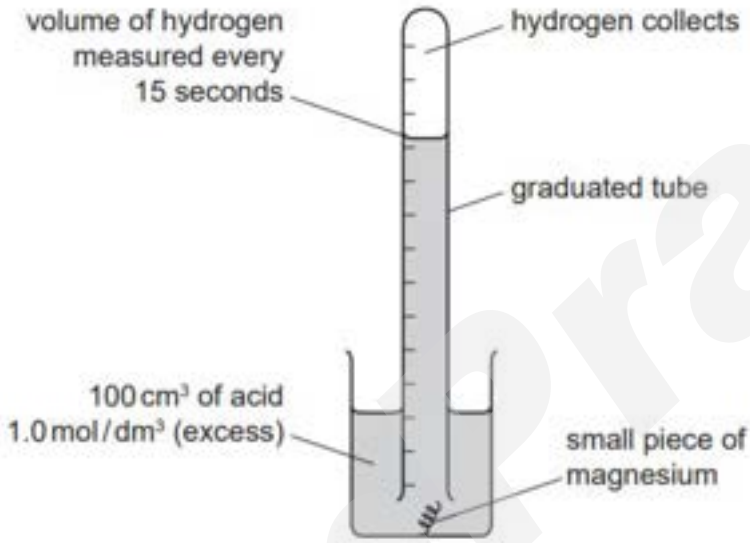
Chemical Reactions

(Past Year Topical Questions 2010-2015)

May/June 2010 (31)

3 A diagram of the apparatus which could be used to investigate the rate of reaction between magnesium and an excess of an acid is drawn below.



(a) The magnesium kept rising to the surface. In one experiment, this was prevented by twisting the magnesium around a piece of copper. In a second experiment, the magnesium was held down by a plastic net fastened to the beaker.

(i) Suggest a reason why magnesium, which is denser than water, floated to the surface.

.....

..... [1]

(ii) Iron, zinc and copper have similar densities. Why was copper a better choice than iron or zinc to weigh down the magnesium?

.....

..... [1]

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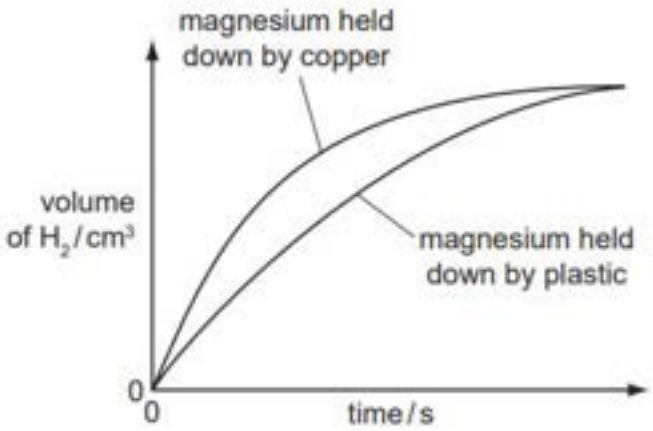
(b) The only difference in the two experiments was the method used to hold down the magnesium. The results are shown below.



(i) In which experiment did the magnesium react faster?

..... [1]

(ii) Suggest a reason why the experiment chosen in (i) had the faster rate.

..... [1]

(c) The experiment was repeated using 1.0 mol / dm^3 propanoic acid instead of 1.0 mol / dm^3 hydrochloric acid. Propanoic acid is a weak acid.

(i) How would the graph for propanoic acid **differ** from the graph for hydrochloric acid?

..... [1]

(ii) How would the graph for propanoic acid be the **same** as the graph for hydrochloric acid?

..... [1]

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(d) Give **two** factors which would alter the rate of this reaction.
For each factor explain why it alters the rate.

factor .....

explanation .....

.....

factor .....

explanation .....

..... [4]

[Total: 10]

May/June 2010 (32)/Q6

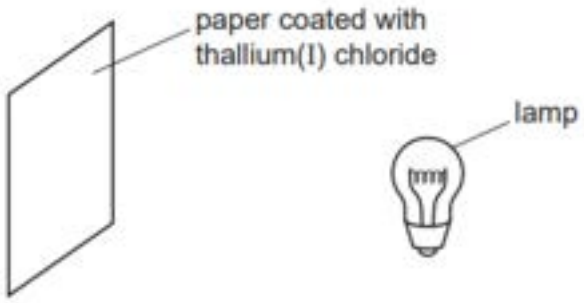
(c) When thallium(I) chloride is exposed to light, a photochemical reaction occurs. It changes from a white solid to a violet solid.

(i) Name another metal halide which changes colour when exposed to light. Give the major use of this metal halide.

name .....

use ..... [2]

(ii) A piece of paper coated with thallium(I) chloride is exposed to a bright light.



Suggest **two** ways of increasing the time it takes for the violet colour to appear.

.....

.....

..... [2]

Oct/Nov 2010 (32)

3 The decomposition of hydrogen peroxide is catalysed by manganese(IV) oxide.

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

To 50 cm^3 of aqueous hydrogen peroxide, 0.50 g of manganese(IV) oxide was added. The volume of oxygen formed was measured every 20 seconds. The average reaction rate was calculated for each 20 second interval.

time / s	0	20	40	60	80	100
volume of oxygen / cm^3	0	48	70	82	88	88
average reaction rate in cm^3 / s	2.4	1.1	.....	0.3	0.0	0.0

(a) Explain how the average reaction rate, 2.4 cm^3 / s, was calculated for the first 20 seconds.

.....

..... [2]

(b) Complete the table. [1]

(c) Explain why the average reaction rate decreases with time.

.....

..... [2]

(d) The experiment was repeated but 1.0 g of manganese(IV) oxide was added.
What effect, if any, would this have on the reaction rate and on the final volume of oxygen?
Give a reason for each answer.

effect on rate ..... [1]

reason .....

..... [2]

effect on final volume of oxygen ..... [1]

reason .....

..... [2]

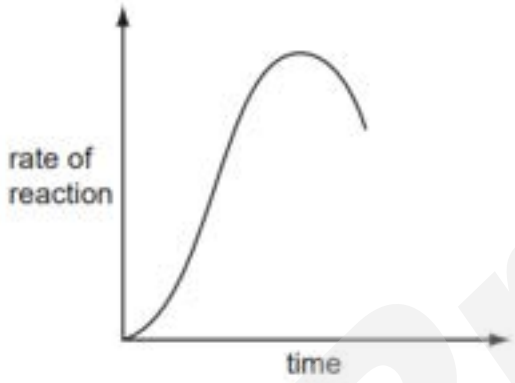
[Total: 11]

Oct/Nov 2010 (32)/Q6

(d) The alcohol ethanol can be made by fermentation. Yeast is added to aqueous glucose.

