C_3H_8O_3(\ell) + 3\tfrac{1}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell) \quad \Delta H = -1654\ \text{kJ mol}^{-1}$$

Show your working clearly.

37.

23.

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



(*a*) The enthalpy of combustion of ethanol is -1367 kJ mol^{-1}.

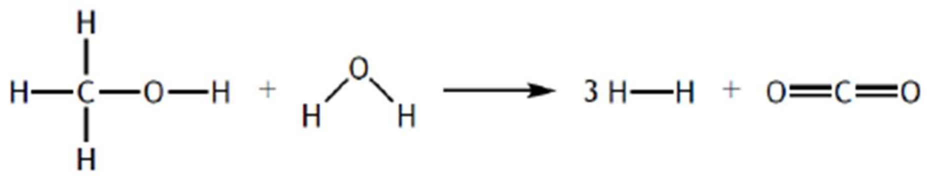
Using this value, calculate the number of moles of ethanol required to raise the temperature of 500 g of water from 18 °C to 100 °C.

Show your working clearly.

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

38.

24. Methanol is used a a source of hydrogen for fuel cells. The industrial process involves the reaction of methanol with steam.

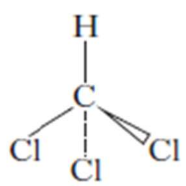


(a) State why it is important for chemists to predict whether reactions in an industrial process are exothermic or endothermic.

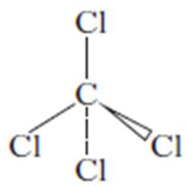
(b) Using bond enthalpies for the data booklet, calculate the enthalpy change, in $kJmol^{-1}$, for the reaction of methanol with steam.

25.

The structures below show molecules that contain chlorine atoms.



trichloromethane



tetrachloromethane

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

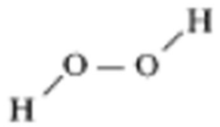
$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

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

26.

Hydrogen peroxide has a high viscosity.

The structure of hydrogen peroxide is shown below.



Hydrogen peroxide may be prepared from its elements.

The equation for the reaction is:

$$H_2(g) \quad + \quad O_2(g) \longrightarrow H_2O_2(\ell)$$

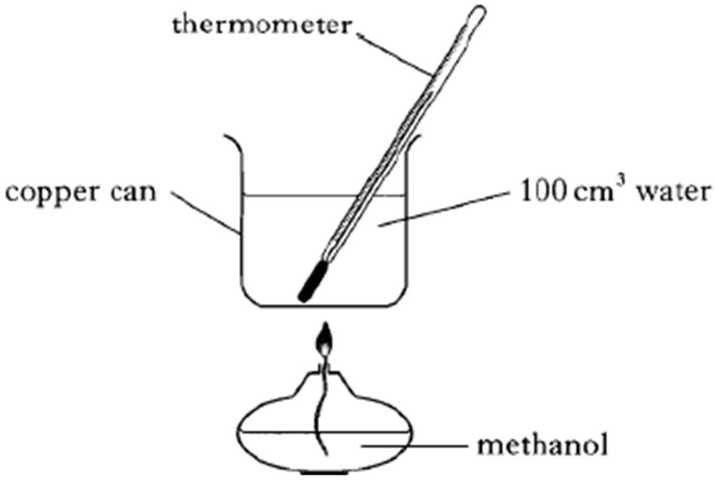
Calculate the enthalpy change, in kJ mol^{-1}, for the above reaction using the enthalpy of combustion of hydrogen from the data booklet and the enthalpy change for the following reaction.

$$H_2O_2(\ell) \longrightarrow \tfrac{1}{2}O_2(g) + H_2O(\ell) \qquad \Delta H = -98 \text{ kJ mol}^{-1}$$

Show your working clearly.

27.

The enthalpy of combustion of methanol (CH_3OH) can be determined from measurements using the apparatus shown.



In an experiment, the following results were obtained.

mass of methanol burned = 0·45 g

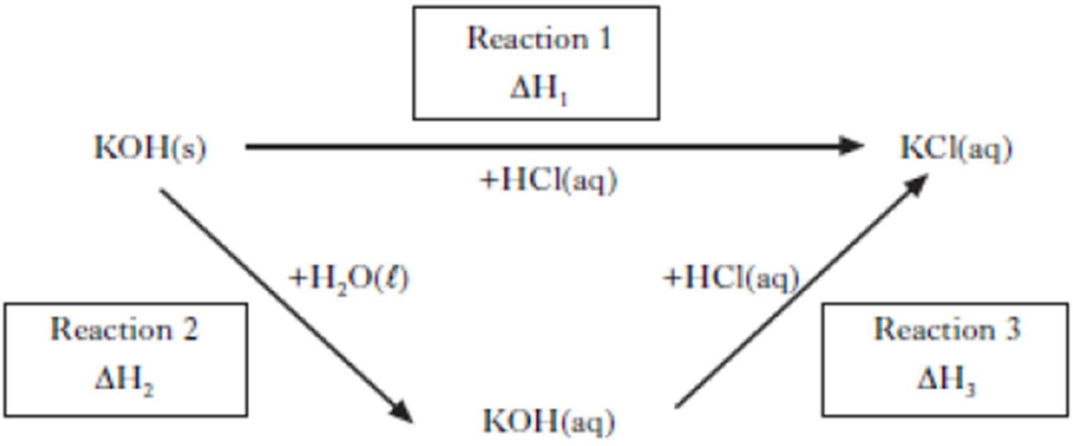
temperature rise of water = 10·0 °C

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

Show your working clearly.

28.

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



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

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) Explain why the reaction was carried out in a polystyrene cup.

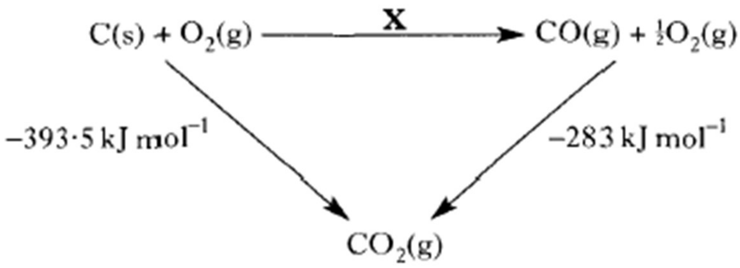
(iii) A student found that 1.08 kJ of energy was released when 1.2 g of potassium hydroxide was dissolved completely in water.

Calculate the enthalpy change for this reaction.

(b) State Hess's Law

29.

Consider the reaction pathway shown.



According to Hess's Law, what is the enthalpy change for reaction **X**?

A $+110{\cdot}5\ kJ\ mol^{-1}$

B $-110{\cdot}5\ kJ\ mol^{-1}$

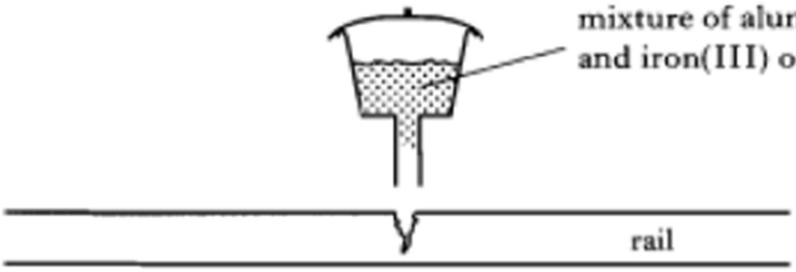
C $-676{\cdot}5\ kJ\ mol^{-1}$

D $+676{\cdot}5\ kJ\ mol^{-1}$

30.

The Thermite Process involves the reaction between aluminium and iron(III) oxide to produce iron and aluminium oxide.

This highly exothermic reaction, which generates so much heat that the temperature of the mixture rises to around 3000 °C, is used for repairing cracked railway lines as shown in the diagram below.



(*a*) Suggest why this process is suitable for repairing cracked railway lines.

(*b*) The enthalpy changes for the formation of one mole of aluminium oxide and one mole of iron(III) oxide are shown below.

