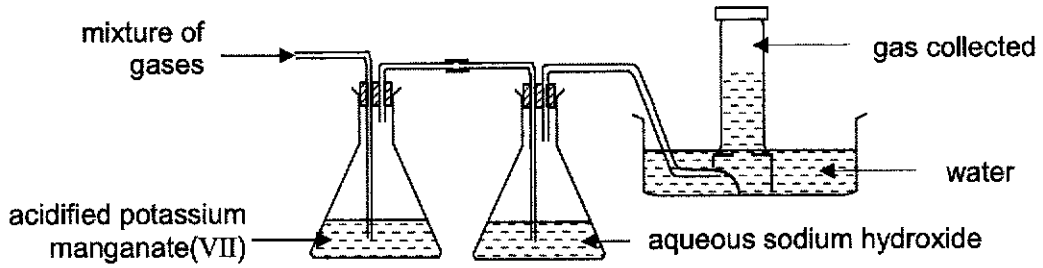
1 A gaseous mixture of hydrogen, carbon dioxide, sulfur dioxide and chlorine is passed through the apparatus shown. Only one of the gases is collected at the end.

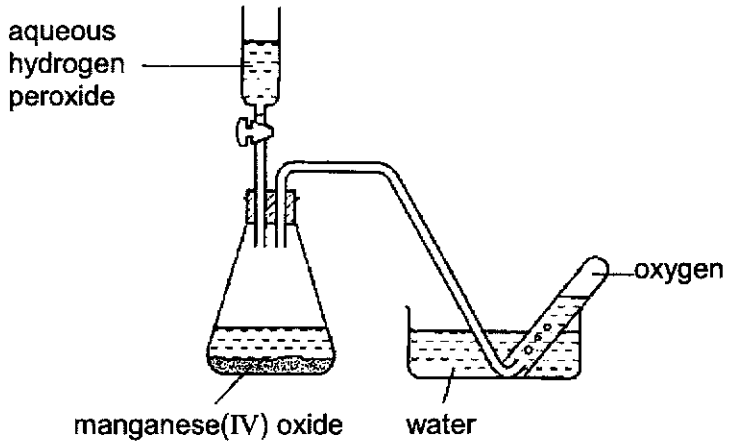


What is the property of the gas collected at the end?

A Gas bleaches damp blue litmus paper.
B Gas produces white precipitate with limewater.
C Gas extinguishes lighted splint with a 'pop' sound.
D Gas turns damp blue litmus paper red.

2 Using manganese(IV) oxide as a catalyst, aqueous hydrogen peroxide decomposes to form oxygen.

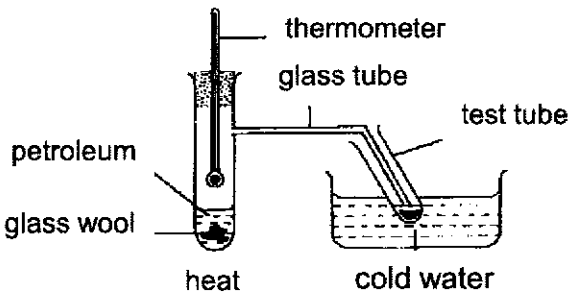
This reaction was used to make and collect oxygen as shown in the diagram below.



The first few test tubes of collected gas should be rejected because the oxygen would be contaminated by

A hydrogen
B nitrogen
C hydrogen peroxide
D chlorine

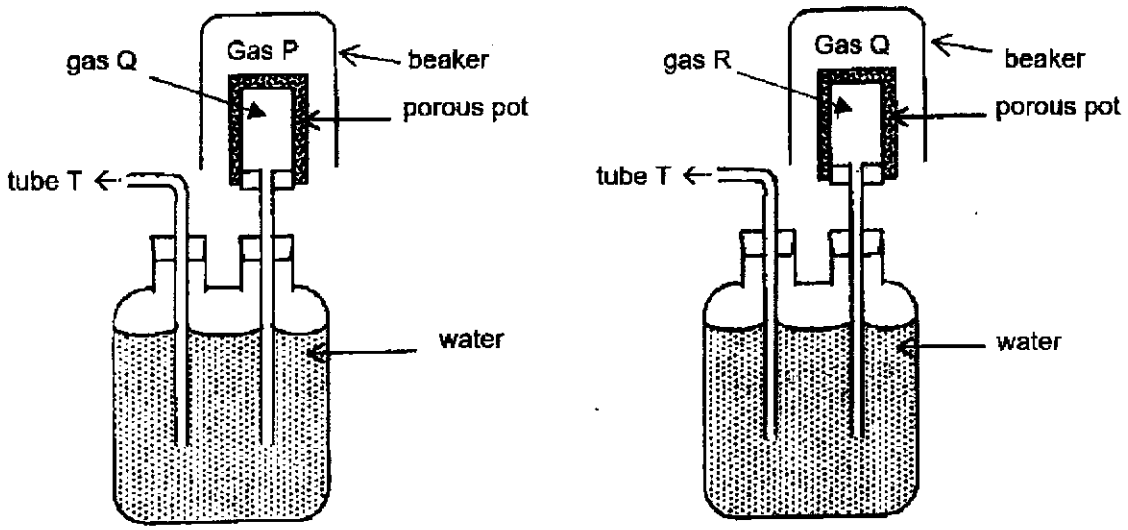
3 The diagram below shows the experimental set-up for fractional distillation of petroleum. However, there is an error in the set-up.



What is the error?

A The glass wool should be placed above the petroleum.
B The test-tube should be placed higher up from the cold water.
C The bulb of the thermometer should be placed at the junction of the glass tube.
D The stopper should be removed to prevent pressure from building up.

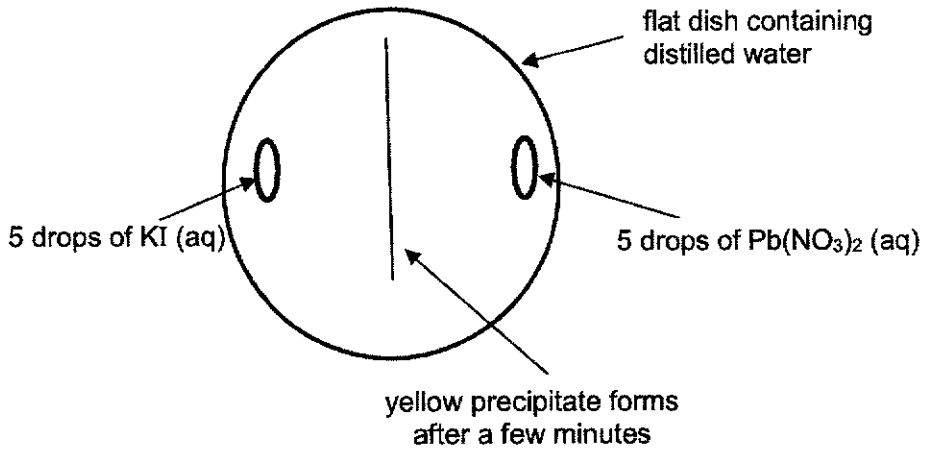
4 In each of the following diagrams, two gases are placed in a set-up using a porous pot. It is observed that some water is forced out of the tube T in both set-ups.



Which list gives the molecular masses of gases P, Q and R in decreasing order?

	largest molecular mass ⟶		lowest molecular mass
A	P	Q	R
B	P	R	Q
C	R	P	Q
D	R	Q	P

5 A yellow precipitate is formed in an experiment as illustrated in the diagram.



Which is a correct sequence of how the precipitate forms?

A Particles collide, diffuse and then react.
B Particles collide, react and then diffuse.
C Particles diffuse, collide and then react.
D Particles diffuse, react and then collide.

6 The table below shows the melting and boiling points of substances W to Z.

substance	melting point / °C	boiling point / °C
W	−120	−15
X	−4	42
Y	40	229
Z	413	899

Which statements are true?

1 X is a volatile liquid.
2 Particles of Y and Z vibrate and rotate in fixed positions at room temperature.
3 Two of the above substances undergo a change of state when heated from room temperature to 80°C.

A 1 and 2 only
B 2 and 3 only
C 1 and 3 only
D All of the above

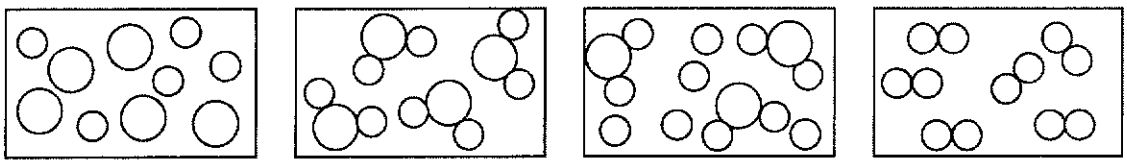
7 Which statements are true about compounds?

1 They can be made from a metal and a non-metal.
2 They can be made from another compound.
3 They can be made from metals alone.
4 They can be made from non-metals alone.

A 1, 2 and 3
B 1, 2 and 4
C 1, 3 and 4
D 2, 3 and 4

8 In the diagrams, each circle represents an atom. Circles of different sizes represent different elements.

Which diagram represents a pure compound?



A **B** **C** **D**

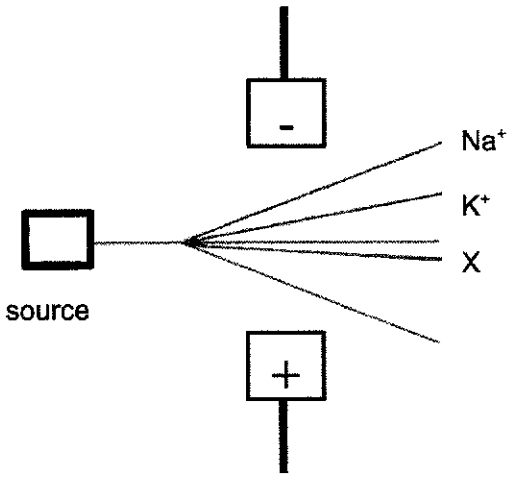
9 Four statements are being made about elements, compounds and mixtures by a student.

Statement 1: Elements and compounds have fixed melting points.
Statement 2: The properties of a compound are similar to that of its elements.
Statement 3: A mixture can be separated into its components by physical means.
Statement 4: Elements can exist either in the form of atoms or molecules.

How many statement(s) is/are **not** correct?

A one
B two
C three
D four

10 In an experiment, a sample was vapourised, ionised and passed through an electric field. Analysis of the deflection occurring at the electric region revealed the following data for the sample.



What is a possible identity of the unknown particle, X?
[Ar: Li, 7 ; F, 19 ; Na, 23 ; K, 39 ; Br, 80 ; Rb, 85]

A Br^-
B F^-
C Li^+
D Rb^+

11 The following describes three different substances.

Silicon carbide, SiC, has a structure similar to diamond.
Graphene is an allotrope of carbon with a structure similar to graphite.
Bronze is an alloy of copper and tin.