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

Carbon dioxide is given off and the mixture becomes warm as the reaction is exothermic. The graph shows how the rate of reaction varies over several days.



(i) Suggest a method of measuring the rate of this reaction.

.....

..... [2]

(ii) Why does the rate increase initially?

.....

..... [1]

(iii) Suggest **two** reasons why the rate eventually decreases.

.....

..... [2]

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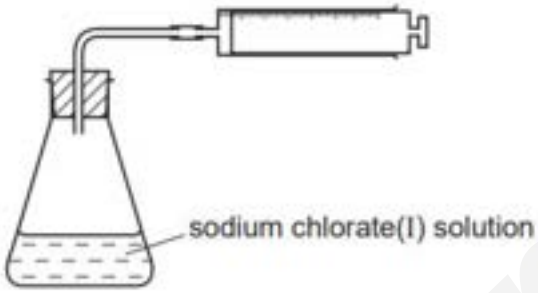
Oct/Nov 2010 (33)/Q4

(c) Sodium chlorate(I) is made by the reaction between chlorine and sodium hydroxide. It is used as bleach but over time it decomposes.

$$2NaClO(aq) \rightarrow 2NaCl(aq) + O_2(g)$$

The rate of decomposition can be studied using the apparatus shown below.



(i) How could you measure the rate of decomposition of sodium chlorate(I)?

.....[1]

(ii) Describe how you could show that the rate of decomposition of sodium chlorate(I) is a photochemical reaction.

.....

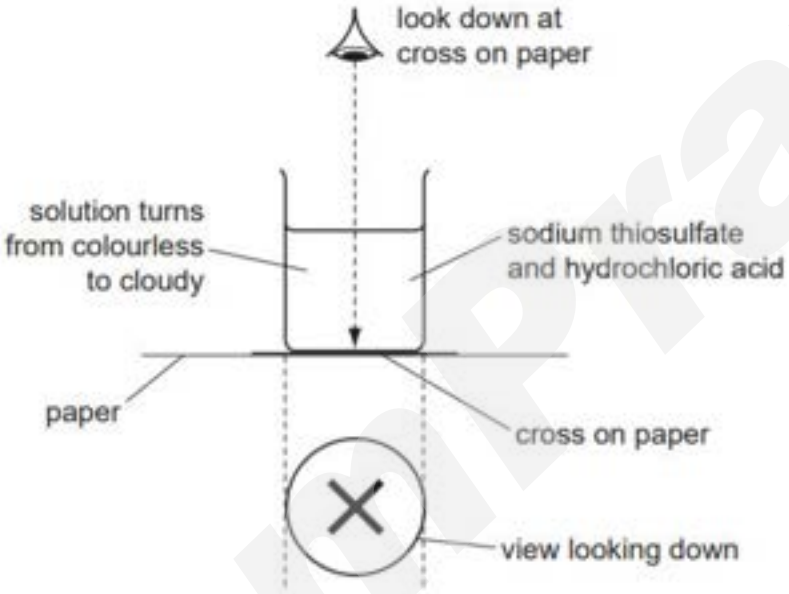
.....[2]

May/June 2011 (32)

3 The equation for the reaction between sodium thiosulfate and hydrochloric acid is given below.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + S(s) + SO_2(g) + H_2O(l)$$

The speed of this reaction was investigated using the following experiment. A beaker containing 50 cm^3 of 0.2 mol/dm^3 sodium thiosulfate was placed on a black cross. 5.0 cm^3 of 2.0 mol/dm^3 hydrochloric acid was added and the clock was started.



Initially the cross was clearly visible. When the solution became cloudy and the cross could no longer be seen, the clock was stopped and the time recorded.

(a) The experiment was repeated with 25 cm^3 of 0.2 mol/dm^3 sodium thiosulfate and 25 cm^3 of water. Typical results for this experiment and a further two experiments are given in the table.

experiment	1	2	3	4
volume of thiosulfate / cm^3	50	40	25	10
volume of water / cm^3	0	10	25	40
volume of acid / cm^3	5	5	5	5
total volume / cm^3	55	55	55	55
time / s	48	60	96	.....

(i) Explain why it is necessary to keep the total volume the same in all the experiments.

.....

.....

..... [2]

(ii) Complete the table. [1]

(iii) How and why does the speed of the reaction vary from experiment 1 to 4?

.....

.....

..... [3]

(b) The idea of collisions between reacting particles is used to explain changes in the speed of reactions. Use this idea to explain the following results.

volume of sodium thiosulfate / cm^3	25	25
volume of water / cm^3	25	25
volume of acid / cm^3	5	5
temperature / °C	20	42
time / s	96	40

.....

.....

.....

..... [4]

[Total: 10]

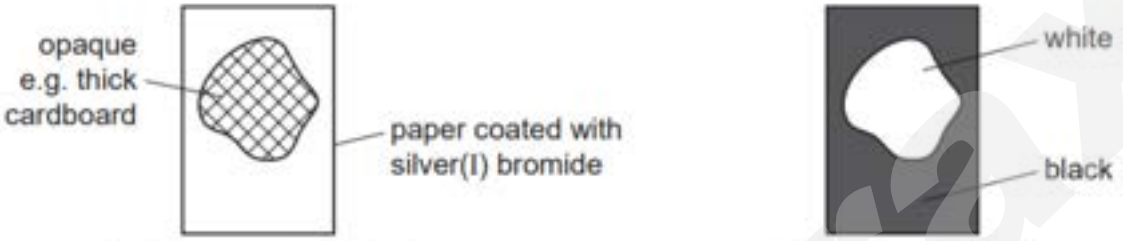
Oct/Nov 2011 (33)/Q5

(c) The reduction of silver(I) bromide to silver is the basis of film photography.

$$2AgBr \rightarrow 2Ag + Br_2$$

white black

An opaque object is placed on a piece of paper coated with silver(I) bromide which is then exposed to a bright light. The light is switched off and the opaque object removed.



before exposed to light

after exposed to light
cardboard removed

Explain how the image is formed.

.....

.....

..... [4]

May/June 2012 (31)/Q4

(c) Vanadium(V) oxide is used to catalyse the exothermic reaction between sulfur dioxide and oxygen in the Contact Process.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The rate of this reaction can be increased either by using a catalyst or by increasing the temperature. Explain why a catalyst is used and not a higher temperature.

.....

.....