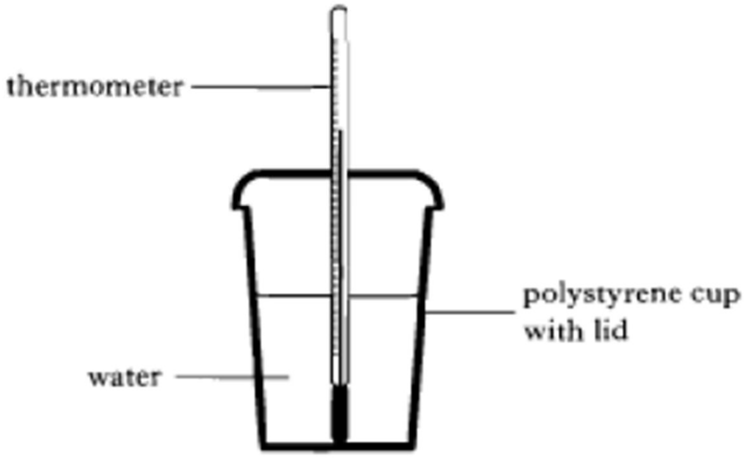
$$2Al(s) + 1\tfrac{1}{2}O_2(g) \longrightarrow Al_2O_3(s) \quad \Delta H = -1676\ kJ\ mol^{-1}$$
$$2Fe(s) + 1\tfrac{1}{2}O_2(g) \longrightarrow Fe_2O_3(s) \quad \Delta H = -825\ kJ\ mol^{-1}$$

Use the above information to calculate the enthalpy change for the reaction:

$$2Al(s) + Fe_2O_3(s) \longrightarrow Al_2O_3(s) + 2Fe(s)$$

31.

The following apparatus can be used to determine the enthalpy of solution of a substance. (The enthalpy of solution is the energy change when 1 mole dissolves completely.)



(*a*) Why was the experiment carried out in a polystyrene cup with a lid?

(*b*) In an experiment to find the enthalpy of solution of potassium hydroxide, KOH, a student added 3·6 g of the solid to the water in the polystyrene cup and measured the temperature rise. From this, it was calculated that the heat energy produced in the reaction was 3·5 kJ.

Use this information to calculate the enthalpy of solution of potassium hydroxide.

Show your working clearly.

32.

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

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.

33.

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.

The equation for the overall reaction is:

$$C_6H_4(OH)_2(aq) \quad + \quad H_2O_2(aq) \quad \rightarrow \quad C_6H_4O_2(aq) \quad + \quad 2H_2O(\ell)$$

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

$$C_6H_4(OH)_2(aq) \rightarrow C_6H_4O_2(aq) + H_2(g) \qquad \Delta H = +177{\cdot}4\ kJ\ mol^{-1}$$

$$H_2(g) + O_2(g) \rightarrow H_2O_2(aq) \qquad \Delta H = -191{\cdot}2\ kJ\ mol^{-1}$$

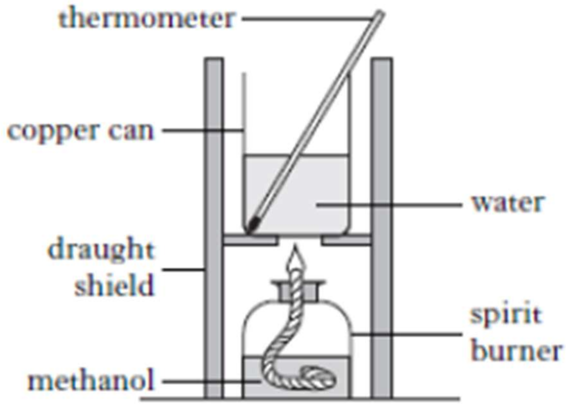
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad \Delta H = -241{\cdot}8\ kJ\ mol^{-1}$$

$$H_2O(g) \rightarrow H_2O(\ell) \qquad \Delta H = -43{\cdot}8\ kJ\ mol^{-1}$$

Show your working clearly.

34.

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

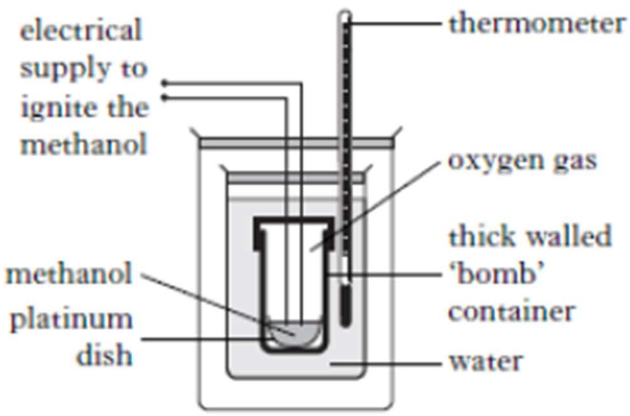


(*a*) (i) What measurements are needed to calculate the energy released by the burning methanol?

(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.

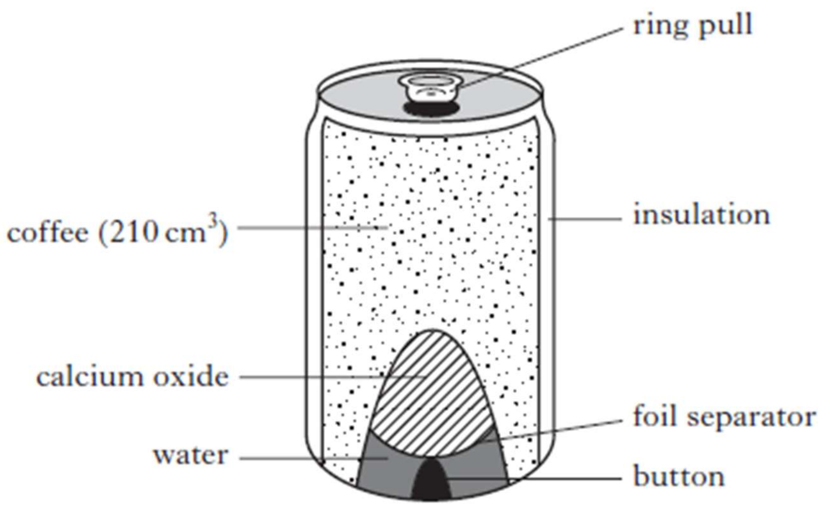
Give **one** other reason for the value being more accurate in the bomb calorimeter method.

35.

Self-heating cans may be used to warm drinks such as coffee.

When the button on the can is pushed, a seal is broken allowing water and calcium oxide to mix and react.

The reaction produces solid calcium hydroxide and releases heat.



The equation for this reaction is:

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(s) \qquad \Delta H = -65\ kJ\ mol^{-1}$$

(*a*) Calculate the mass, in grams, of calcium oxide required to raise the temperature of 210 cm^3 of coffee from 20 °C to 70 °C.

Show your working clearly.

(*b*) If more water is used the calcium hydroxide is produced as a solution instead of as a solid.

The equation for the reaction is:

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$$

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

$$Ca(s) + \tfrac{1}{2}O_2(g) \rightarrow CaO(s) \qquad \Delta H = -635\ kJ\ mol^{-1}$$

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

$$Ca(s) + O_2(g) + H_2(g) \rightarrow Ca(OH)_2(s) \qquad \Delta H = -986\ kJ\ mol^{-1}$$

$$Ca(OH)_2(s) \rightarrow Ca(OH)_2(aq) \qquad \Delta H = -82\ kJ\ mol^{-1}$$

Show your working clearly.

36.

Vinegar is a dilute solution of ethanoic acid.

Hess's Law can be used to calculate the enthalpy change for the formation of ethanoic acid from its elements.

$$\underset{\text{(graphite)}}{2C(s)} + 2H_2(g) + O_2(g) \rightarrow CH_3COOH(\ell)$$

Calculate the enthalpy change for the above reaction, in kJ mol^{-1}, using information from the data booklet and the following data.

$$CH_3COOH(\ell) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(\ell) \quad \Delta H = -876\,\text{kJ mol}^{-1}$$

Show your working clearly.

(d) 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.

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

4.

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 $AgNO_3$

D NaOBr.

5.

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.

6.

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

7.

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

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

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.

8.

$$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
$$\Delta H = -36 \text{ kJ mol}^{-1}$$

The solubility of ammonia in water will be increased by

A increasing pressure and cooling

B decreasing pressure and cooling

C decreasing pressure and warming

D increasing pressure and warming.

9.

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.

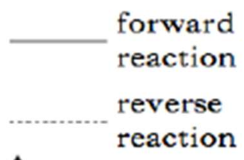
D Insufficient ethanoic acid was used.