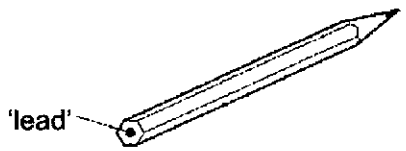
Three different statements are given to describe the different substances.

1 All are bonded covalently.
2 All except silicon carbide conduct electricity when solid.
3 All have high melting points.

Which statement(s) about silicon carbide, boron nitride and bronze are correct?

A 1 and 2 only
B 2 and 3 only
C 3 only
D 1, 2 and 3

12 The 'lead' in a pencil is made of a mixture of graphite and clay.



When the percentage of graphite is increased, the pencil slides across the paper more easily.

Which statement explains this observation?

A Graphite is a form of carbon.
B Graphite is a lubricant.
C Graphite is a non-metal.
D Graphite has a high melting point.

13 Onion peeling often causes tearing of the eyes due to the release of a sulfide compound. Peeling them under running water reduces the problem.

Which statements are true of the sulfide compound?

1 It is soluble in water.
2 It has a low boiling point.
3 It has small and light ions with weak bonding.
4 It is a covalent compound with weak covalent bonds.

A 1 and 2 only
B 1 and 4 only
C 1, 2 and 3 only
D 1, 2 and 4 only

14 Four elements, W, X, Y and Z belong to the same period in the Periodic Table.

X and Z react to form an ionic compound XZ. W and Y react to form an ionic compound WY.

When molten XZ and WY undergo electrolysis, 1 mole of WY requires twice the amount of electricity for discharge compared to 1 mole of XZ.

Which groups in the Periodic Table do W, X, Y and Z belong to?

	W	X	Y	Z
A	II	I	VI	VII
B	I	II	VII	VI
C	II	I	VII	VI
D	I	II	VI	VII

15 Upon strong heating, a metal nitrate compound undergoes decomposition according to the following equation:

$$2XNO_3(s) \rightarrow 2X(s) + 2NO_2(g) + O_2(g)$$

Complete decomposition of 3.40 g of the nitrate gives 240 cm^3 of oxygen, measured at room temperature and pressure.

What is the relative atomic mass of X?

A 85
B 108
C 133
D 170

16 When iron(III) oxide is reduced in a blast furnace, iron is formed. The equation for the reaction is:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$$

80 kg of iron(III) oxide was reduced and 49 kg of iron was obtained. Calculate the percentage yield of the iron obtained from this reaction.
[M_r: Fe_2O_3, 160]

A 49 %
B 75 %
C 87.5 %
D 100 %

17 Vodka is a distilled beverage composed primarily of water and ethanol, C_2H_5OH, sometimes with traces of impurities and flavourings. 10.0 g of vodka was acidified and then titrated with 2.0 mol/dm^3 of potassium manganate(VII) in order to determine its alcohol content. The average volume of potassium manganate(VII) obtained was 34.8 cm^3.

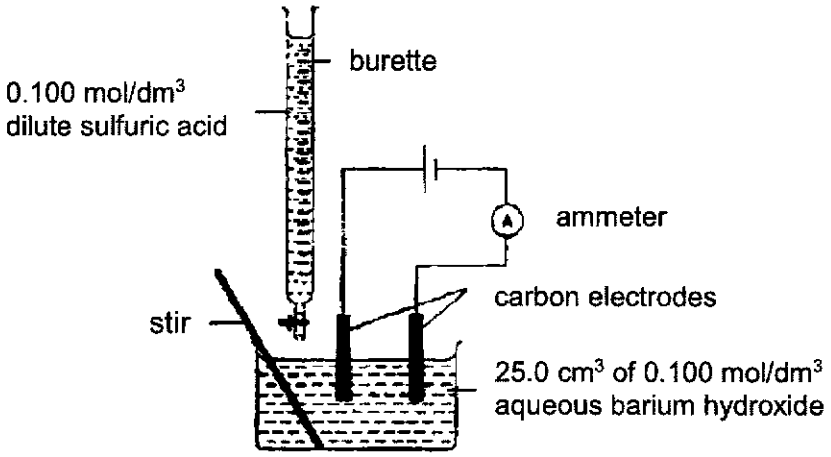
The equation for the reaction that occurs is as follows:

$$4MnO_4^-(aq) + 5C_2H_5OH(aq) + 12H^+(aq) \rightarrow 4Mn^{2+}(aq) + 5CH_3COOH(aq) + 11H_2O$$

What is the percentage by mass of ethanol in this sample of vodka?
[M_r: C_2H_5OH, 46]

A 10.0 %
B 32.0 %
C 40.0 %
D 80.0 %

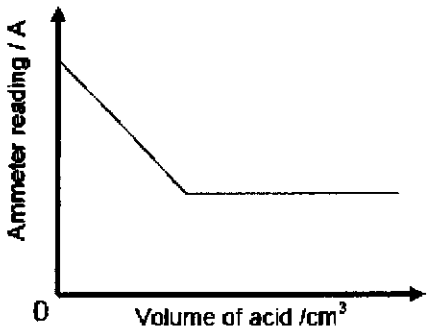
18 In an experiment, 0.100 mol/dm^3 dilute sulfuric acid was added to 25.0 cm^3 of 0.100 mol/dm^3 aqueous barium hydroxide as shown in the diagram below.



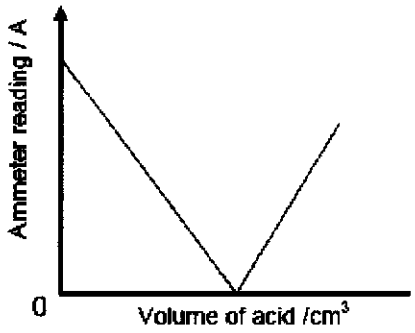
The acid was added from the burette in portions of 5.00 cm^3 until 30.00 cm^3 of the acid was added. After each addition, the solution was stirred and the ammeter reading was noted.

Which graph correctly represents the relationship between the ammeter reading and the volume of acid added?

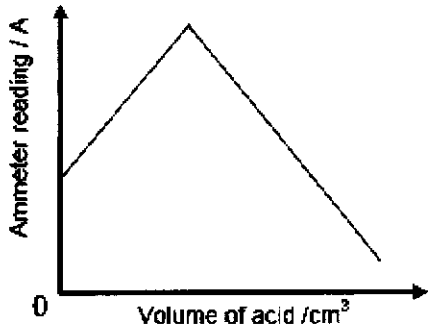
A



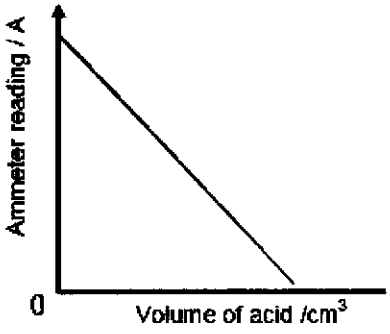
B



C



D



19 Nitrogenous fertiliser such as ammonium nitrate is used to increase crop yield.

Which substance can be added to increase the pH of acidic soil containing ammonium nitrate without causing a loss of nitrogen?

A calcium carbonate
B calcium hydroxide
C magnesium hydroxide
D potassium hydroxide

20 An experiment is carried out to determine the change in mass when different copper-based solids are added to excess nitric acid.

Solids of similar masses are added to the nitric acid as shown.

Beaker X: 10.0 g of copper foil added to 1.00 dm^3 of nitric acid
Beaker Y: 10.0 g of powdered copper(II) oxide added to 1.00 dm^3 of nitric acid
Beaker Z: 10.0 g of powdered copper(II) carbonate added to 1.00 dm^3 of nitric acid

Which of the following correctly shows the changes in mass for each beaker?

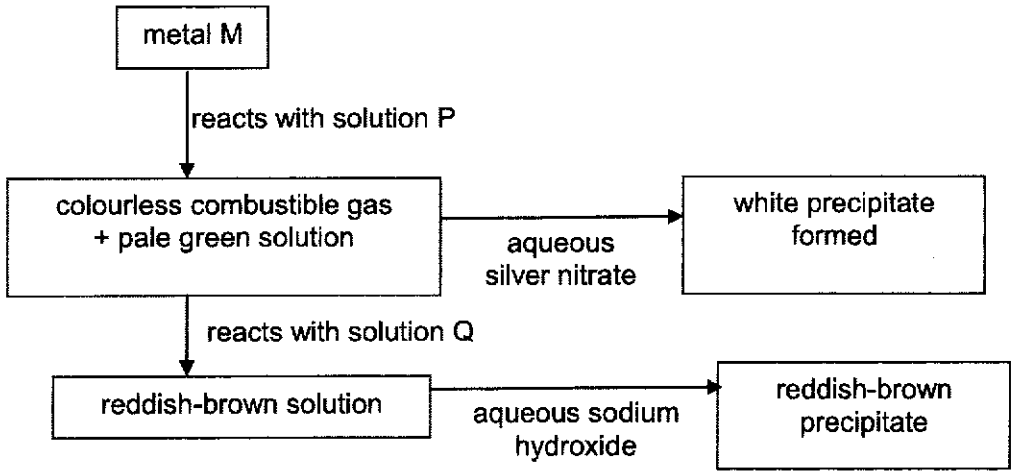
	Beaker X	Beaker Y	Beaker Z
A	decreases	no change	no change
B	increases	increases	increases
C	no change	decreases	decreases
D	no change	no change	decreases

21 A piece of zinc metal does not react when placed in a solution of hydrogen chloride which is dissolved in toluene.

Which change will cause a reaction?

A Add water and stir well.
B Bubble more hydrogen chloride gas into the solution to increase its concentration.
C Remove the layer of oxide on the zinc metal before placing it in the solution.
D Use zinc powder instead of zinc metal as rate of reaction will increase.

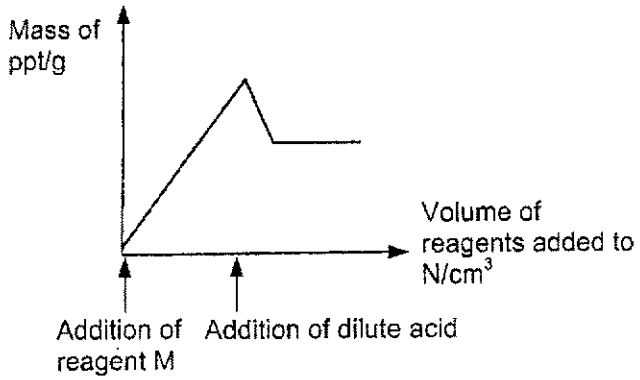
22 In the reaction scheme below, solutions P and Q are involved in some reactions.
Identify P and Q.