..... [2]

May/June 2012 (32)

6 A length of magnesium ribbon was added to 50 cm^3 of sulfuric acid, concentration 1.0 mol/dm^3. The time taken for the magnesium to react was measured. The experiment was repeated with the same volume of different acids. In all these experiments, the acid was in excess and the same length of magnesium ribbon was used.

(a)

experiment	acid	concentration in mol/dm^3	time / s
A	sulfuric acid	1.0	20
B	propanoic acid	0.5	230
C	hydrochloric acid	1.0	40
D	hydrochloric acid	0.5	80

(i) Write these experiments in order of reaction speed. Give the experiment with the fastest speed first.

..... [1]

(ii) Give reasons for the order you have given in (i).

.....

.....

.....

.....

.....

..... [5]

(b) Suggest **two** changes to experiment C which would increase the speed of the reaction and explain why the speed would increase. The volume of the acid, the concentration of the acid and the mass of magnesium used were kept the same.

change 1 .....

explanation .....

.....

change 2 .....

explanation .....

..... [5]

[Total: 11]

Oct/Nov 2012 (31)

3 The speed (rate) of a chemical reaction depends on a number of factors which include temperature and the presence of a catalyst.

(a) Reaction speed increases as the temperature increases.

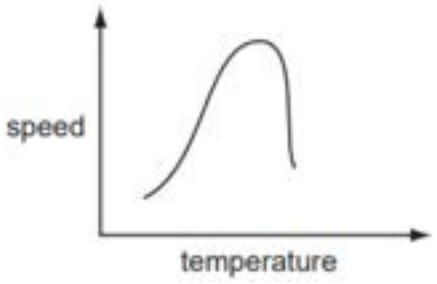
(i) Explain why reaction speed increases with temperature.

.....

.....

..... [3]

(ii) Reactions involving enzymes do not follow the above pattern.
The following graph shows how the speed of such a reaction varies with temperature.



Suggest an explanation why initially the reaction speed increases then above a certain temperature the speed decreases.

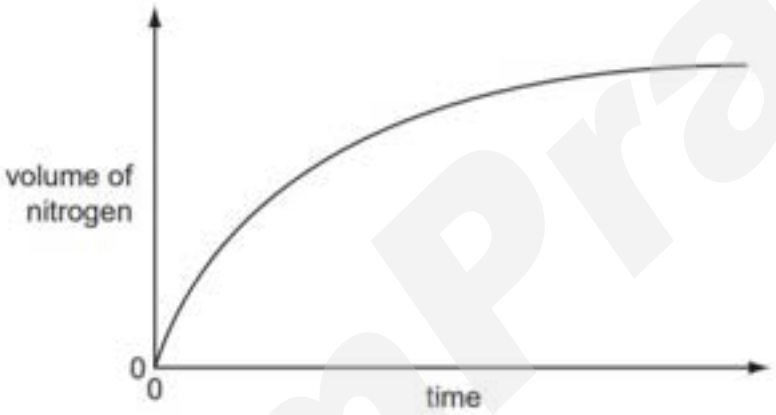
.....

..... [2]

(b) An organic compound decomposes to give off nitrogen.

$$C_6H_5N_2Cl(aq) \rightarrow C_6H_5Cl(l) + N_2(g)$$

The speed of this reaction can be determined by measuring the volume of nitrogen formed at regular intervals. Typical results are shown in the graph below.



(i) The reaction is catalysed by copper.
Sketch the graph for the catalysed reaction on the diagram above. [2]

(ii) How does the speed of this reaction vary with time?

..... [1]

(iii) Why does the speed of reaction vary with time?

.....

..... [2]

5 Carbonyl chloride, $COCl_2$, is widely used in industry to make polymers, dyes and pharmaceuticals.

(a) Carbonyl chloride was first made in 1812 by exposing a mixture of carbon monoxide and chlorine to bright sunlight. This is a photochemical reaction.

$$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$$

(i) Explain the phrase *photochemical reaction*.

.....

..... [2]

(ii) Give another example of a photochemical reaction and explain why it is important either to the environment or in industry.

.....

.....

..... [3]

May/June 2013 (31)

3 A small piece of marble, $CaCO_3$, was added to 5.0 cm^3 of hydrochloric acid, concentration 1.0 mol / dm^3, at 25 °C. The time taken for the reaction to stop was measured. The experiment was repeated using 5.0 cm^3 of different solutions of acids. The acid was in excess in all of the experiments.

Typical results are given in the table.

experiment	temperature / °C	acid solution	time / min
1	25	hydrochloric acid 1.0 mol / dm^3	3
2	25	hydrochloric acid 0.5 mol / dm^3	7
3	25	ethanoic acid 1.0 mol / dm^3	10
4	15	hydrochloric acid 1.0 mol / dm^3	8

(a) (i) Explain why it is important that the pieces of marble are the same size and the same shape.

.....

.....

..... [2]

(ii) How would you know when the reaction had stopped?

..... [1]

(c) (i) Explain why the reaction in experiment 1 is faster than the reaction in experiment 2.

.....

..... [1]

(ii) The acids used for experiment 1 and experiment 3 have the same concentration. Explain why experiment 3 is slower than experiment 1.

.....

.....

..... [2]

(iii) Explain in terms of collisions between reacting particles why experiment 4 is slower than experiment 1.

.....

.....

..... [3]

May/June 2013 (33)

2 One of the factors which determine the reaction rate of solids is particle size.

(a) A mixture of finely powdered aluminium and air may explode when ignited.
An explosion is a very fast exothermic reaction. This causes a large and sudden increase in temperature.

Explain each of the following in terms of collisions between reacting particles.

(i) Why is the reaction between finely powdered aluminium and air very fast?

.....

..... [2]

(ii) Explain why for most reactions the rate of reaction decreases with time.

.....

..... [2]

(iii) Suggest an explanation why the rate of reaction in an explosion could increase rather than decrease with time.

.....

.....

..... [3]

(b) (i) Give another example of a substance other than a metal which, when finely powdered, might explode when ignited in air.

..... [1]

(ii) Describe a simple test-tube reaction which shows the effect of particle size on the rate at which a solid reacts with a solution.