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

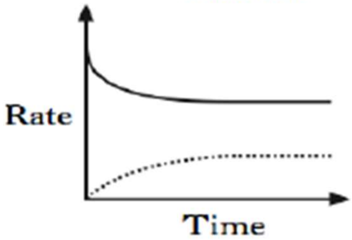
$$CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$$

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

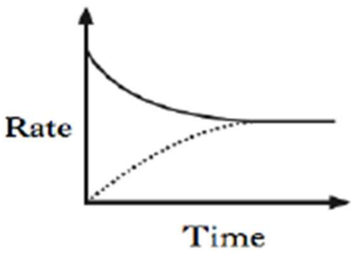
KEY



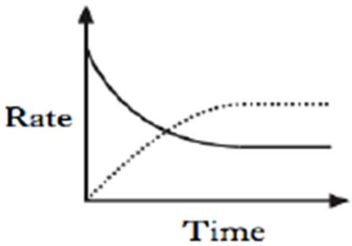
A



B



C



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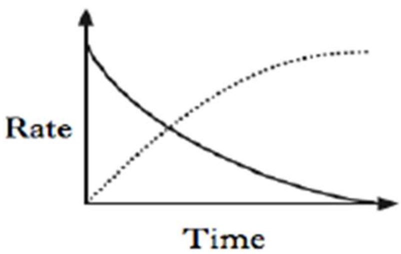


11.

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.

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.

13.

41.

The hypochlorite ion, $ClO^-(aq)$, produced in the reaction shown, is used as a bleach.

$$Cl_2(g) + H_2O(\ell) \rightleftharpoons 2H^+(aq) + ClO^-(aq) + Cl^-(aq)$$

The concentration of ClO^- ions could be increased by the addition of

A solid potassium hydroxide

B concentrated hydrochloric acid solution

C solid sodium chloride

D solid potassium sulphate.

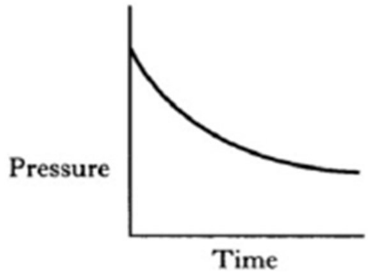
14.

Gaseous iodine and hydrogen were reacted together in a sealed container.

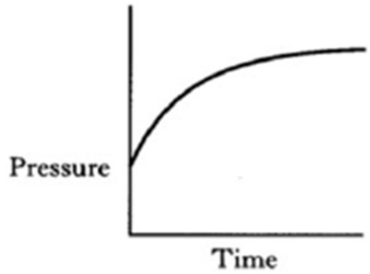
$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

Which of the following graphs shows the pressure inside the vessel as the reaction proceeds at constant temperature?

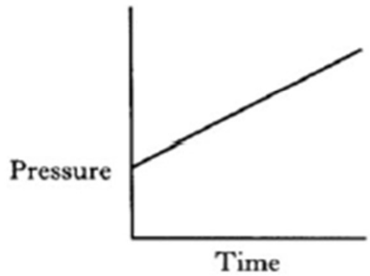
A



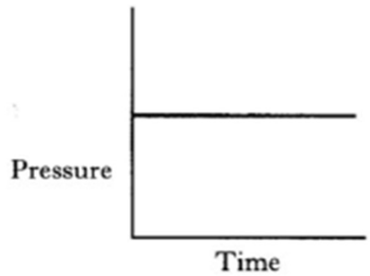
B



C



D



15.

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

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	unchanged	unchanged
B	increases	increases
C	decreases	decreases
D	unchanged	decreases

16.

Which line in the table describes dynamic equilibrium?

	Concentration of reactants and products	Forward and reverse reaction rates
A	constant	equal
B	constant	not equal
C	not constant	equal
D	not constant	not equal

17.

The following reaction takes place in a blast furnace:

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \quad \Delta H = +174\ kJ\ mol^{-1}$$

Which conditions of pressure and temperature would favour the production of carbon monoxide?

A Low pressure and low temperature

B High pressure and low temperature

C Low pressure and high temperature

D High pressure and high temperature

18.

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.

19.

$$ICl(\ell) + Cl_2(g) \rightleftharpoons ICl_3(s) \quad \Delta H = -106\ kJ\ mol^{-1}$$

Which line in the table identifies correctly the changes that will cause the greatest increase in the proportion of solid in the above equilibrium?

	Temperature	Pressure
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

20.

Which line in the table applies correctly to the use of a catalyst in a chemical reaction?

	Position of equilibrium	Effect on value of ΔH
A	Moved to right	Decreased
B	Unaffected	Increased
C	Moved to left	Unaffected
D	Unaffected	Unaffected

21.

Some solid ammonium chloride is added to a dilute solution of ammonia.

Which of the following ions will decrease in concentration as a result?

A Ammonium

B Hydrogen

C Hydroxide

D Chloride

22.

Chemical reactions are in a state of dynamic equilibrium only when

A the reaction involves zero enthalpy change

B the concentrations of reactants and products are equal

C the rate of the forward reaction equals that of the backward reaction

D the activation energies of the forward and backward reactions are equal.

23.

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.

$$NH_3(g) \quad + \quad O_2(g) \quad \rightarrow \quad NO(g) \quad + \quad H_2O(g)$$

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

$$2NO(g) \quad + \quad O_2(g) \quad \rightleftharpoons \quad 2NO_2(g)$$

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

24.

Rivers and drains are carefully monitored to ensure that they remain uncontaminated by potentially harmful substances from nearby industries. Chromate ions, CrO_4^{2-}, are particularly hazardous.

When chromate ions dissolve in water the following equilibrium is established.

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} \quad + \quad 2H^+(aq) \quad \rightleftharpoons \quad \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} \quad + \quad H_2O(\ell)$$

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

25.

Which line in the table applies correctly to the use of a catalyst in a chemical reaction?

	Position of equilibrium	**Effect on value of ΔH**
A	Moved to right	Decreased
B	Unaffected	Increased
C	Moved to left	Unaffected
D	Unaffected	Unaffected

26.

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 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

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

27.

$Cl_2(g) + H_2O(\ell) \rightleftharpoons Cl^-(aq) + ClO^-(aq) + 2H^+(aq)$

The addition of which of the following substances would move the above equilibrium to the right?

A Hydrogen

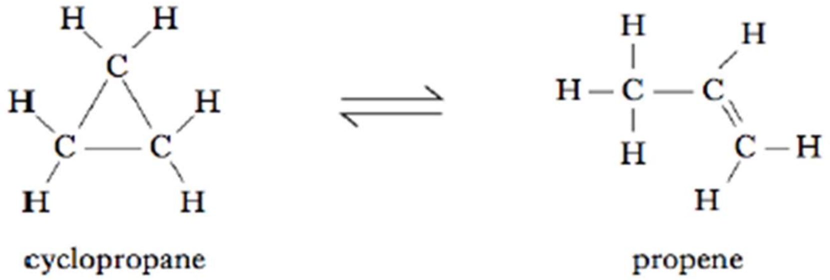
B Hydrogen chloride

C Sodium chloride

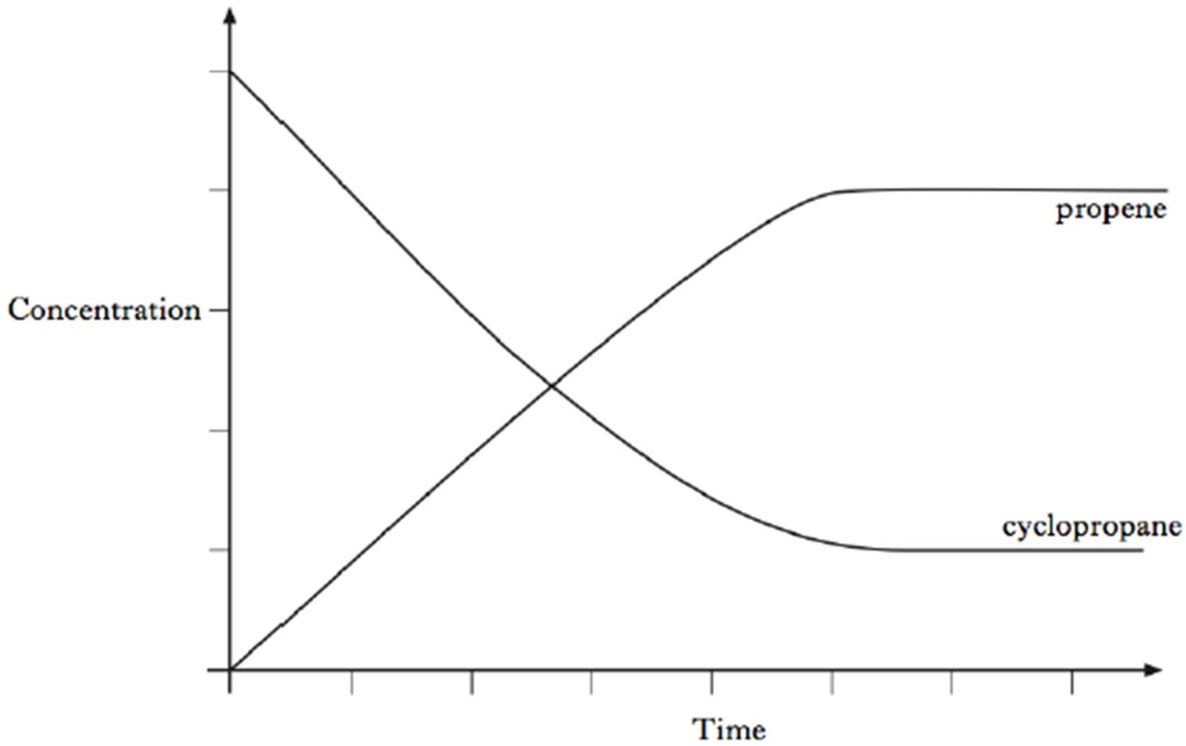
D Sodium hydroxide

28.