	P	Q
A	dilute hydrochloric acid	chlorine
B	dilute hydrochloric acid	potassium iodide
C	dilute nitric acid	chlorine
D	dilute nitric acid	potassium iodide

23 Ryan added reagent M gradually to a salt solution N (that contains either 1 or 2 different anions), followed by a dilute acid.

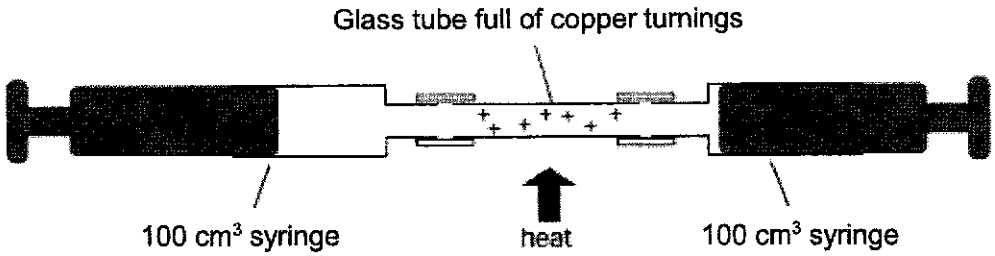
The graph below shows how the mass of precipitate formed changes with the reagents added.



Which combination would produce the given results?

	anion(s) in N	reagents (M and acid) added
A	CO_3^{2-}	add aqueous silver nitrate, followed by dilute nitric acid
B	Cl^- , CO_3^{2-}	add aqueous barium chloride, followed by dilute hydrochloric acid
C	NO_3^-, CO_3^{2-}	add aqueous silver nitrate, followed by dilute hydrochloric acid
D	SO_4^{2-}, CO_3^{2-}	add aqueous barium chloride, followed by dilute hydrochloric acid

24 The percentage of oxygen in the air is found using the apparatus shown in the diagram below. In an investigation, 100 cm^3 of air was passed over heated copper turnings until there was no further decrease in volume.



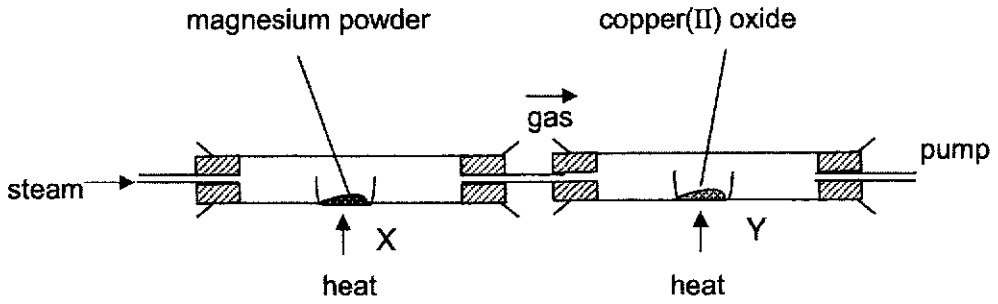
The volume of the gas after the reaction should be about 80 cm^3, but was instead measured to be 90 cm^3.

1 There was insufficient copper to react with all the oxygen in the syringe.
2 There was leakage of air out of the syringes.
3 The volume of gas was measured while it was still hot.

Which statement(s) correctly explain(s) the above observation?

A 1 only
B 1 and 3
C 2 and 3
D 1, 2 and 3

25 In the experiment shown below, steam is passed into the combustion tube for some time.



What are the products at X and Y respectively?

A magnesium hydroxide, copper
B magnesium hydroxide, copper(II) hydroxide
C magnesium oxide, copper
D magnesium oxide, copper(II) hydroxide

26 Which statement about the production of iron from iron(III) oxide in a blast furnace is correct?

A Coke is used to remove acidic impurities.
B Molten iron floats on slag at the furnace base.
C The iron(III) oxide is reduced by carbon monoxide.
D The iron is obtained using carbon as an oxidising agent.

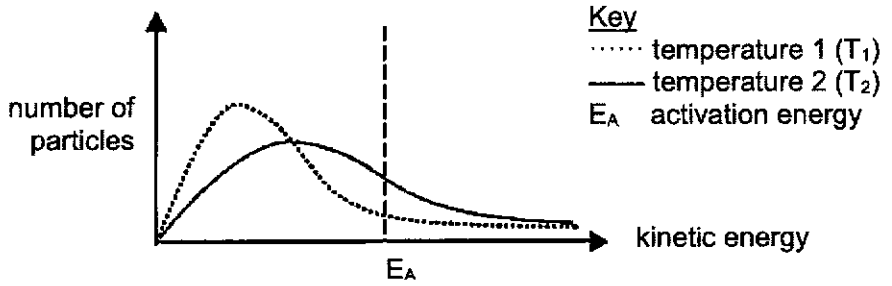
27 Approximately 40% of all iron and steel is produced by recycling. The following statements are possible reasons for recycling iron.

1 Recycling reduces the amount of waste taken to landfill sites.
2 Recycling reduces the amount of pollution at the site of the ore extraction.
3 Scrap steel contains a higher percentage of iron than iron ore.
4 Recycling reduces the need to collect the scrap iron and steel.

Which statements are correct?

A 1 and 2 only
B 1, 2 and 3 only
C 1, 2 and 4 only
D 1, 2, 3 and 4

28 The diagram represents the distribution of kinetic energy of reactant particles at two different temperatures.

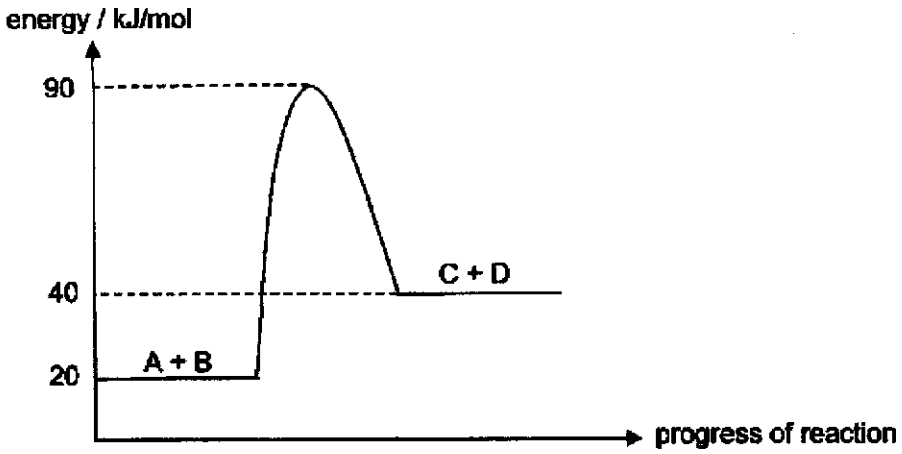


Given that the areas under the two curves represent the number of particles, which statement about the reaction is correct?

A At T_1, the activation energy is lower than at T_2.
B At T_1, the enthalpy change of the reaction is higher than at T_2.
C At T_2, a greater number of particles have sufficient energy to react.
D At T_2, the reaction takes a longer time to complete.

29 The energy profile diagram of a reversible reaction is shown below.

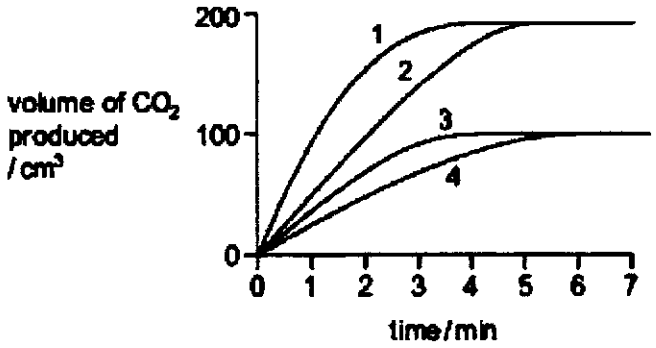
$$A + B \rightleftharpoons C + D$$



Which statement is correct about the reaction?

A Activation energy of the backward reaction is given by +50 kJ/mol.
B Activation energy of the forward reaction is given by +90 kJ/mol.
C Enthalpy change of the backward reaction is given by +20 kJ/mol.
D Enthalpy change of the forward reaction is given by –20 kJ/mol.

30 In four separate experiments, 1, 2, 3 and 4, nitric acid was added to excess marble chips and the volume of carbon dioxide formed was measured.
In all four experiments the same volume of nitric acid was used.
Its concentration, or temperature, or both concentration and temperature, were changed.
The results of the experiments are shown on the graph.



Which statement is correct?

A A lower concentration of acid was used in experiment 3 than in experiment 1.
B Experiment 4 was faster than experiment 3.
C The acid used in experiment 2 was of a lower concentration than in experiment 1.
D The temperature of the acid was the same in experiments 1 and 2.

31 Hydrogen peroxide (H_2O_2) acts as an oxidising agent in some reactions, but in others, as a reducing agent.

reaction 1: $H_2O_2 + 2KI + H_2SO_4 \rightarrow I_2 + K_2SO_4 + 2H_2O$
reaction 2: $5H_2O_2 + 2KMnO_4 + 3H_2SO_4 + \rightarrow 2MnSO_4 + K_2SO_4 + 5O_2 + 8H_2O$
reaction 3: $H_2O_2 + Ag_2O \rightarrow 2Ag + O_2 + 2H_2O$

Which row identifies correctly the role of hydrogen peroxide in each reaction?

	reaction 1	reaction 2	reaction 3
A	oxidising agent	reducing agent	oxidising agent
B	oxidising agent	reducing agent	reducing agent
C	reducing agent	oxidising agent	reducing agent
D	reducing agent	oxidising agent	oxidising agent

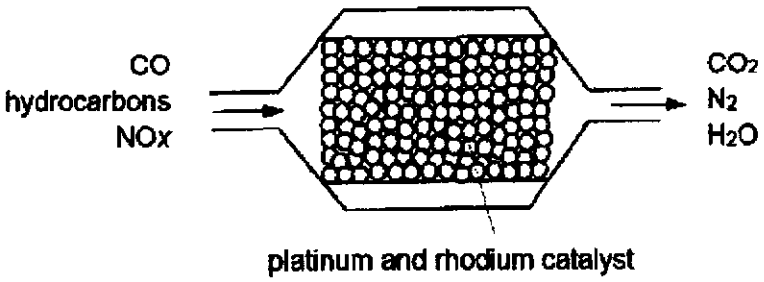
32 Which method would **not** produce ammonia?

A heating ammonium chloride with calcium hydroxide
B heating ammonium sulfate with hydrochloric acid
C heating ammonium sulfate with sodium hydroxide
D heating concentrated aqueous ammonia

33 Ammonia is produced by the Haber process. Which statement is true?

A An iron catalyst is used.
B Each hydrogen molecule reacts with three nitrogen molecules to form two molecules of ammonia.
C Low pressure will increase the yield of ammonia production in the Haber process.
D The reaction is irreversible.