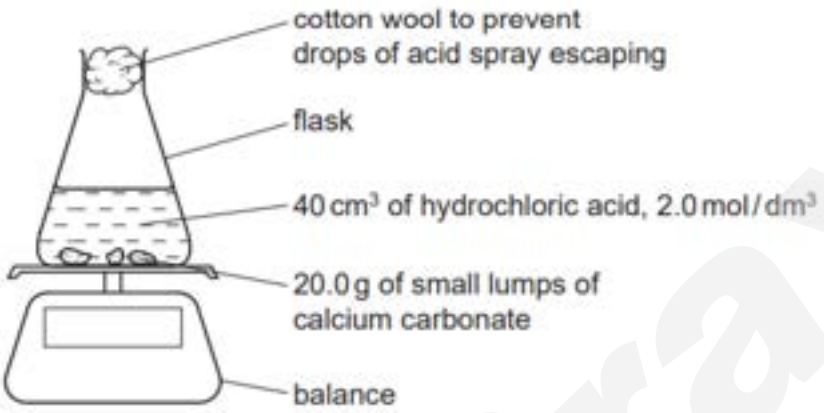
.....

.....

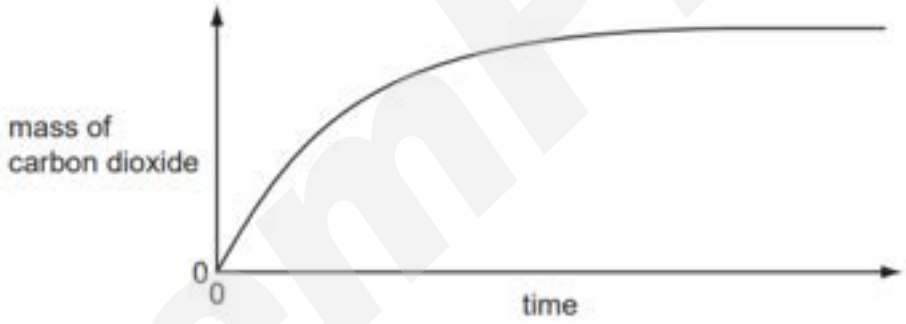
..... [3]

Oct/Nov 2013 (31)

4 20.0 g of small lumps of calcium carbonate and 40 cm^3 of hydrochloric acid, concentration 2.0 mol / dm^3, were placed in a flask on a top pan balance. The mass of the flask and contents was recorded every minute.



The mass of carbon dioxide given off was plotted against time.



$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

In all the experiments mentioned in this question, the calcium carbonate was in excess.

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(a) (i) Explain how you could determine the mass of carbon dioxide given off in the first five minutes.

..... [1]

(ii) Label the graph **F** where the reaction rate is the fastest, **S** where it is slowing down and **0** where the rate is zero. [2]

(iii) Explain how the shape of the graph shows where the rate is fastest, where it is slowing down and where the rate is zero.

.....

.....

..... [2]

(b) Sketch on the same graph, the line which would have been obtained if 20.0 g of small lumps of calcium carbonate and 80 cm^3 of hydrochloric acid, concentration 1.0 mol/dm^3, had been used. [2]

(c) Explain in terms of collisions between reacting particles each of the following.

(i) The reaction rate would be slower if 20.0 g of larger lumps of calcium carbonate and 40 cm^3 of hydrochloric acid, concentration 2.0 mol/dm^3, were used.

.....

.....

..... [2]

(ii) The reaction rate would be faster if the experiment was carried out at a higher temperature.

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.....

..... [2]

Oct/Nov 2013 (32)/Q2

(c) Photochromic glass is used in sunglasses. In bright light, the glass darkens reducing the amount of light reaching the eye. When the light is less bright, the glass becomes colourless increasing the amount of light reaching the eye.

Photochromic glass contains very small amounts of the halides silver(I) chloride and copper(I) chloride.
The reaction between these two chlorides is photochemical.

$$\underset{\text{colourless}}{AgCl} + \underset{\text{colourless}}{CuCl} \rightleftharpoons \underset{\text{black}}{Ag} + \underset{\text{colourless}}{CuCl_2}$$

How does photochromic glass work?

.....

.....

..... [3]

May/June 2014 (31)/Q3

(b) Helium is a gas used to fill balloons. It is present in the air in very small quantities. Diffusion can be used to separate it from the air.

Air at 1000 °C is on one side of a porous barrier. The air which passes through the barrier has a larger amount of helium in it.

(i) Why does the air on the other side of the barrier contain more helium?

..... [1]

(ii) Why is it an advantage to have the air at a high temperature?

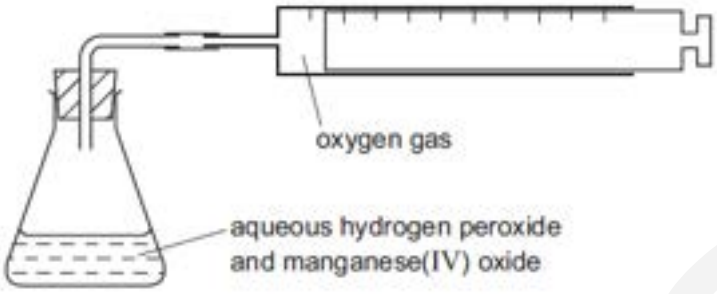
.....

..... [1]

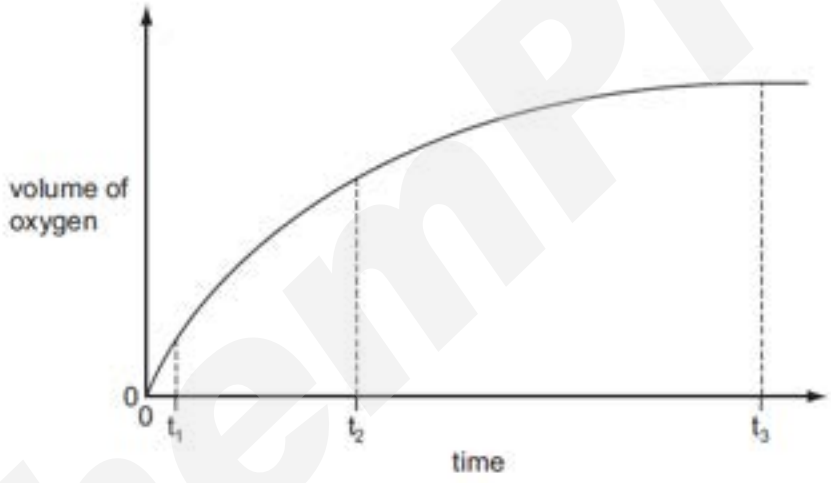
6 Hydrogen peroxide decomposes to form water and oxygen. This reaction is catalysed by manganese(IV) oxide.

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

The rate of this reaction can be investigated using the following apparatus.



40 cm^3 of aqueous hydrogen peroxide was put in the flask and 0.1 g of small lumps of manganese(IV) oxide was added. The volume of oxygen collected was measured every 30 seconds. The results were plotted to give the graph shown below.