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.

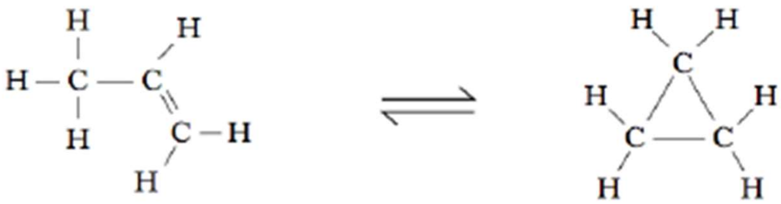


(*a*) Mark clearly on the graph the point at which equilibrium has just been reached.

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

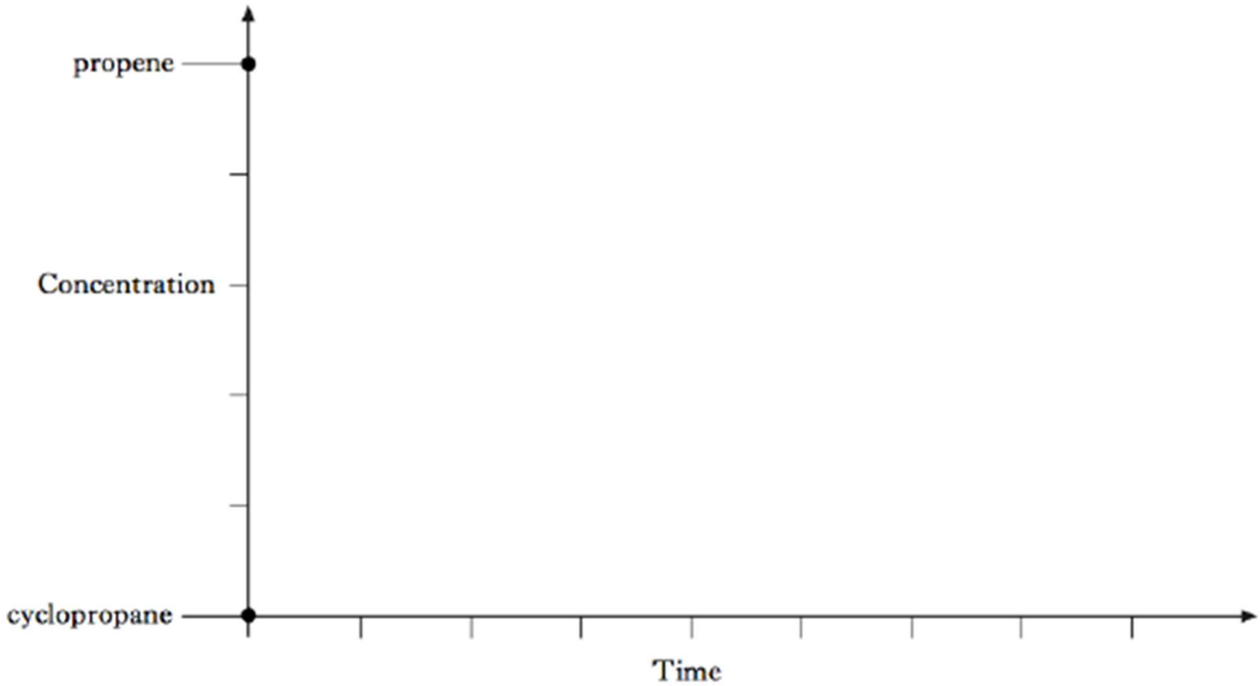
28. (cont)

(*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 this reverse reaction.



29.

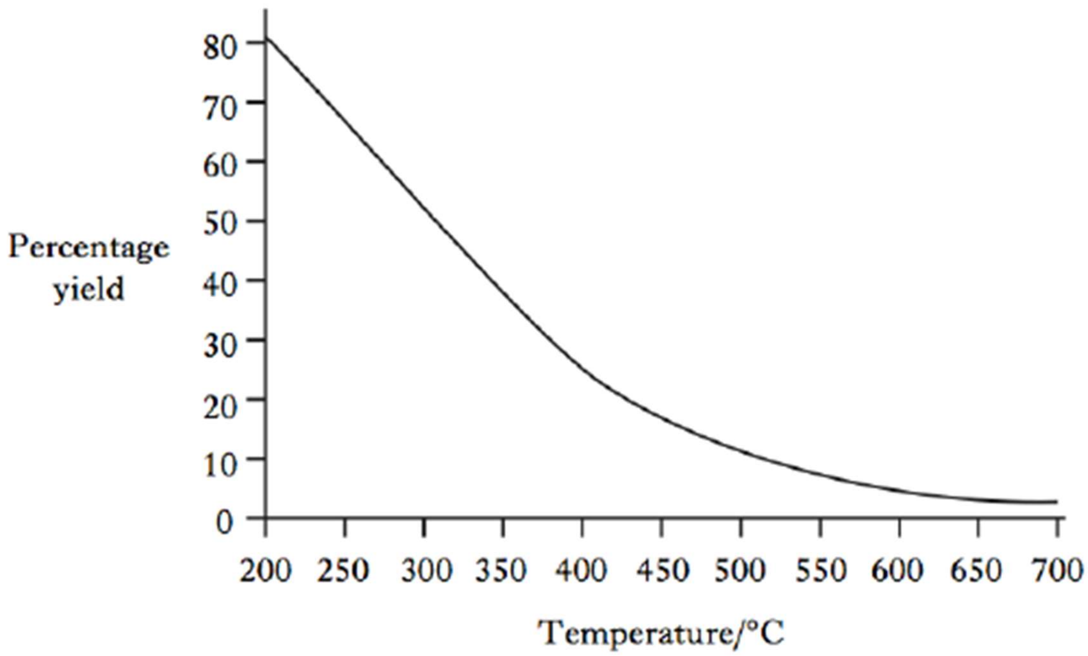
Methyl orange indicator, $C_{14}H_{15}N_3SO_3$, is a weak acid.

The equilibrium in solution is shown.

$$\underset{\text{red}}{C_{14}H_{15}N_3SO_3(aq)} \rightleftharpoons \underset{\text{yellow}}{C_{14}H_{14}N_3SO_3^-(aq)} + H^+(aq)$$

Explain fully the colour that would be observed when the indicator is added to dilute sodium hydroxide solution.

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



(a) A student correctly concludes from the graph that the production of ammonia is an exothermic process.
Explain fully the reasoning for this conclusion

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

31. 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.

$$O_2(g) \rightleftharpoons O_2(aq) \qquad \Delta H = -12.1\ kJmol^{-1}$$

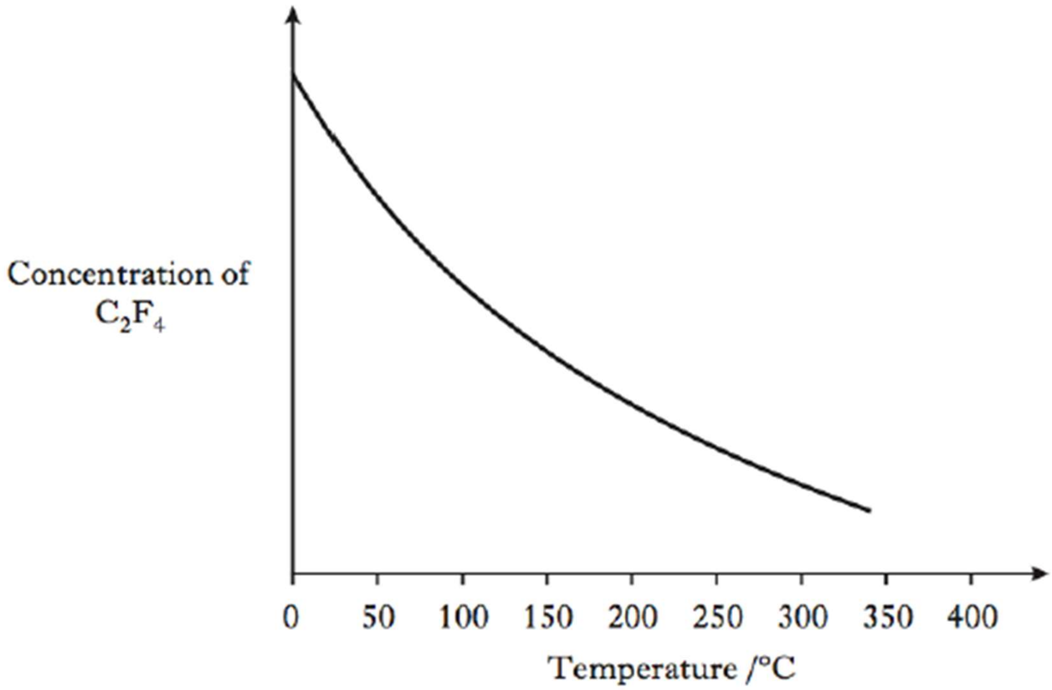
(a) Explain what is meant by a reaction at "equilibrium"

(b) Explain fully what would happen to the concentration of dissolved oxygen if the temperature of the Earth's oceans increased.