34 The diagram below represents a section of a catalytic converter on the exhaust system of a car. Harmful gases are converted into carbon dioxide, nitrogen and water vapour.



Which processes take place in this catalytic converter?

1 Carbon monoxide and hydrocarbons react together
2 Carbon monoxide and nitrogen oxides react together.
3 Platinum and rhodium catalyse redox reactions.

A 1 and 2 only
B 1 and 3 only
C 2 and 3 only
D 1, 2 and 3

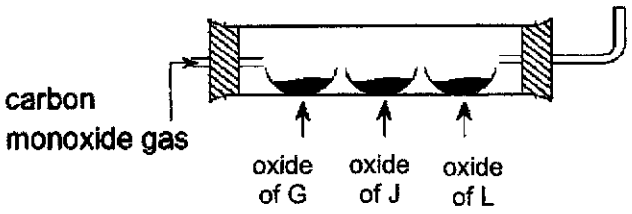
35 The following waste gases from a coal burning power station are passed through wet powdered calcium carbonate to reduce gaseous pollutants from escaping into the atmosphere.

sulfur dioxide	carbon monoxide
nitrogen monoxide	nitrogen dioxide
phosphoric(V) oxide	carbon dioxide

How many waste gases will be removed by the wet powdered calcium carbonate?

A 2
B 3
C 4
D 5

36 Samples of three metal oxides containing metals G, J, and L are heated strongly in a hard glass tube filled with carbon monoxide gas.



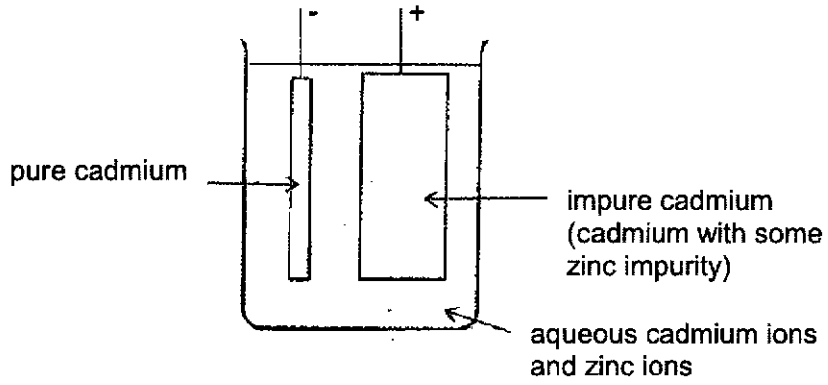
Oxide of G glows slightly, oxide of J glows strongly with many liquid droplets formed, oxide of L has no visible change.

Based on the observations above, arrange metals G, J, and L in decreasing order of reactivity.

A G, J, L
B G, L, J
C J, G, L
D L, G, J

37 Cadmium is a metal used to make rechargeable batteries. The purification of cadmium by electrolysis is shown below.

Cadmium and zinc form ions with the same electric charge.



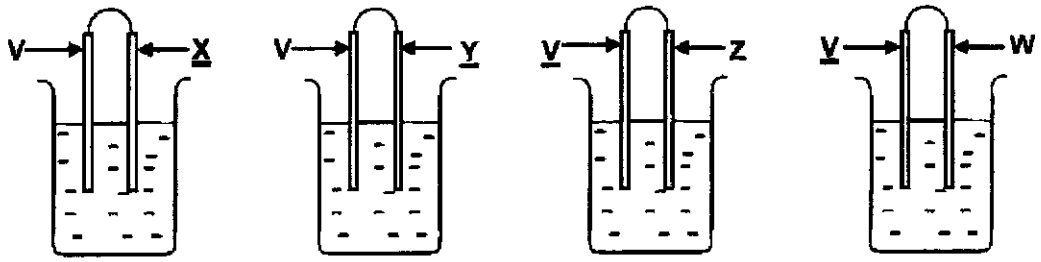
The following results were obtained from an investigation of this process:

	mass of impure cadmium electrode / g	mass of pure cadmium electrode / g
at the start of electrolysis	860	140
at the end of electrolysis	260	700

What is the percentage purity of cadmium in impure cadmium?

A 6.7 %
B 16.3 %
C 23.3 %
D 93.3 %

38 Four simple cells were set up using dilute sulfuric acid as the electrolyte to study the reactivity of the metals.

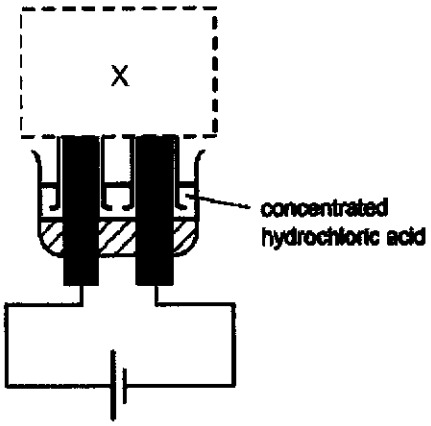


In each cell, only the underlined electrode dissolved. To establish the order of reactivity of metals V, W, X, Y and Z, it is necessary to set up two more cells, cell A and cell B.

Which pairs are needed in addition to the four cells above?

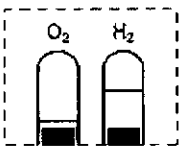
	electrodes in cell A	electrodes in cell B
A	W/Z	X/Y
B	W/Z	W/Y
C	W/X	W/Y
D	W/X	X/Y

39 The electrolysis set-up shown is not complete.

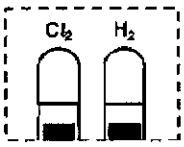


What should be shown at X when the solution has been electrolysed for some time?

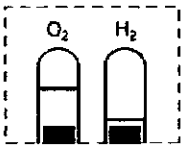
A



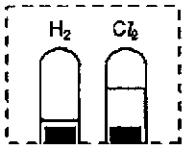
B



C



D



40 Which statement about hydrogen fuel cell is **not** true?

A Hydrogen fuel cell is generally a clean energy source.
B Hydrogen gas undergoes a chemical reaction with oxygen gas.
C The hydrogen gas used is obtained from the fractional distillation of liquefied air.
D The reaction is exothermic.

Section A

Answer **all** questions in this section in the spaces provided.
The total mark for this section is 50.

A1 Some elements in the first four periods in the Periodic Table are shown below.
Choose from the following elements to answer the questions below.

iodine	bromine	calcium
chlorine	copper	fluorine
hydrogen	iron	nitrogen
silver	sodium	zinc

Each element can be used once, more than once or not at all.

Which element

(a) is extracted by reduction with carbon, ... [1]

(b) can form a charge of 2+ and more reactive than zinc, ... [1]

(c) is a liquid at room temperature, ... [1]

(d) is a metal which will float on water, ... [1]

(e) has the highest percentage composition in air, ... [1]

(f) is used for galvanising? ..... [1]

[Total: 6]

A2 The first ionization energy of elements is the energy required for one mole of gaseous atoms to lose one mole of electrons, forming one mole of gaseous ions with a charge of 1+.

Examples of two elements are given below:

$H\ (g) \rightarrow H^+\ (g) + e$ Ionization energy = 1310 kJ/mol
$Li\ (g) \rightarrow Li^+\ (g) + e$ Ionization energy = 500 kJ/mol

Element	Proton number	First ionisation energy (kJ/mol)
Lithium	3	520
Sodium	11	494
Potassium	19	418
Rubidium	37	403
Berylium	4	900
Magnesium	12	738
Calcium	20	590
Strontium	38	550
Argon	18	1520

(a) Suggest why the first ionization energy of Group I metals **decreases** down the group.

.....

.....

.....[2]

(b) Explain why Argon (Ar) in Group 0 in the Periodic Table have the highest ionisation energy when compared with the other elements.

.....

.....

.....[2]

(c) Using the data provided, compare the reactivity between lithium and beryllium.
Explain your answer.

.....

.....[1]

(d) Lithium contains two isotopes, lithium−6 and lithium−7. Do you think that the ionisation energy of both the isotopes is the same? Explain your answer.

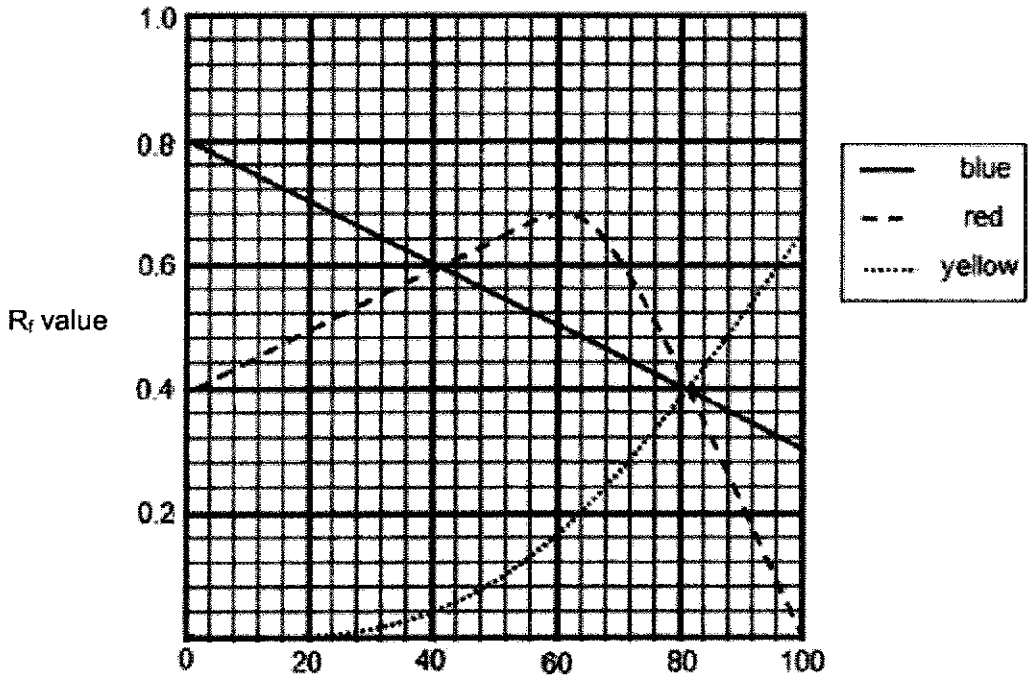
.....[1]

(e) Sodium reacts with sulfur to form sodium sulfide. Draw a 'dot and cross' diagram to show the bonding in this compound. Only the valence electrons need to be shown.