(a) (i) How do the rates at times t_1, t_2 and t_3 differ?

.....

..... [2]

(ii) Explain the trend in reaction rate that you described in **(a)(i)**.

.....

.....

..... [2]

(b) The experiment was repeated using 0.1 g of finely powdered manganese(IV) oxide. All the other variables were kept the same.

(i) On the axes opposite, sketch the graph that would be expected. [2]

(ii) Explain the shape of this graph. .....

.....

.....

..... [2]

(c) Describe how you could show that the catalyst, manganese(IV) oxide, was not used up in the reaction. Manganese(IV) oxide is insoluble in water.

.....

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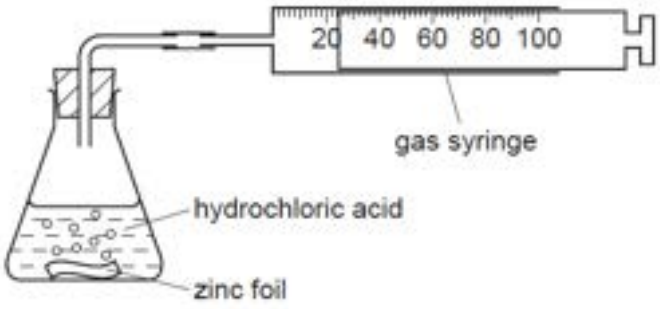
.....

.....

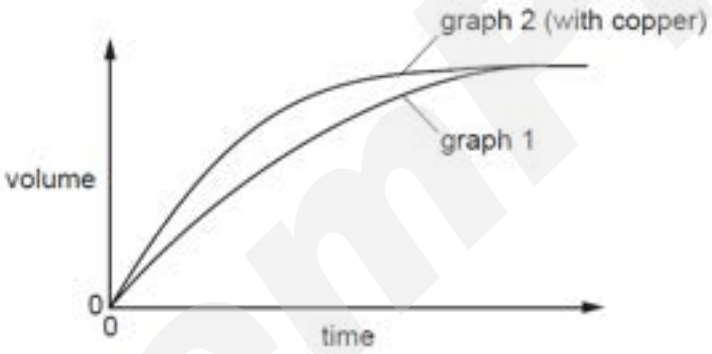
..... [4]

May/June 2015 (31)/Q3

(b) The rate of reaction between a metal and an acid can be investigated using the apparatus shown below.



A piece of zinc foil was added to 50 cm^3 of hydrochloric acid, of concentration 2.0 mol/dm^3. The acid was in excess. The hydrogen evolved was collected in the gas syringe and its volume measured every minute. The results were plotted and labelled as graph 1.



The experiment was repeated to show that the reaction between zinc metal and hydrochloric acid is catalysed by copper. A small volume of aqueous copper(II) chloride was added to the acid before the zinc was added. The results of this experiment were plotted on the same grid and labelled as graph 2.

(i) Explain why the reaction mixture in the second experiment contains copper metal. Include an equation in your explanation.

.....

..... [2]

(ii) Explain how graph 2 shows that copper catalyses the reaction.

.....

.....

..... [3]

(c) If the first experiment was repeated using ethanoic acid, CH_3COOH, instead of hydrochloric acid, how and why would the graph be different from graph 1?

.....

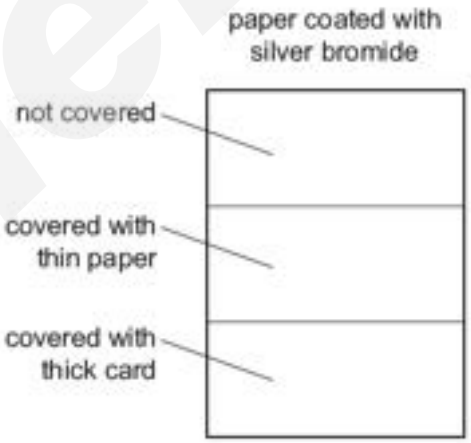
.....

.....

..... [4]

Oct/Nov 2015 (31)

(b) A piece of white paper was coated with silver bromide and exposed to the light. Sections of the paper were covered as shown in the diagram.



Predict the appearance of the different sections of the paper after exposure to the light and the removal of the card. Explain your predictions.

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.....

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.....

.....

..... [4]

May/June 2010 (31)

6 Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
There is an equilibrium between these iodine chlorides.

$$ICl(l) + Cl_2(g) \rightleftharpoons ICl_3(s)$$

dark brown yellow

(a) Explain what is meant by *equilibrium*.

.....

.....

..... [2]

(b) When the equilibrium mixture is heated it becomes a darker brown colour.
Is the reverse reaction endothermic or exothermic? Give a reason for your choice.

.....

.....

..... [2]

(c) The pressure on the equilibrium mixture is decreased.

(i) How would this affect the position of equilibrium and why?

It would move to the ..... [1]

reason .....

..... [1]

(ii) Describe what you would observe.

.....

..... [1]

[Total: 7]

May/June 2010 (32)/Q8

(b) At most temperatures, samples of nitrogen dioxide are equilibrium mixtures.

$$\underset{\text{dark brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{pale yellow}}{N_2O_4(g)}$$

(i) At 25 °C, the mixture contains 20 % of nitrogen dioxide. At 100 °C this has risen to 90 %. Is the forward reaction exothermic or endothermic?
Give a reason for your choice.

.....

.....

..... [2]

(ii) Explain why the colour of the equilibrium mixture becomes lighter when the pressure on the mixture is increased.

.....

.....

..... [2]

Oct/Nov 2010 (31)/Q4

(b) Ammonia is made by the Haber Process.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ forward reaction is exothermic

The percentage of ammonia in the equilibrium mixture varies with conditions.

pressure / atmospheres	100	200	300	400
% ammonia at 300 °C	45	65	72	78
% ammonia at 500 °C	9	18	25	31

The conditions actually used are 200 atmospheres, 450 °C and an iron catalyst.

(i) The original catalyst was platinum. Suggest a reason why it was changed to iron.

..... [1]

(ii) Explain why the highest pressure gives the highest percentage of ammonia in the equilibrium mixture.

.....

..... [2]

(iii) What happens to the unreacted nitrogen and hydrogen?

.....

..... [1]

(iv) State **one** advantage and one disadvantage of using a lower temperature.

advantage .....

..... [1]

disadvantage .....

..... [1]

May/June 2011 (31)/Q4

(b) Sulfur dioxide is used to make sulfur trioxide in the Contact Process.

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

The forward reaction is exothermic. The conditions used are:

temperature: 450 °C
pressure: 2 atmospheres
catalyst: vanadium(V) oxide

Explain, mentioning both position of equilibrium and rate, why these conditions give the most economic yield.