32. Fluorine is an extremely reactive element. Its' compounds are found in a range of products. Tetrafluoroethene, C2F4 is produced in industry by a series of reactions. The final reaction in its manufacture is shown below.

$$2CHClF_2(g) \rightleftharpoons C_2F_4(g) + 2HCl(g)$$

(a) The graph shows the variation in the concentration of C_2F_4 formed at equilibrium as temperature is increased.



What conclusion can be drawn about the enthalpy change for the formation of tetrafluoroethene?

(b) Sketch a graph to show how the concentration of C_2F_4 formed at equilibrium would vary with increasing pressure.

33. Hydrogen sulfide is a toxic gas with the smell of rotten eggs.

Hydrogen sulfide dissolves readily in water.

$$H_2S(aq) \rightleftharpoons HS^-(aq) + H^+(aq)$$

What effect would the addition of ammonia solution have on the position of equilibrium in the above reaction?

34.

The balanced equation for a reaction at equilibrium is:

$$\mathbf{aA + bB \rightleftharpoons cC + dD}$$

(*a*) For this reaction, the equilibrium constant, **K**, can be defined as:

$$\mathbf{K = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}}$$

where **[A]** represents the concentration of **A**, etc and **a** represents the number of moles of **A**, etc.

(i) Write down the expression for the equilibrium constant for the following equilibrium.

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

(ii) What will happen to the position of an equilibrium if the reaction is carried out over a catalyst?

(*b*) In industry, the reaction of nitrogen with hydrogen to produce ammonia by the Haber Process does **not** attain equilibrium.

Give **one** feature of the operating conditions which leads to the Haber Process not reaching equilibrium.

35.

If the conditions are kept constant, reversible reactions will attain a state of equilibrium.

(*a*) Circle the correct words in the table to show what is true for reactions at equilibrium.

Rate of forward reaction compared to rate of reverse reaction	faster / same / slower
Concentrations of reactants compared to concentrations of products	usually different / always the same

(*b*) The following equilibrium involves two compounds of phosphorus.

$$PCl_3(g) + 3NH_3(g) \rightleftharpoons P(NH_2)_3(g) + 3HCl(g)$$

(i) An increase in temperature moves the above equilibrium to the left.

What does this indicate about the enthalpy change for the forward reaction?

(ii) What effect, if any, will an increase in pressure have on the above equilibrium?

36. Urea, H_2NCONH_2, has several uses, *e.g.* as a fertiliser and for the manufacture of some thermosetting plastics.

It is produced in a two-step process.

Step one:

$$CO_2(g) + 2NH_3(l) \rightleftharpoons H_2NCOONH_4(s) \quad \Delta H<0$$

Step two:

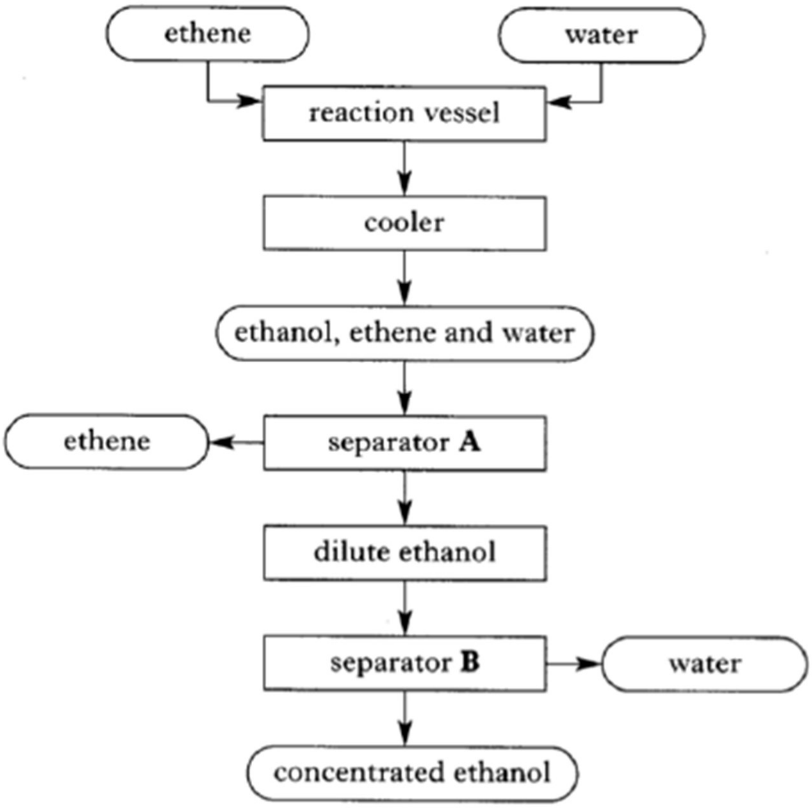
$$H_2NCOONH_4(s) \rightleftharpoons H_2NCONH_2(s) + H_2O(g) \quad \Delta H>0$$

(a) What would happen to the equilibrium position in **step one** if the temperature was increased?

(b) Step two is carried out at low pressure

Why does lowering the pressure move the equilibrium position to the right?

(c) An industrial method for the production of ethanol is outlined in the flow diagram.



In the reaction vessel, ethanol is produced in an exothermic reaction

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

What would happen to the equilibrium position if the temperature inside the reaction vessel was increased?

(e) Chemical Analysis

1.

$45\ cm^3$ 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.

2.

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.

3.

Which of the following would **not** help a student determine the end point of a titration accurately?

A Swirling the flask.

B Using a white tile.

C Adding the solution dropwise near the end-point.

D Repeating the titration.

4.

The correct method of filling a $20\ cm^3$ pipette is to draw the liquid into the pipette

A doing it slowly at the end, until the top of the meniscus touches the mark

B doing it slowly at the end, until the bottom of the meniscus touches the mark

C to above the mark and then release liquid from the pipette until the top of the meniscus touches the mark

D to above the mark and then release liquid from the pipette until the bottom of the meniscus touches the mark.

5.

A $0{\cdot}10\ mol\ l^{-1}$ solution could be prepared most accurately from a $1{\cdot}0\ mol\ l^{-1}$ solution using

A a $1\ cm^3$ dropping pipette and a $10\ cm^3$ measuring cylinder

B a $10\ cm^3$ measuring cylinder and a $100\ cm^3$ volumetric flask

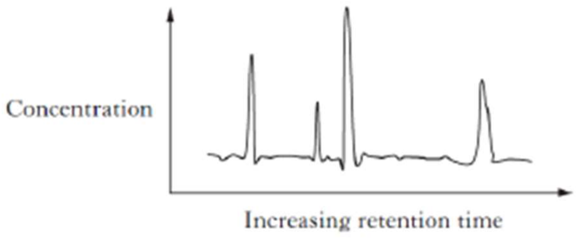
C a $25\ cm^3$ pipette and a $250\ cm^3$ volumetric flask

D a $50\ cm^3$ burette and a $500\ cm^3$ measuring cylinder.