[2]

[Total: 8]

A3 A sample of ink contains a mixture of red, blue and yellow dyes. To separate the dyes in the ink, the solvent used is a mixture of water and ethanol. The R_f values of the coloured dyes in solvents with different percentage of ethanol present are shown.



(a) Use the information in the graph to explain why a pure solvent of either water or ethanol **cannot** be used to separate the dyes in the ink.

.....

.....

.....[2]

(b) A mixture of water and ethanol was used to separate a sample of this ink. Only one spot was formed on the chromatogram. Using evidence from the graph, explain why it **cannot** be concluded that the ink sample is a pure substance.

.....

.....

.....[2]

(c) What is the R_f value of the blue, red and yellow dye when a solvent mixture containing 90 cm^3 ethanol and 60 cm^3 water is used in the chromatography?

Blue: ..... Red: ..... Yellow: ..... [1]

[Total: 5]

A4 The graph in Fig. 4.1 shows how the average temperature at the Earth's surface has changed over the last 150 thousand years.
The graph in Fig. 4.2 shows how the percentage of carbon dioxide in the atmosphere has changed over the last 150 thousand years.

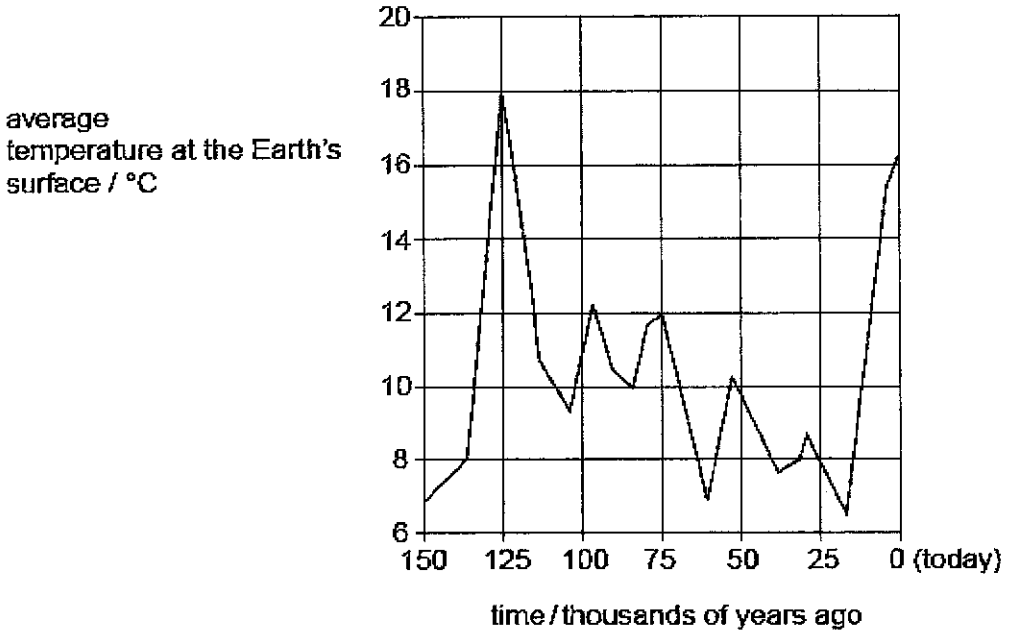


Fig. 4.1

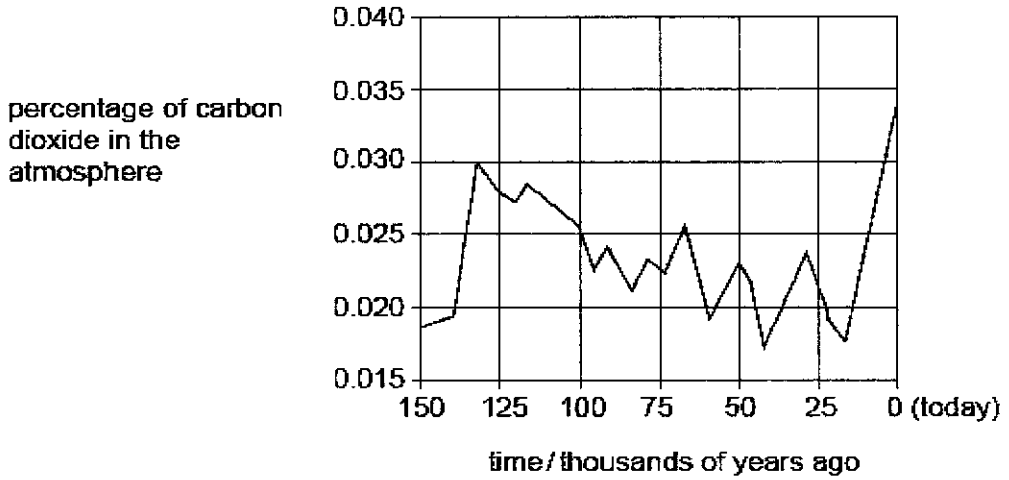


Fig. 4.2

(a) (i) Using the graphs in Fig. 4.1 and Fig. 4.2, describe the relationship between the percentage of carbon dioxide in the atmosphere and the average temperature at the Earth's surface.

.....

.....[1]

(ii) Nicole thinks that global warming is due to the increase in carbon dioxide in the atmosphere only. Do you agree with the statement? Explain your answer.

.....

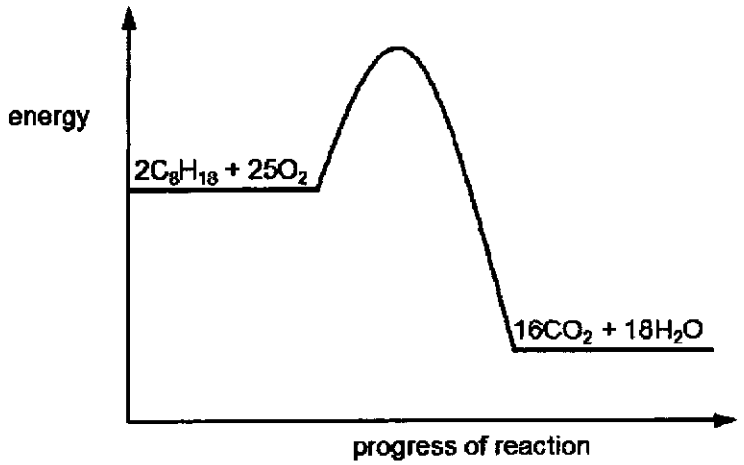
.....[1]

(iii) Describe one consequence of global warming.

.....

.....[1]

(b) One source of carbon dioxide is the combustion of fossil fuels like octane.
The energy profile diagram for the reaction is shown below.



(i) Label clearly on the energy profile diagram the enthalpy change, ΔH, and activation energy, E_a, of the reaction. [2]

(ii) Explain how the diagram above shows that the combustion of fossil fuels is considered an exothermic reaction.

.....

.....[1]

(iii) The table below shows some bond energies, measured in kilojoules per mole, kJ/mol.

bond	bond energy, in kJ/mol	bond	bond energy, in kJ/mol
O – O	150	C – O	360
O = O	496	C – H	412
C = C	612	C – C	348
C = O	743	O – H	463

Given that the amount of heat energy absorbed to break the bonds present in octane and oxygen is 32104 kJ, calculate the enthalpy change for the combustion of octane.

[3]

[Total: 9]

A5 Joel performed three experiments using the metals chromium, iron and manganese.

In the first experiment he added the metals separately into dilute sulfuric acid. In the second experiment he heated the metals in air, and in the last experiment he put strips of the metals in different salt solutions.

Table 5.1 shows the results of the first two experiments.

Table 5.1

metal	reaction with sulfuric acid	reaction with air
chromium	metal dissolves readily with effervescence, a violet solution of chromium(III) sulfate, is formed	burns in air to form green chromium(III) oxide, Cr_2O_3
iron	metal dissolves slowly with effervescence, a pale green solution is formed	burns in air to form dark brown iron(III) oxide
manganese	metal dissolves quickly with effervescence, a pale pink solution of manganese(II) sulfate, is formed	burns in air with an intense white light forming a red solid, manganese(II, III) oxide, $MnO.Mn_2O_3$

(a) With reference to **two** pieces of evidence from the table above, explain why chromium, iron and manganese are considered as transition metals.

.....

.....

.....

.....

.....[2]

(b) Suggest the order of reactivity of the three metals, chromium, iron and manganese.

most reactive .....

.....

least reactive ..... [1]

(c) **(i)** Describe one observation when chromium strip is added in iron(II) sulfate solution.

.....

.....[1]

(ii) Write a chemical equation of the reaction in **(c)(i)**.

.....[1]

(d) Carbon is often added to iron to form steel as it is stronger and harder than pure iron.

(i) Explain why steel is stronger and harder than pure iron.

.....

.....[1]

(ii) Suggest a method that could be used to apply the chromium coating to the iron.

.....[1]

[Total: 7]

A6 Mendeleev published his Periodic Table in 1869. Part of it is shown below.

	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII
Period 1	H						
Period 2	Li	Be	B	C	N	O	F
Period 3	Na	Mg	Al	Si	P	S	Cl
Period 4	K Cu	Ca Zn	* *	Ti *	V As	Cr Se	Mn Br
Period 5	Rb Ag	Sr Cd	Y In	Zr Sn	Nb Sb	Mo Te	* I

Gaps left by Mendeleev are shown as asterisks (*).

Study the table above and answer the following questions.

(a) Write the symbol of the element which

(i) combines with oxygen to form giant covalent structure.

.....[1]

(ii) forms a reddish brown solution when added to potassium bromide.

.....[1]

(iii) react most explosively with water to form a solution that turns Universal indicator violet.

.....[1]

(b) State two ways by which Mendeleev's Periodic Table differs from the modern Periodic Table used today.

.....

.....

.....

.....

.....[2]

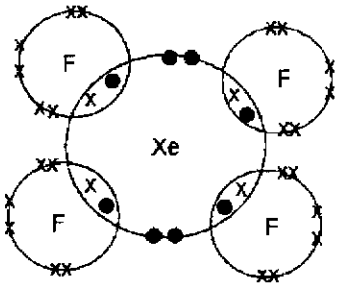
(c) Xenon is a noble gas in air and is unreactive. However, under very high pressure, xenon can react with fluorine to form compounds.

(i) Suggest why xenon reacts with fluorine but not with other non-metals.

.....

.....[1]

(ii) One compound formed between xenon and fluorine has the formula XeF_4. This diagram shows the bonding in XeF_4.



Give one reason why the bonding in XeF_4 is unusual.

.....

.....

.....[1]

[Total: 7]

A7 A dilute solution of hydrogen peroxide can be used to bleach hair. It decomposes very slowly in aqueous solution according to the following equation:

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

(a) (i) Sketch a graph to show the volume of oxygen produced/cm^3 against time/min. Label it graph **X**.