.....

.....

.....

..... [4]

Oct/Nov 2011 (31)

4 Reversible reactions can come to equilibrium. The following are three examples of types of gaseous equilibria.

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$ **reaction 1**

$A_2(g) + 3B_2(g) \rightleftharpoons 2AB_3(g)$ **reaction 2**

$2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$ **reaction 3**

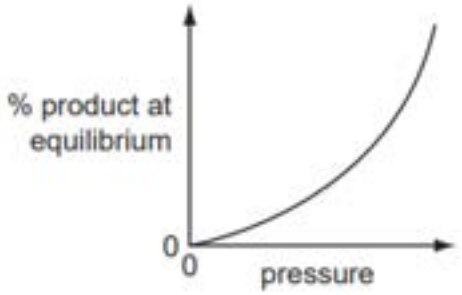
(a) Explain the term *equilibrium*.

.....

..... [2]

(b) The following graphs show how the percentage of products of a reversible reaction at equilibrium could vary with pressure.
For each graph, decide whether the percentage of products decreases, increases or stays the same when the pressure is **increased**, then match each graph to one of the above reactions and give a reason for your choice.

(i)



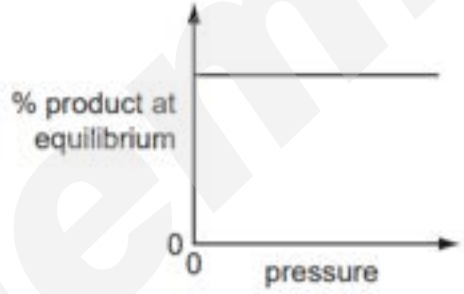
effect on percentage of products .....

reaction .....

reason .....

..... [3]

(ii)



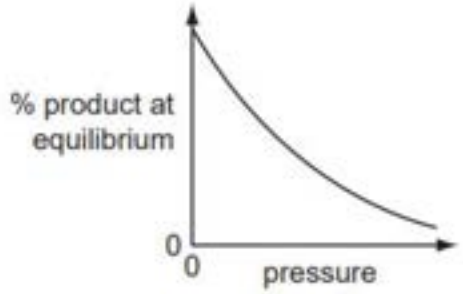
effect on percentage of products .....

reaction .....

reason .....

..... [3]

(iii)



effect on percentage of products .....

reaction .....

reason .....

..... [3]

[Total: 11]

Oct/Nov 2011 (32)/Q4

(c) When antimony chloride is added to water, a faint white precipitate forms and the mixture slowly goes cloudy.

$$\underset{\text{colourless}}{SbCl_3(aq)} + \underset{\text{backward}}{H_2O(l)} \overset{\text{forward}}{\rightleftharpoons} 2HCl(aq) + \underset{\text{white}}{SbOCl(s)}$$

(i) Explain why after some time the appearance of the mixture remains unchanged.

.....

..... [2]

(ii) When a few drops of concentrated hydrochloric acid are added to the mixture, it changes to a colourless solution. Suggest an explanation.

.....

..... [1]

(iii) Suggest how you could make the colourless solution go cloudy.

..... [1]

Oct/Nov 2011 (33)/Q6

(b) Nickel ores are converted into nickel(II) oxide. This can be reduced to impure nickel by heating with carbon. The nickel is purified by the following reversible reaction.

$$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$$

nickel carbonyl

(i) Impure nickel is heated at 60 °C. The forward reaction occurs.

$$Ni(s) + 4CO(g) \rightarrow Ni(CO)_4(g)$$

impure

The nickel carbonyl, a gas, moves into a hotter chamber at 200 °C. The backward reaction occurs and the nickel carbonyl decomposes.

$$Ni(CO)_4(g) \rightarrow Ni(s) + 4CO(g)$$

pure

Is the forward reaction exothermic or endothermic? Give a reason for your answer.

.....

.....

..... [2]

(ii) Explain why the forward reaction is favoured by an increase in pressure.

.....

..... [2]

Oct/Nov 2012 (31)/Q5

(b) Carbonyl chloride is now made by the reversible reaction given below.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

The forward reaction is exothermic.
The reaction is catalysed by carbon within a temperature range of 50 to 150 °C.

(i) Predict the effect on the yield of carbonyl chloride of increasing the pressure. Explain your answer.

.....

..... [2]

(ii) If the temperature is allowed to increase to above 200 °C, very little carbonyl chloride is formed. Explain why.

.....

..... [2]

(iii) Explain why a catalyst is used.

..... [1]

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Oct/Nov 2012 (32)/Q7

(b) Methanol is manufactured using the following method.

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g) \quad \text{reaction 1}$$

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \text{reaction 2}$$

The conditions for reaction 2 are:

pressure	100 atmospheres
catalyst	a mixture of copper, zinc oxide and aluminium oxide
temperature	250 °C

The forward reaction is exothermic.

(i) Why is high pressure used in reaction 2?

.....

..... [2]

(ii) Explain why using a catalyst at 250 °C is preferred to using a higher temperature of 350 °C and no catalyst.

.....

.....

..... [3]

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Oct/Nov 2012 (33)

7 Ammonia is made by the Haber process.

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

(a) State **one** major use of ammonia.

..... [1]

(b) Describe how hydrogen is obtained for the Haber process.

.....

.....

..... [3]

(c) This reaction is carried out at a high pressure, 200 atmospheres.
State, with an explanation for each, **two** advantages of using a high pressure.

.....

.....

.....

.....

..... [5]

May/June 2013 (31)/Q6

(b) Ammonia is manufactured by the Haber Process. The economics of this process require that as much ammonia as possible is made as quickly as possible.
Explain how this can be done using the following information.

The conditions for the following reversible reaction are:

- 450 °C
- 200 atmospheres pressure
- iron catalyst

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ the reaction is exothermic

.....

.....

.....

.....

.....

..... [5]

May/June 2013 (32)

4 At present the most important method of manufacturing hydrogen is steam reforming of methane.

(a) In the first stage of the process, methane reacts with steam at 800 °C.

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

In the second stage of the process, carbon monoxide reacts with steam at 200 °C.

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

(i) Explain why the position of equilibrium in the first reaction is affected by pressure but the position of equilibrium in the second reaction is not.

.....

.....

..... [2]

(ii) Suggest why a high temperature is needed in the first reaction to get a high yield of products but in the second reaction a high yield is obtained at a low temperature.

.....