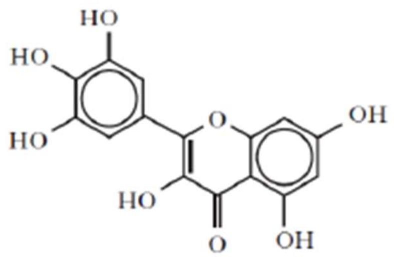
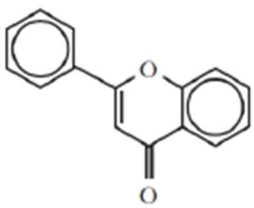
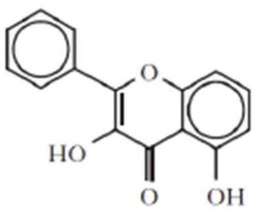
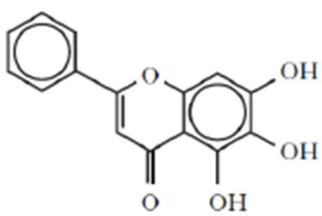
6.

A chemist analysed a mixture of four dyes A, B, C and D using gas-liquid chromatography.

When a polar column was used the following chromatogram was obtained.



Which of the following compounds was present in greatest concentration?

Dye	Structure
A	
B	
C	
D	

7.

Some fruit drinks claim to be high in antioxidants such as vitamin C.

(*a*) The vitamin C content in a fruit drink can be determined by titrating it with iodine.

The redox reaction which takes place is shown.

$$\underset{\text{vitamin C}}{C_6H_8O_6(aq)} + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

(i) Write the ion-electron equation for the oxidation reaction taking place.

(ii) Some students carried out an investigation of fruit drinks to determine their vitamin C content. The following steps were followed in each experiment.

Step 1 A 20·0 cm^3 sample of fruit drink was transferred to a conical flask by pipette.

Step 2 A burette was filled with a standard iodine solution.

Step 3 The fruit drink sample was titrated with the iodine.

Step 4 Titrations were repeated until concordant results were obtained.

The burette, pipette and conical flask were all rinsed before they were used.

Tick the appropriate boxes below to show which solution should be used to rinse each piece of glassware.

Glassware used	Rinse with water	Rinse with iodine	Rinse with fruit drink
pipette			
burette			
conical flask			

7.

(a) (cont)

(iii) Titrating a whole carton of fruit drink would require large volumes of iodine solution.

Apart from this disadvantage, give another reason for titrating several smaller samples of fruit drink.

(iv) An average of $25{\cdot}4\,cm^3$ of $0{\cdot}00125\ mol\,l^{-1}$ iodine solution was required for the complete titration of the vitamin C in a $20{\cdot}0\,cm^3$ sample of fruit drink.

Calculate the mass, in grams, of vitamin C in the 1 litre carton of fruit drink.

(mass of 1 mole vitamin C = 176 g)

Show your working clearly.

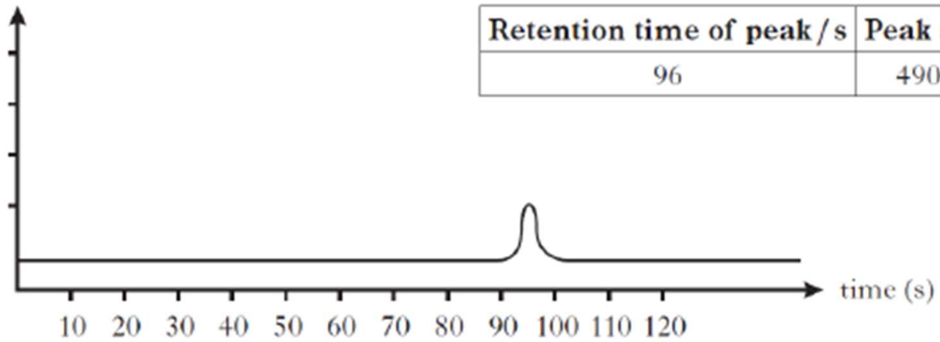
(*b*) The recommended daily allowance (RDA) for vitamin C is 60 mg.

A one litre carton of an orange fruit drink contains 240 mg of vitamin C.

What percentage of the RDA is provided by $200\,cm^3$ of this drink?

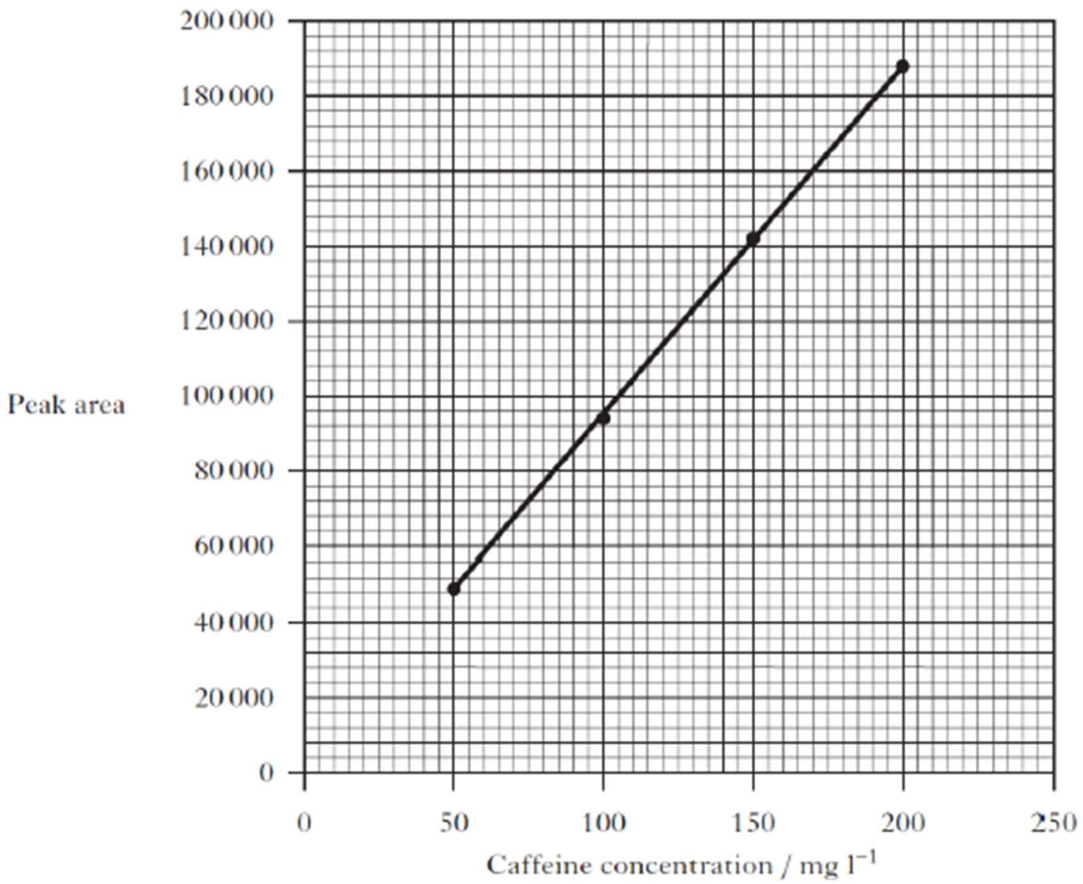
46.

8. Caffeine is added to some soft drinks. The concentration of caffeine can be found using chromatography. A chromatogram for a standard solution containing 50 mgl^{-1} of caffeine is shown below.



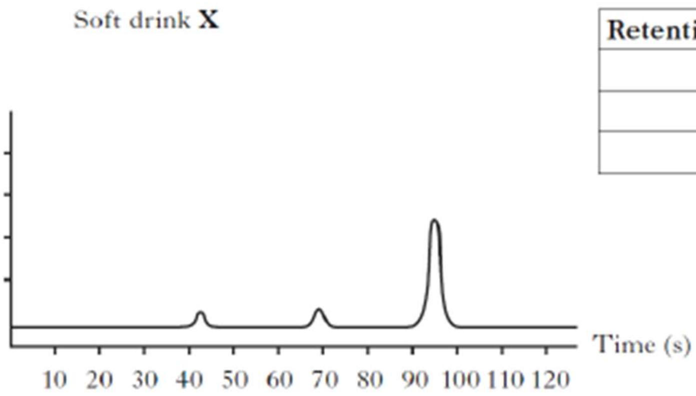
Retention time of peak / s	Peak area
96	49000

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

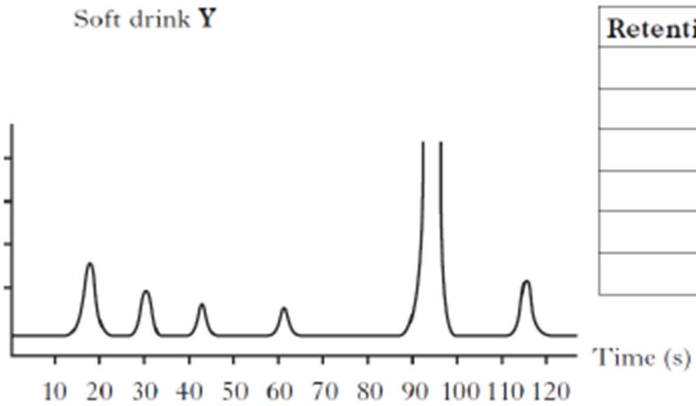


8. (cont)

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) Calculate the caffeine content, in mgl-1 of soft drink X.