[2]

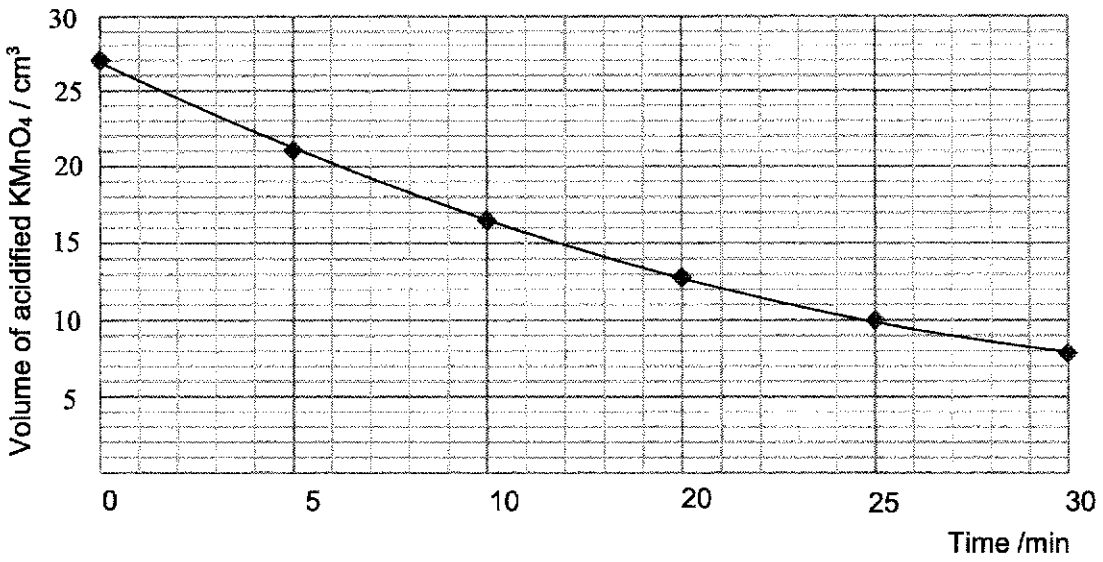
(ii) On the graph above, sketch the graph that you would expect to see if a higher concentration of aqueous hydrogen peroxide is used instead. Label it graph **Y**. [1]

(b) In another experiment, a 1.62 mol/dm^3 hydrogen peroxide solution was added to a bottle contaminated with transition metal ions, which act as catalysts for the decomposition. To follow the rate of decomposition, 20.0 cm^3 of solutions were withdrawn from the bottle at various times and titrated with 0.120 mol/dm acidified potassium manganate(VII) solution, according to the following ionic equation:

$$2MnO_4^-\,(aq) + 5H_2O_2\,(aq) + 6H^+\,(aq) \rightarrow 2Mn^{2+}\,(aq) + 8H_2O\,(l) + 5O_2\,(g)$$

The results are shown below.

time / min	0	5	10	15	20	25
volume of acidified $KMnO_4$ for complete titration / cm^3	Refer to graph					



Use ideas about collisions between particles to explain how the presence of transition metal ions affect the rate of reaction.

.....

.....

.....

.....[2]

(c) **(i)** Given that the concentration of potassium manganate(VII) and manganate(VII) ions are the same, calculate the concentration of hydrogen peroxide at the time the first portion is withdrawn at t = 0 seconds.

[1]

(ii) From the graph, estimate the time taken for the hydrogen peroxide solution to decrease to half of its original concentration from t = 0.

.....[1]

(iii) Given that "*half-life*" is the time taken for the concentration of hydrogen peroxide solution at any one time to reduce to half of its initial value, estimate the duration that the hydrogen peroxide solution was added to the contaminated bottle before the experiment was conducted at t = 0.

.....[1]

[Total: 8]

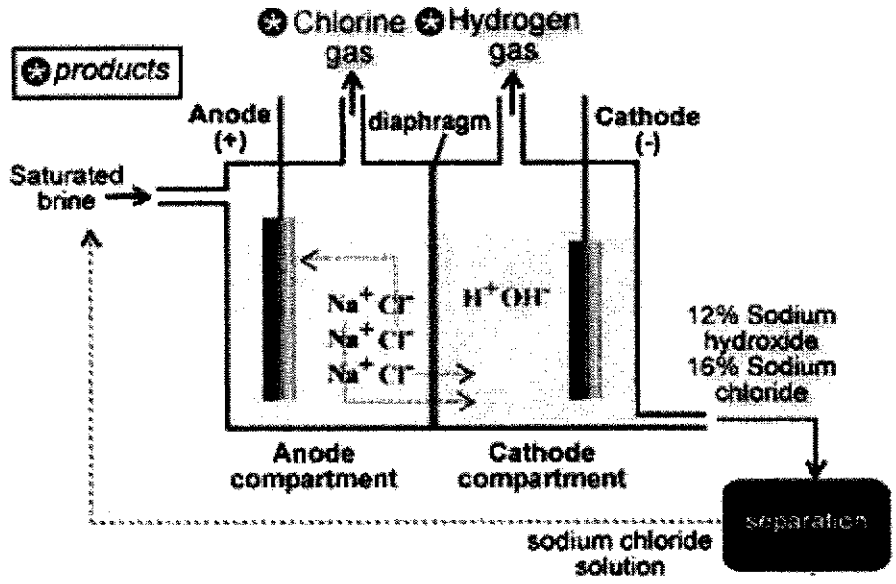
Section B

Answer all **three** questions in this section.

B8 Electrolysis reactions are the basic foundations of today's modern industry. There are various elements, chemical compounds and organic compounds that can only be produced by electrolysis. For example, chlorine and sodium hydroxide.

Brine is a saturated solution of sodium chloride, containing about 25% by mass of sodium chloride. Industrial electrolysis of brine can be carried out in a **diaphragm** cell and a **membrane** cell.

The diagram below shows how the **diaphragm** cell works.



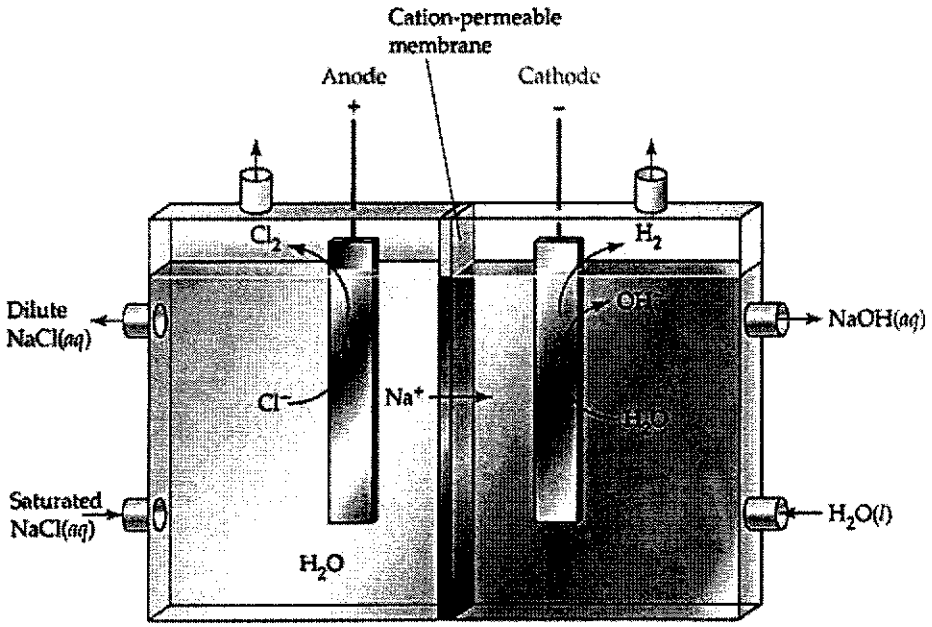
Picture source: http://www.greener-industry.org.uk/pages/chlorine/7chlorine_PM2.htm

The brine is contained in the anode compartment and the electrode which is used can either be made up of graphite or titanium. However, graphite is commonly preferred over titanium.

On the cathode side, the hydroxide ions and hydrogen gas are formed due to the reduction of water. Due to the difference in the solution level between the anode and the cathode, there will be a gradual flow of sodium chloride from the anode into the cathode. However, there will not be any backflow of sodium ions into the anode. If chlorine and sodium hydroxide come into contact, chlorine turns into ClO^-, ClO_3^- and Cl^- ions.

To ensure that a pure sodium hydroxide can be collected, purification of sodium chloride out of the sodium hydroxide will have to be carried out. After purification, the industry is able to get a solution of 50% of aqueous sodium hydroxide and about 1% of sodium chloride.

The diagram below shows how the **membrane** cell works.



Picture source: https://slideplayer.com/slide/3452638/

In the membrane cell, the coated titanium anode and nickel cathode are used. The current passing through will result in the aqueous sodium chloride to split into sodium ions and chloride ions. The ion exchange membrane is made from a polymer which only allows positive ions to pass through it. The sodium ions will flow through the membrane and react with the hydroxide ions that are produced through the reduction of water to form aqueous sodium hydroxide. With the ion exchange membrane, the purity of sodium hydroxide will be kept high as it will not be contaminated with sodium chloride.

The table below shows some information about the two types of cells.

cell type	construction	operation of cell	quality of NaOH produced
diaphragm cell	Relatively simple and inexpensive.	Frequent replacement of diaphragm. Operates at 3.8 V.	Must be evaporated to concentrate from 12% to 50% and to crystallise out the salt.
membrane cell	Cheap to construct and install.	Requires high purity brine. Operates at 3.3 V. Membrane changes every 2 to 3 years.	High purity. Must be evaporated to concentrate from 33% to 50%.

(a) **(i)** Based on the information given, construct a half ionic equation for the reaction that happens at the cathode of the diaphragm cell.

.....[1]

(ii) Graphite is preferred over titanium to be used as electrode in the diaphragm cell as it is inert. Suggest another reason why it is preferred.

.....[1]

(b) When chlorine and sodium hydroxide comes into contact, a disproportionation reaction happens. Disproportionation happens when the oxidation state of the same element both increases and decreases in the reaction.

Use ideas about oxidation states to explain why the reaction of chlorine and sodium hydroxide is a disproportionation reaction.

.....

.....

.....[2]

(c) **(i)** Write an equation for the overall reaction that happens in the membrane cell.

.....[1]

(ii) Calculate the volume of hydrogen gas that can be produced from two tonnes of sodium chloride in membrane cell at r.t.p.

[3]

(d) "Industries should adopt using membrane cell to produce sodium hydroxide instead of diaphragm cell."

Using the relevant information, explain one reason why membrane cell is used.

.....

.....[1]

(e) Sandra made the following comment.

"In school laboratory, I can obtain pure aqueous sodium hydroxide by using concentrated sodium bromide solution with graphite electrodes over a long period of time."