..... [2]

May/June 2013 (33)/Q5

(b) Almost all samples of nitrogen dioxide are an equilibrium mixture of nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4.

$$\underset{\text{dark brown}}{2NO_2(g)} \underset{\text{reverse reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} \underset{\text{colourless}}{N_2O_4(g)}$$

In the forward reaction, a bond forms between the two nitrogen dioxide molecules.

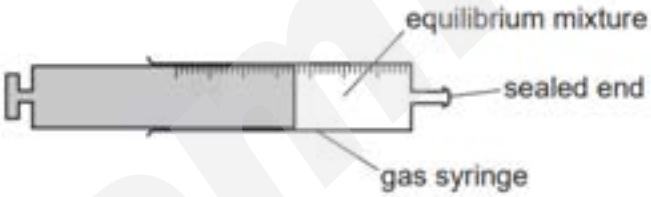
$$NO_2 + NO_2 \rightarrow O_2N-NO_2$$

(i) Explain the term *equilibrium mixture*.

.....

..... [1]

(ii) The syringe contains a sample of the equilibrium mixture. The plunger was pulled back reducing the pressure.
How would the colour of the gas inside the syringe change? Give an explanation for your answer.



.....

..... **[3]**

(iii) A sealed tube containing an equilibrium mixture of nitrogen dioxide and dinitrogen tetroxide was placed in a beaker of ice cold water.
The colour of the mixture changed from brown to pale yellow.

Is the forward reaction exothermic or endothermic? Give an explanation for your choice.

.....

..... [2]

Oct/Nov 2013 (31)

3 Ammonia is manufactured by the Haber process.

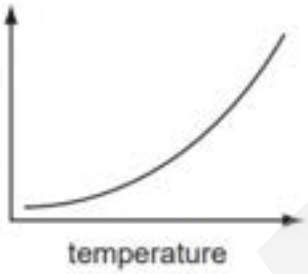
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

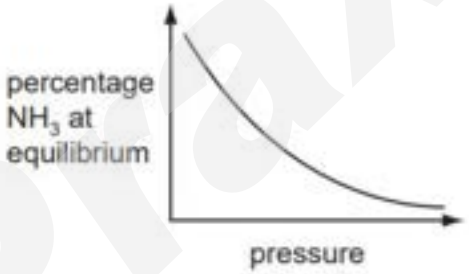
The forward reaction is exothermic.

(b) The percentage of ammonia in the equilibrium mixture varies with temperature and pressure.

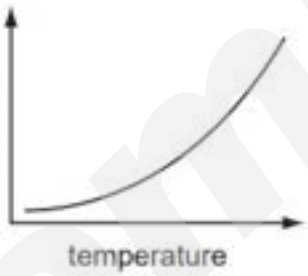
(i) Which pair of graphs, **A**, **B** or **C**, shows correctly how the percentage of ammonia at equilibrium varies with temperature and pressure?

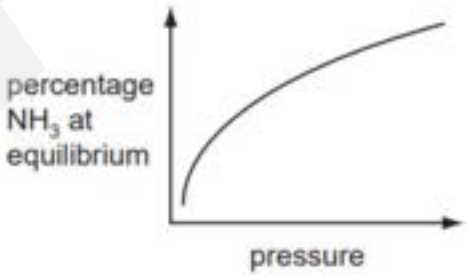
pair **A**



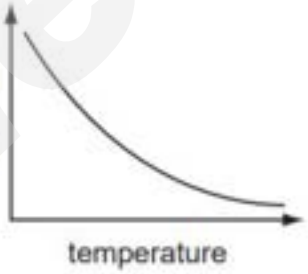


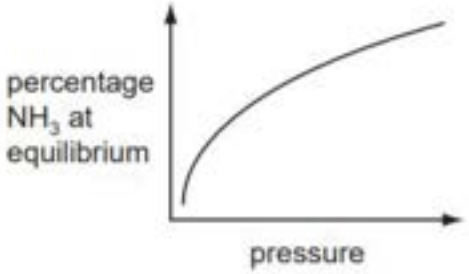
pair **B**





pair **C**





The pair with **both graphs correct** is ..... [1]

(ii) Give a full explanation of why the pair of graphs you have chosen in (i) is correct.

.....

.....

.....

.....

.....

.....

..... [6]

(iii) Catalysts do not alter the position of equilibrium. Explain why a catalyst is used in this process.

.....

.....

.....

..... [2]

Oct/Nov 2013 (32)

3 **(a)** Nitric acid is now made by the oxidation of ammonia. It used to be made from air and water. This process used very large amounts of electricity.

Air was blown through an electric arc and heated to 3000 °C.

$$N_2(g) + O_2(g) \rightleftharpoons \underset{\text{nitric oxide}}{2NO(g)} \qquad \textbf{equilibrium 1}$$

The equilibrium mixture leaving the arc contained 5% of nitric oxide. This mixture was cooled rapidly. At lower temperatures, nitric oxide will react with oxygen to form nitrogen dioxide.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2 \qquad \textbf{equilibrium 2}$$

Nitrogen dioxide reacts with oxygen and water to form nitric acid.

(i) Suggest a reason why the yield of nitric oxide in **equilibrium 1** increases with temperature.

.....[1]

(ii) What effect, if any, would increasing the pressure have on the percentage of nitric oxide in **equilibrium 1**? Explain your answer.

.....

.....[2]

(iii) Deduce why **equilibrium 2** is only carried out at lower temperatures.

.....

.....[2]

May/June 2014 (32)

5 Carbonyl chloride is made from carbon monoxide and chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

(a) Two methods of preparing carbon monoxide are from methane and oxygen, and from methane and steam.

(i) The reaction between methane and oxygen can also form carbon dioxide. How can carbon monoxide be made instead of carbon dioxide?

..... [1]

(ii) The following reaction is used to make carbon monoxide and hydrogen.
The reaction is carried out at 1100 °C and normal pressure.

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

The reaction is reversible and comes to equilibrium. Suggest why a high temperature is used.

.....

.....

..... [2]

(iii) What is the disadvantage of using a high pressure for the reaction given in **(a)(ii)**?

.....

..... [2]

May/June 2014 (33)

5 Ammonia is made by the Haber process.

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

The forward reaction is exothermic.
The conditions in the reaction chamber are:

- a pressure of 200 atmospheres,
- a catalyst of finely divided iron,
- a temperature of 400 to 450 °C.

(a) What are the **two** advantages of using a high pressure? Give a reason for both.

advantage 1 .....

reason .....

.....

advantage 2 .....

reason .....

[4]

(b) A higher temperature would give a faster reaction rate.
Why is a higher temperature **not** used?

.....

.....