(b) The caffeine content of the soft drink Y cannot be determined from the chromatogram. Explain what should be done to the sample of soft drink Y so that the caffeine content can be reliably calculated.

9.

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 thiosulphate ions.

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

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

(*b*) Three $20{\cdot}0\,cm^3$ samples of a sheep treatment solution were titrated with $0{\cdot}10\,mol\,l^{-1}$ thiosulphate solution.

The results are shown below.

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

(i) Why is the volume of sodium thiosulphate used in the calculation taken to be $18{\cdot}15\,cm^3$, 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.

10.

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.

$$H_2O_2(aq) \quad + \quad 2H^+(aq) \quad + \quad 2e^- \quad \rightarrow \quad 2H_2O(\ell)$$

Write a balanced redox equation for the reaction of hydrogen peroxide with iodide ions.

(*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.

$$2Na_2S_2O_3(aq) \quad + \quad I_2(aq) \quad \rightarrow \quad 2NaI(aq) \quad + \quad Na_2S_4O_6(aq)$$

In an analysis of seaweed, 14·9 cm^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.

11.

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**.

(*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**.

(*c*) If $50{\cdot}4\,cm^3$ of $0{\cdot}10\ mol\,l^{-1}$ 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.

12.

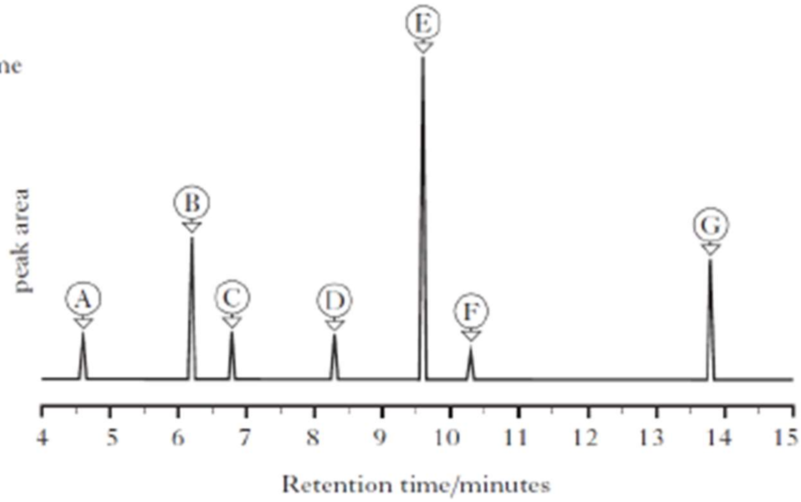
Up to 10% of perfumes sold in the UK are counterfeit versions of brand name perfumes.

One way to identify if a perfume is counterfeit is to use gas chromatography. The gas chromatograms from a brand name perfume and two counterfeit perfumes, A and B, are shown below. The chromatograms were run under identical conditions.

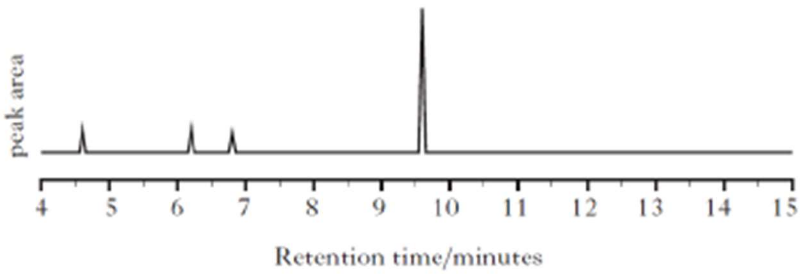
Some of the peaks in the brand name perfume have been identified as belonging to particular compounds.

Brand name perfume

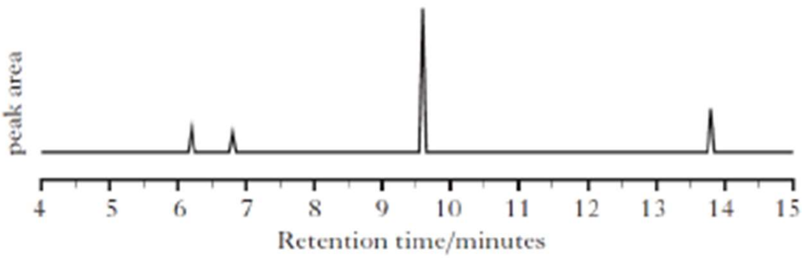
(A) linalool
(B) citronellol
(C) geraniol
(D) eugenol
(E) anisyl alcohol
(F) coumarin
(G) benzyl salicylate



Counterfeit A



Counterfeit B



12. (cont)

(*a*) Identify one compound present in the brand name perfume that appears in both counterfeit perfumes.

(*b*) Some compounds in the brand name perfume are not found in the counterfeit perfumes.

State another difference that the chromatograms show between the counterfeit perfumes and the brand name perfume.

(*c*) The gas used to carry the perfume sample along the chromatography column is helium.

(i) Suggest why helium is used.

(ii) Apart from the polarity of the molecules, what else would affect the retention time of molecules during gas chromatography?

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:

$$5(COOH)_2(aq) + 6H^+(aq) + 2MnO_4^-(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(aq) + 8H_2O(\ell)$$

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

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

(*c*) In an investigation using a 500 cm^3 carton of rhubarb juice, separate 25·0 cm^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 = 26·9 cm^3.

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

(ii) Calculate the number of moles of oxalic acid in the 500 cm^3 carton of rhubarb juice.

Show your working clearly.

14.

Rivers and drains are carefully monitored to ensure that they remain uncontaminated by potentially harmful substances from nearby industries. Chromate ions, CrO_4^{2-}, are particularly hazardous.

The concentration of chromate ions in water can be measured by titrating with a solution of iron(II) sulphate solution.

A 50·0 cm^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:

$$3Fe^{2+}(aq) + CrO_4^{2-}(aq) + 8H^+(aq) \rightarrow 3Fe^{3+}(aq) + Cr^{3+}(aq) + 4H_2O(\ell)$$

Calculate the chromate ion concentration, in mol l^{-1}, present in the sample of water.

Show your working clearly.

15.

Compounds containing sulphur occur widely in nature.

Hydrogen sulphide, H_2S, formed by the decomposition of proteins, can cause an unpleasant odour in water supplies.

Chlorine, added to the water, removes the hydrogen sulphide.

The equation for the reaction taking place is

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

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 sulphide concentration, in mol l^{-1}, present in the water sample.

Show your working clearly.

16. Vitamin C is required by our bodies for producing the protein, collagen. Collagen can form sheets that support skin and internal organs.

A standard solution of iodine can be used to determine the mass of vitamin C in orange juice.

Iodine reacts with vitamin C as shown by the following equation

$$\mathbf{C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)}$$

Vitamin C

In an investigation using a carton containing 500 cm^3 of orange juice, separate 50.0 samples were measured out. Each sample was then titrated with a 0.0050 mol l^{-1} solution of iodine.

(a) Why would starch solution be added to each 50.0 cm^3 sample of orange juice before titrating against iodine solution?

(b) Titrating the whole carton of orange juice would require large volumes of iodine solution. Apart from this disadvantage, give another reason for titrating several smaller samples of orange juice.

(c) An average of 21.4 cm^3 of the iodine solution was required for the complete reaction with the vitamin C in 50.0 cm^3 of orange juice. Use this result to calculate the mass of vitamin C, in grammes in the 500 cm^3 carton of orange juice.

17.

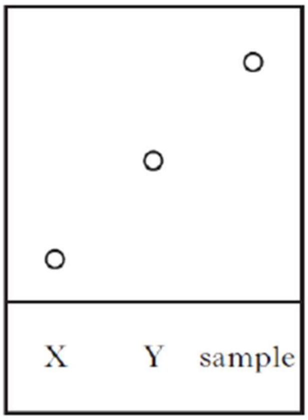
An organic chemist is attempting to synthesise a fragrance compound by the following chemical reaction.

compound **X** + compound **Y** → fragrance compound

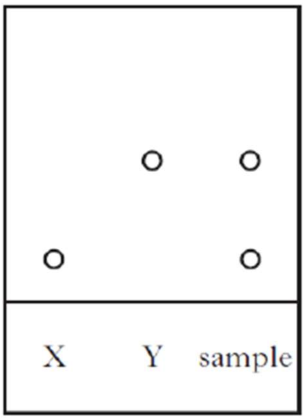
After one hour, a sample is removed and compared with pure samples of compounds **X** and **Y** using thin-layer chromatography.