Explain whether you agree with Sandra.

.....

.....

.....

.....[2]

(f) There are many advantages of using membrane cell. However, diaphragm calls are still being used in today's modern industry. Suggest why.

.....

.....[1]

[Total: 12]

B9 Fig. 9.1 shows the Haber process.

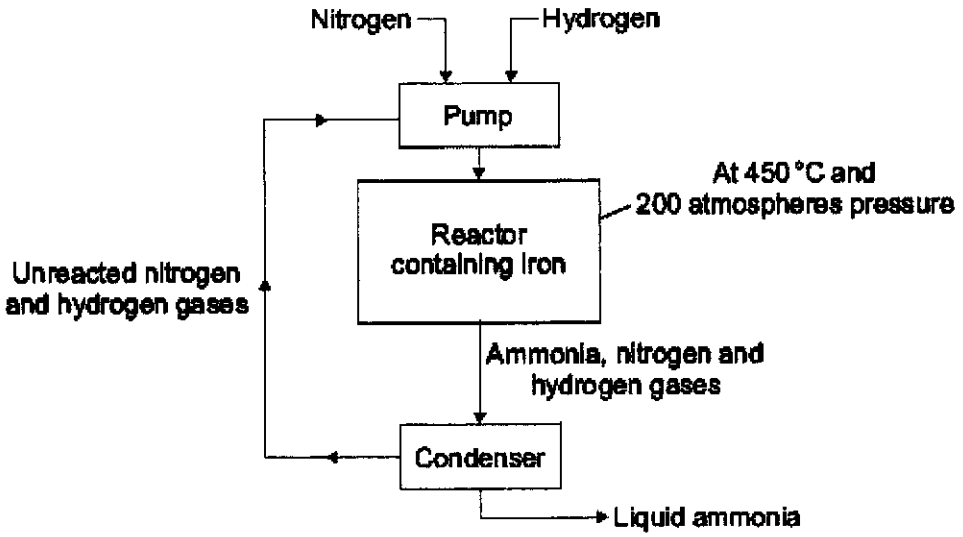


Fig. 9.1

Fig. 9.2 shows the yield of ammonia that is made under different conditions.

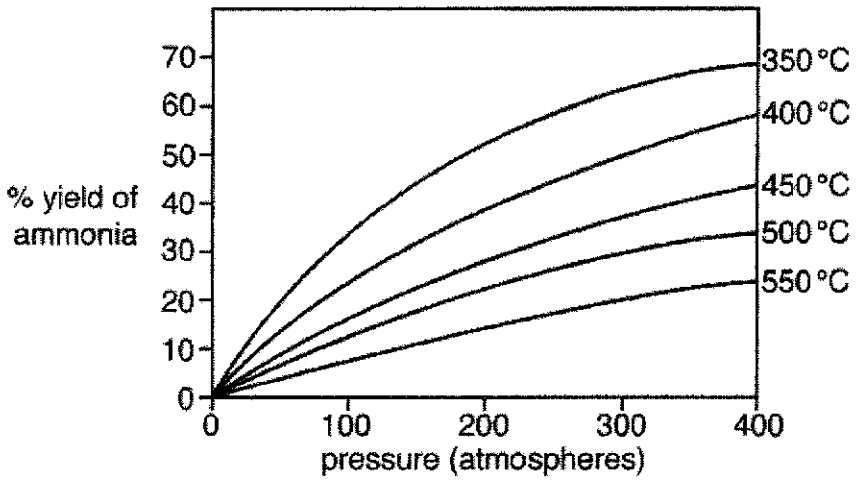


Fig. 9.2

(a) In present times, the Haber process has been adapted to work at a lower temperature of 250 °C. Predict and explain how a lower temperature affects the relative amounts of ammonia, nitrogen and hydrogen that leaves the reactor.

.....

.....

.....[2]

(b) In the condenser, ammonia is separated out as a liquid. Explain how this is achieved.

.....

.....[1]

(c) 60 dm^3 of nitrogen and 60 dm^3 of hydrogen were each pumped into the reactor The volume of ammonia produced was found to be 6 dm^3.
Calculate the percentage yield of ammonia for the reaction.

[2]

(d) Aqueous ammonia is formed when ammonia gas is dissolved in water. When aqueous ammonia is added dropwise to a sample of contaminated water, a mixture of white and blue precipitate is formed. On adding excess aqueous ammonia, a dark blue solution is formed.
State the formulae of the possible cations present in the water sample.

.....[1]

(e) Ammonium nitrate is a common fertiliser used by farmers. Rain water can wash ammonium nitrate off the farmland and into rivers and lakes. Ammonium nitrate in drinking water supplies is harmful to health.
Describe tests to identify the presence of ammonium nitrate in drinking water.

.....

.....

.....

.....

.....[2]

[Total: 8]

B10 A strong acid is completely ionised while a weak acid is partially ionised when dissolved in water. The general equation below shows the reaction for a monobasic weak acid in water, where HA represents the acid molecule and A^- represents the anion of the acid.

$$HA \rightleftharpoons H^+ + A^-$$

The HA molecules, H^+ and A^- ions are in equilibrium in water. Weak acids have different degree of ionisation. The further the equilibrium lies to the left, the lower the degree of ionisation, the weaker the acid. The measure of the position of the equilibrium or degree of ionisation can be determined by the acid dissociation constant, K_a. The lower the value of the K_a, the more the equilibrium lies to the left, the weaker the acid.

Ka can be expressed as

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Key:
$[H^+]$ = concentration of H^+ ions
$[A^-]$ = concentration of A^- ions
[HA] = concentration of HA molecules

Carbonic acid, H_2CO_3, a weak dibasic acid ionises in two steps as shown below.

Step	Equation	K_a/ mol/dm^3
1	$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$	4.3×10^{7}
2	$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$	5.6×10^{-11}

(a) **(i)** Which acid, H_2CO_3 or HCO_3^-, is a weaker acid? Explain your answer.

.....

.....[1]

(ii) Write an expression for the acid dissociation constant, K_a for step 1.

[1]

(iii) Given that the concentration of HCO_3^- is the same as the concentration of H_2CO_3, use the K_a expression in **(a)(ii)** to deduce the concentration of H^+ ions.

[1]

(b) In a school laboratory, a student titrated 25.0 cm^3 of 0.100 mol/dm^3 carbonic acid, H_2CO_3, with 0.0625 mol/dm^3 barium hydroxide, $Ba(OH)_2$.

(i) State **two** observations you will observe in the conical flask as the titration proceeds.

.....

.....[1]

(ii) Calculate the volume of $Ba(OH)_2$ needed to completely react with the H_2CO_3.

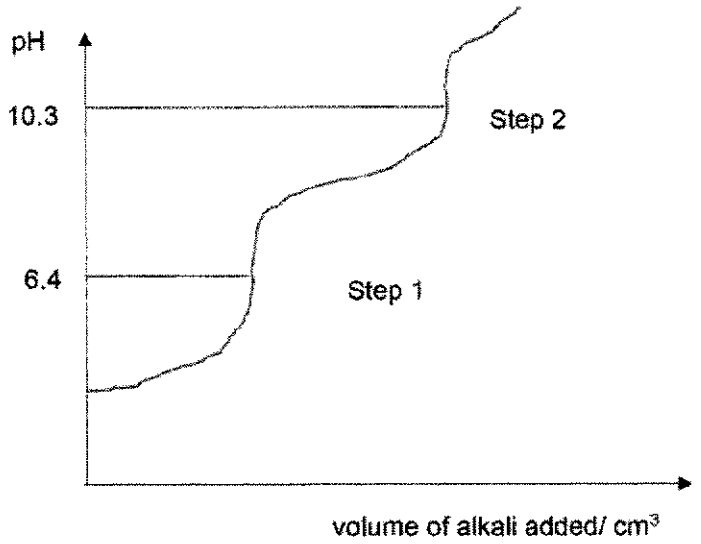
[2]

(iii) Suggest why the actual volume of $Ba(OH)_2$ used is lesser than the volume calculated in **(b)(ii)**.

.....

.....[1]

(c) The pH curve for the titration between H_2CO_3 and $Ba(OH)_2$ in **(b)** is shown below.



The pH range at which various indicators change colour is shown in the table below.

indicator	pH range for colour change
thymolphthalein	9.3 – 10.5
phenolphthalein	8.3 – 10.5
bromothymol blue	6.0 – 7.6
creseol red	7.2 – 8.8
methyl orange	3.1 – 4.4

(i) State a suitable indicator to track the end-point for Step 2.

.....[1]

(ii) Bryan used bromothylmol blue for the titration but could not get the correct volume of $Ba(OH)_2$ required for the complete neutralisation of H_2CO_3. Explain why this is so.

.....

.....

.....[1]

(iii) Suggest what Bryan can do to estimate the correct volume of $Ba(OH)_2$ required for complete neutralisation of H_2CO_3, using bromothymol blue as indicator.

.....

.....[1]

[Total: 10]

End of Paper

The Periodic Table of Elements

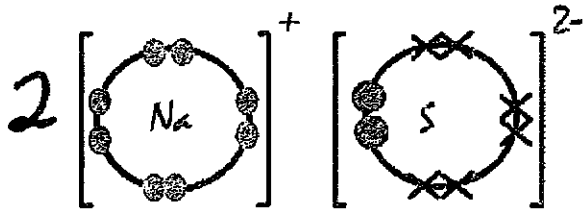
Group																	
I	II											III	IV	V	VI	VII	0
						1 H hydrogen 1											2 He helium 4
3 Li lithium 7	4 Be beryllium 9		Key proton (atomic) number atomic symbol name relative atomic mass									5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium -	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57 – 71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89 – 103 actinoids	104 Rf Rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

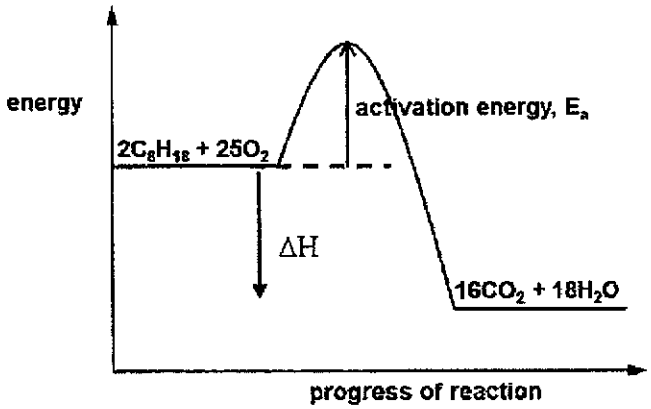
lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