..... [3]

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(c) (i) Why is the iron catalyst used as a fine powder?

.....

..... [1]

(ii) Give **two** reasons why a catalyst is used.

.....

.....

.....

..... [2]

(d) The equilibrium mixture leaving the reaction chamber contains 15% ammonia. Suggest how the ammonia could be separated from the mixture.

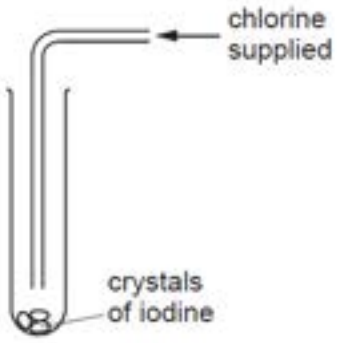
	boiling point / °C
hydrogen	–253
nitrogen	–196
ammonia	–33

.....

..... [2]

May/June 2015 (31)/Q5

(c) Iodine reacts with chlorine to form a dark brown liquid, iodine monochloride.



$$I_2(s) + Cl_2(g) \rightarrow \underset{\text{dark brown}}{2ICl(l)}$$

When more chlorine is added and the tube is sealed, a reversible reaction occurs and the reaction comes to equilibrium.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

(i) Give another example of a reversible reaction.

..... [1]

(ii) Explain the term *equilibrium*.

.....

..... [2]

(d) Chlorine is removed from the tube and a new equilibrium is formed.

Explain why there is less of the yellow solid and more dark brown liquid in the new equilibrium mixture.

.....

.....

..... [2]

(e) A sealed tube containing the equilibrium mixture is placed in ice-cold water. There is an increase in the amount of yellow solid in the equilibrium mixture.

What can you deduce about the forward reaction in this equilibrium?

$$ICl(l) + Cl_2(g) \rightleftharpoons ICl_3(s)$$

Explain your deduction.

.....

.....

.....

..... [3]

May/June 2015 (32)/Q4

4 Ammonia is made by the Haber process.

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

The forward reaction is exothermic.

Typical reaction conditions are:

- finely divided iron catalyst,
- temperature 450 °C,
- pressure 200 atmospheres.

(a) Explain why the catalyst is used as a very fine powder and larger pieces of iron are not used.

.....

.....

..... [2]

(b) Using the above conditions, the equilibrium mixture contains about 15% ammonia.

State two changes to the reaction conditions which would increase the percentage of ammonia at equilibrium.

.....

.....

..... [2]

(c) Suggest why the changes you have described in **(b)** are **not** used in practice.

.....

.....

..... [2]

[Total: 6]

May/June 2012 (31)/Q4

(d) The oxidation states of vanadium in its compounds are V(+5), V(+4), V(+3) and V(+2). The vanadium(III) ion can behave as a reductant or an oxidant.

(i) Indicate on the following equation which reactant is the oxidant.

$$2V^{3+} + Zn \rightarrow 2V^{2+} + Zn^{2+}$$

[1]

(ii) Which change in the following equation is oxidation? Explain your choice.

$$V^{3+} + Fe^{3+} \rightarrow V^{4+} + Fe^{2+}$$

.....

..... [2]

May/June 2013 (31)

5 The reactivity series shows the metals in order of reactivity.

(a) The reactivity series can be established using displacement reactions. A piece of zinc is added to aqueous lead nitrate. The zinc becomes coated with a black deposit of lead.

$$Zn + Pb^{2+} \rightarrow Zn^{2+} + Pb$$

Zinc is more reactive than lead.

The reactivity series can be written as a list of ionic equations.

..... → ..... + ... most reactive metal : the best reductant (reducing agent)

$Zn \rightarrow Zn^{2+} + 2e^-$

$Fe \rightarrow Fe^{2+} + 2e^-$

$Pb \rightarrow Pb^{2+} + 2e^-$

$Cu \rightarrow Cu^{2+} + 2e^-$

$Ag \rightarrow Ag^{+} + e^-$

(i) In the space at the top of the list, write an ionic equation for a metal which is more reactive than zinc. [1]

(ii) Write an ionic equation for the reaction between aqueous silver(I) nitrate and zinc.

..... [2]

(iii) Explain why the positive ions are likely to be oxidants (oxidising agents).

..... [1]

(iv) Deduce which ion is the best oxidant (oxidising agent).

..... [1]

(v) Which ion(s) in the list can oxidise lead metal?

..... [1]

Oct/Nov 2013 (32)

6 The following reactivity series shows both familiar and unfamiliar elements in order of decreasing reactivity. Each element is represented by a redox equation.

$$Rb \rightleftharpoons Rb^{+} + e^{-}$$
$$Mg \rightleftharpoons Mg^{2+} + 2e^{-}$$
$$Mn \rightleftharpoons Mn^{2+} + 2e^{-}$$
$$Zn \rightleftharpoons Zn^{2+} + 2e^{-}$$
$$H_2 \rightleftharpoons 2H^{+} + 2e^{-}$$
$$Cu \rightleftharpoons Cu^{2+} + 2e^{-}$$
$$Hg \rightleftharpoons Hg^{2+} + 2e^{-}$$

Two of the uses of the series are to predict the thermal stability of compounds of the metals and to explain their redox reactions.

(b) (i) Define in terms of electron transfer the term *oxidation*.

..... [1]

(ii) Explain why the positive ions in the above equations are oxidising agents.

.....

..... [1]

May/June 2015 (31)

3 **(a)** The reactions between metals and acids are redox reactions.

$$Zn + 2H^{+} \rightarrow Zn^{2+} + H_2$$

(i) Which change in the above reaction is oxidation, Zn to Zn^{2+} or $2H^{+}$ to H_2? Give a reason for your choice.

.....

..... [2]

(ii) Which reactant in the above reaction is the oxidising agent? Give a reason for your choice.

.....

..... [2]

May/June 2015 (32)/Q3

(c) The reaction between calcium and nitrogen to form calcium nitride is a redox reaction.

In terms of electron transfer, explain why calcium is the reducing agent.

.....

.....

.....

..... [3]

Oct/Nov 2015 (31)

7 The rate of a photochemical reaction is affected by light.

(a) The decomposition of silver bromide is the basis of film photography. This is a redox reaction.

$$\underset{\text{cream}}{2AgBr} \rightarrow \underset{\text{black}}{2Ag} + Br_2$$

step 1 $2Br^- \rightarrow Br_2 + 2e^-$

step 2 $Ag^+ + e^- \rightarrow Ag$

(i) Which step is reduction? Explain your answer.

..... [1]

(ii) Which ion is the oxidising agent? Explain your answer.

..... [1]