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

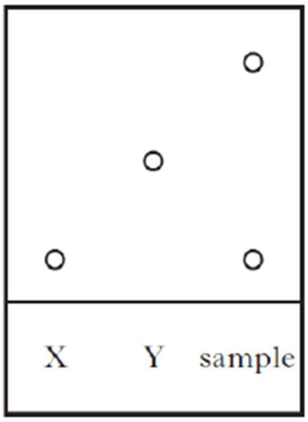
A



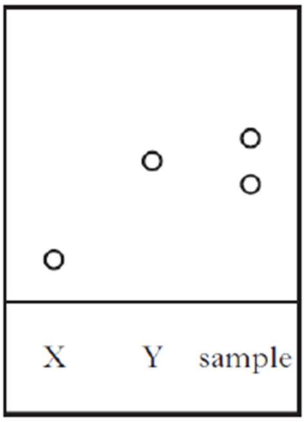
B



C



D



18. A student analysed a local water supply to determine fluoride and nitrite ion levels.
The concentration of nitrite ions in the water supply was determined by titrating water samples with acidified permanganate solution.

(a) Suggest two points of good practice that should be followed to ensure that an accurate end point is reached during a titration.

(b)

(i) An average of 21.6 cm^3 of 0.015 mol l^{-1} acidified permanganate solution was required to react completely with the nitrite ions in a 25.0 cm^3 sample of water.
The equation for the reaction taking place is

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

Calculate the nitrite ion concentration in mol l^{-1},in the water.

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

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

19.

A tablet contains 0·5 g, of calcium carbonate. In order to determine the quantity of calcium, a student dissolved the tablet in 250 cm^3 of a standard solution of 0.5 mol l^{-1} hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$$

(a) What is meant by a standard solution?

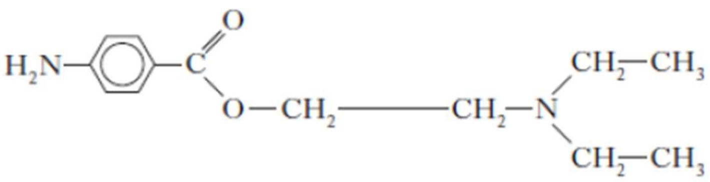
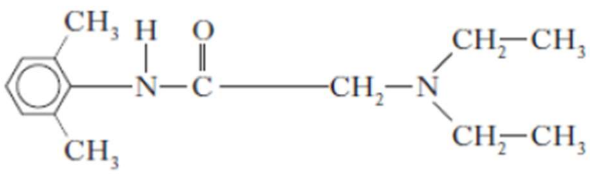
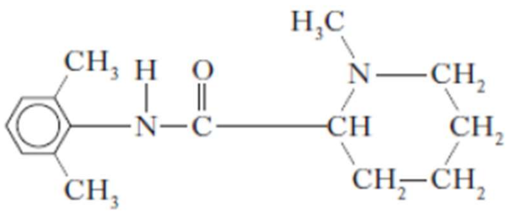
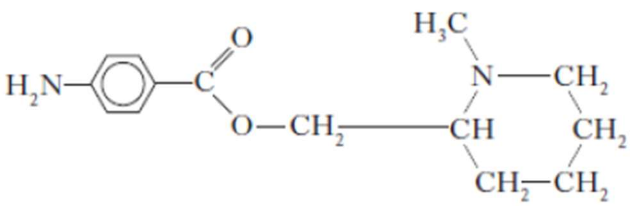
(b) Calculate the number of moles of hydrochloric acid present in the standard solution.

(c) Calculate the number of moles of calcium carbonate in the tablet.

(d) (i) Which reactant is in excess?

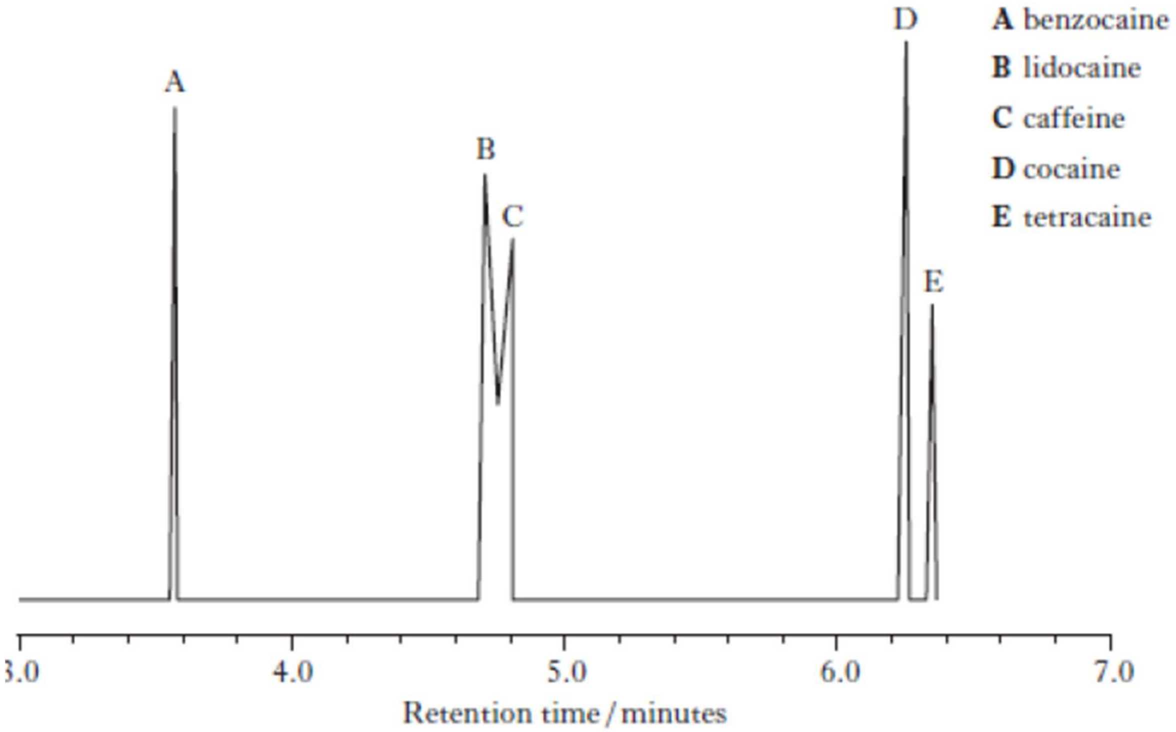
(ii) Name a technique that can be used to measure this excess.

20. Dental anaesthetics are substances used to reduce discomfort during treatment. The table below shows the duration of numbness for common anaesthetics.

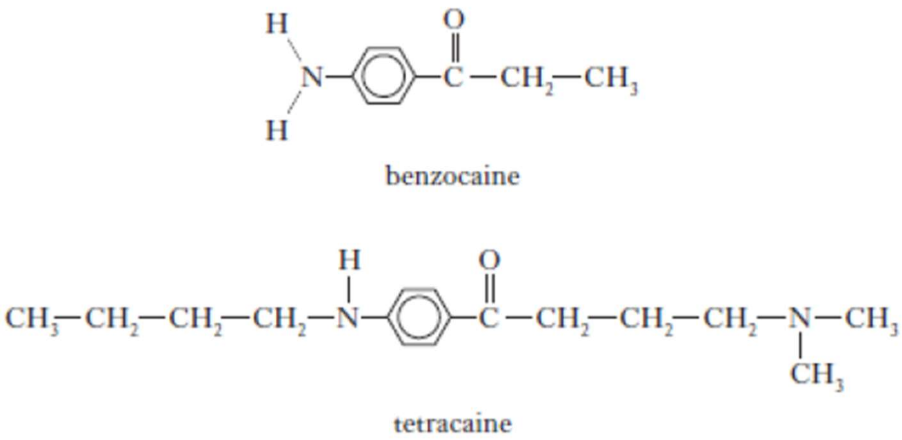
Name of anaesthetic	Structure	Duration of numbness/ minutes
procaine		7
lidocaine		96
mepivacaine		114
anaesthetic **X**		

20. (cont)

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.



The structures of benzocaine and tetracaine are shown below.



(a) Explain why bezoncaine has a lower retention time than tetracaine.

(b) Explain why it is difficult to obtain accurate values for the amount of lidocaine present in a sample containing large amounts of caffeine.