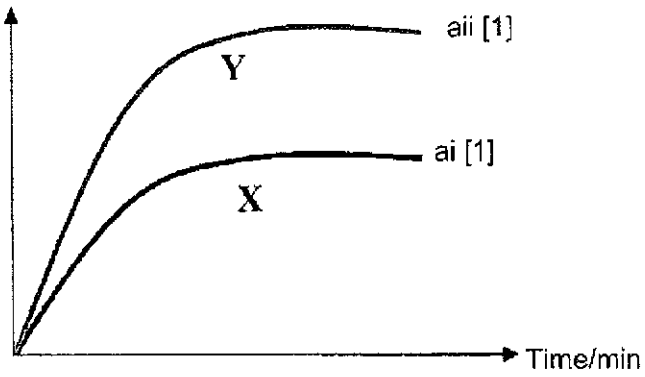
1	2	3	4	5	6	7	8	9	10
C	B	C	D	C	D	B	B	A	A
11	12	13	14	15	16	17	18	19	20
B	B	A	A	B	C	C	B	A	D
21	22	23	24	25	26	27	28	29	30
A	A	D	B	C	C	B	C	A	A
31	32	33	34	35	36	37	38	39	40
B	B	A	C	C	D	D	A	B	C

Paper : 6092/02

A1	**(a)**	Iron/ zinc	**1**
	(b)	Calcium	**1**
	(c)	Bromine	**1**
	(d)	Sodium	**1**
	(e)	Nitrogen	**1**
	(f)	Zinc	**1**
A2	**(a)**	When going down group I, there will be an <u>extra shell</u> in every element. Therefore the further the valence electron from the nucleus, <u>the weaker the electrostatic forces of attraction</u> between the nucleus and valence electrons. [1] Hence, <u>easier / lesser energy</u> needed to lose / remove the outer electrons. [1]	**2**
	(b)	Completely filled stable electronic configuration [1] which requires a great amount of energy to remove an electron. [1]	**2**
	(c)	Lithium is more reactive than beryllium because lithium has a lower ionisation energy of 520 kJ/mol than beryllium which is 900 kJ/mol.	**1**
	(d)	Yes. Both contain the same number of protons and electrons.	**1**
	(e)	 Correct sodium ion diagram and ratio – 1m Correct sulfide ion diagram – 1m	**2**
A3	**(a)**	In pure water, the <u>Rf value of yellow dye is 0</u>. This shows that <u>yellow dye does not dissolve</u> in the solvent so it does not separate from the sample ink. [1] In pure ethanol, the <u>Rf value of red dye is 0</u>. This shows that the <u>red dye does not dissolve</u> in the solvent so it does not separate from the sample ink. [1]	**2**

	(b)	When the solvent is 80% ethanol, only one spot will be observed as all three dyes have the same R_f value of 0.4		1 1
	(c)	Blue: 0.50 Red: 0.68 Yellow: 0.16 All must be correct to be awarded.		1
A4	(a)	(i)	As the percentage of carbon dioxide in the atmosphere increases, the average temperature at the Earth's surface increases.	1
		(ii)	The statement is not true. There are other factors such as increase in the amount of other greenhouse gases like methane will also result in global warming.	1
		(iii)	- polar ice caps will melt, causing sea level to rise and flood low-lying land - reduced rain fall can cause a decrease in crops yield and consequently, shortage of food. - more occurrences of unusual weather conditions such as warm spells, droughts, unexpected storms and hurricanes, and floods in some parts of the world - rise in ocean temperature results in lesser volume of carbon dioxide being able to dissolve in the sea water and this leads to an increase in the amount of carbon dioxide in the atmosphere, aggravating global warming. *Any of the consequences*	1
	(b)	(i)	 1m for ΔH 1m for E_a	2
		(ii)	The energy level of the products are lower than the energy level of the reactants.	1
		(iii)	Amount of heat energy released to form carbon dioxide = 16 × 2 × 743 = 23776 kJ [1] Amount of heat energy released to form water = 18 × 2 × 463 = 16668 kJ [1] Enthalpy change = 32104 – 16668 – 23776	3

			= −8340 kJ **[1]**	
A4	(a)	• form coloured compounds e.g. chromium (III) sulfate is purple / iron (II) sulfate is green/ manganese (II) sulfate is pale pink [1] • form ions of different oxidation states / charges e.g. iron (ii) and iron (III) ions can be formed/ manganese(II) and manganese (III) ions can be formed. [1] (must show evidence from table)		2
	(b)	manganese chromium iron all three correct - [1]		1
	(c)	(i)	Pale green solution turns violet. Grey deposit formed. Any 1	1
		(ii)	$2Cr + 3FeSO_4 \rightarrow Cr_2(SO_4)_3 + 3Fe$	
	(d)	(i)	The atoms of different size will disrupt the orderly arrangement of the iron atoms, making the layers difficult to slides over one another when a force is applied.	1
		(ii)	electroplating	1
A6	(a)	(i)	Si	1
		(ii)	Cl / F	1
		(iii)	Rb	1
	(b)	The noble gases are not found in Mendeleev's Periodic Table but they are present in the modern Periodic Table. [1] Hydrogen is placed in Group I in Mendeleev's Periodic Table but it is placed separate from other groups in the modern Periodic Table. [1] The transition elements are placed in specific groups in Mendeleev's Periodic Table but in the modern Periodic Table, the transition elements are placed in the central block which are separated from other groups. [1] In Mendeleev's Periodic Table, there are 7 groups and 5 periods but in the modern Periodic Table, there are 8 groups and 7 periods. [1] Any 2 answers		2
	(c)	(i)	Fluorine is the most reactive non-metal in the Periodic Table. Hence it is able to react with xenon.	1
		(ii)	Unusual: The valence electron shell of xenon has 12 electrons instead of the expected 8 for noble gas configuration/ octet structure.	1

A7	(a)	(i) (ii)	Volume of oxygen gas / cm^3  Deduct 1 m for wrong axes.	2
	(b)		The transition metal ions act as catalyst, which provides an alternative pathway with lower activation energy. More particles have energy equal or greater than the activation energy. [1] Increase frequent effective collisions. Higher speed of reaction. [1]	2
	(c)	(i)	Number of moles of $KMnO_4$ $= 0.120 \times \frac{27}{1000}$ 0.00324 mol [1] Number of moles of MnO_4^- : Number of moles of H_2O_2 2 : 5 0.00324 : 0.0081 Concentration of H_2O_2 $= 0.0081 \div \frac{20.0}{1000}$ $= 0.405$ mol/dm^3 [1]	2
		(ii)	17 minutes [1]	1
		(iii)	1.62 mol/dm^3 → 0.81 mol/dm^3 → 0.405 mol/dm^3 2 half-lives have passed 17×2 = 34 minutes [1]	1
B8	(a)	(i)	$2H_2O$ (l) + 2e → $2OH^-$ (aq) + H_2(g)	1
		(ii)	Graphite is cheaper than titanium. OR Graphite is easier to obtain than titanium.	1
	(b)	Oxidation state of Cl increases from 0 in Cl_2 to +1 in ClO^- / +5 in ClO_3^-. [1] Therefore, Cl_2 is oxidized. Oxidation state of Cl decreases from 0 in Cl_2 to -1 in Cl^-. [1] Therefore, Cl_2 is reduced.		2
	(c)	(i)	$2NaCl + 2H_2O \rightarrow Cl_2 + 2NaOH + H_2$	1

		(ii)	Number of moles of NaCl = 2000000 x 0.25 / (23 + 35.5) = 8547.00855 moles [1] Number of moles of H_2 = 4273.5 moles [1] Volume of H_2 = 4273.5 x 24 = 102564 = 103000 dm^3 [1]	3
	(d)		Membrane cell operates at a lower voltage as compared to diaphragm cell, hence cheaper to operate. Or Membrane needs to be changed every 2-3 years whereas diaphragm needs to be frequently replaced.	1
	(e)		Disagree. Bromide ions are preferentially discharged and not hydroxide ions due to concentration effect and hydrogen ions are preferentially discharged to sodium ions. [1] However, when the concentration of bromide ions are low, hydroxide ions will be preferentially discharged. The NaOH collected will be contaminated by the Br^- ions. [1]	2
	(f)		Membrane cell uses polymer membrane which is non-biodegradable. It will cause land pollution or take up landfill sites when disposed.	1
B9	(a)		According to the graph, as the temperature decreases, a higher percentage yield of ammonia is obtained.[1] This would result in a increase in the amount of ammonia that leaves the main reactor and an decrease in the amount of unreacted hydrogen and nitrogen.[1]	2
	(b)		Cool ammonia into a liquid at a temperature lower than the boiling point of ammonia but higher than boiling points of nitrogen and hydrogen. / Ammonia has a higher boiling point than nitrogen and hydrogen hence will condense first when cooled.	1
	(c)		Molar volume ratio of N_2 : H_2 : NH_3 = 1: 3 : 2 Since H_2 is limiting, [1] theoretical volume of ammonia produced = 2/3 × 60 = 40dm^3 Percentage yield of ammonia = 6/40 × 100% = 15% [1]	2
	(d)		Zn^{2+}, Cu^{2+}	1
	(e)		Add aqueous sodium hydroxide to a sample of water and warm the mixture. If a pungent and colourless gas evolved turned moist red litmus blue, then ammonium ion is present [1] Add aqueous sodium hydroxide, Al foil and warm the mixture. If a pungent and colourless gas evolved turned moist red litmus blue, then nitrate ion is present [1]	2
B10	(a)	(i)	HCO_3^- It has a lower K_a than that of H_2CO_3 which show a lower degree of ionisation.	1

		(ii)	$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$	1
		(iii)	$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$ Since $[H_2CO_3] = [HCO_3^-]$ $K_a = [H^+] = 4.3 \times 10^{-7}$ mol/dm^3	1
	(b)	(i)	White precipitate formed. Effervescence seen.	1
		(ii)	$Ba(OH)_2 + H_2CO_3 \rightarrow BaCO_3 + 2H_2O$ No. of moles of $H_2CO_3 = 0.100 \times 25/1000 = 0.0025$ mol [1] $H_2CO_3 : Ba(OH)_2 = 1 : 1$ No. of moles of $Ba(OH)_2 = 0.0025$ mol Volume of $Ba(OH)_2 = 0.0025 / 0.0625 = 0.0400$ dm^3 [1]	2
		(iii)	When $Ba(OH)_2$ is added, barium carbonate formed will react with carbonic acid. Hence the volume of $Ba(OH)_2$ is lesser than expected.	1
	(c)	(i)	Thymolphthalein or Phenolphthalein	1
		(ii)	The end point of step 2 (pH = 10.3) does not coincide with the pH range at which bromothymol blue changes colour(6.0 – 7.6). No colour change will be observed. [1] Award 1m only if answer is supported by data.	1
		(ii)	From the volume for the 1st end point for step 1, he can multiply the volume of $Ba(OH)_2$ by 2.	1