Section A

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

A1 **(a)** Select elements from the list to answer the following questions.

You may use each element once, more than once or not at all.

potassium

copper

magnesium

iodine

aluminium

lithium

chlorine

(i) Which **two** elements react together most vigorously?

Potassium and chlorine .... [1]

(ii) Which element bleaches damp blue litmus paper?

chlorine .... [1]

(iii) Which element forms positive ions with different oxidation states?

copper .... [1]

(iv) Which element forms an amphoteric oxide?

aluminium .... [1]

(v) Which **two** elements form ions with the electron arrangement 2,8,8?

chlorine and potassium .... [1]

(b) The following are statements about groups and periods in the Periodic Table.

Put a tick (✓) in **one** box in each row to show which statements are **true** and which are **false**.

	true	**false**
The most unreactive group contains only non-metals.	✓	
Melting point increases across Period 2.		✓
Atoms lose electrons more easily down Group I.	✓	
The strongest non-metal oxidising agent is at the top of a group.	✓	

[3]

[Total: 8]

A2 Fractional distillation is used to separate the alkanes in crude oil.

Fig. 2.1 shows where some alkanes leave the fractionating column.

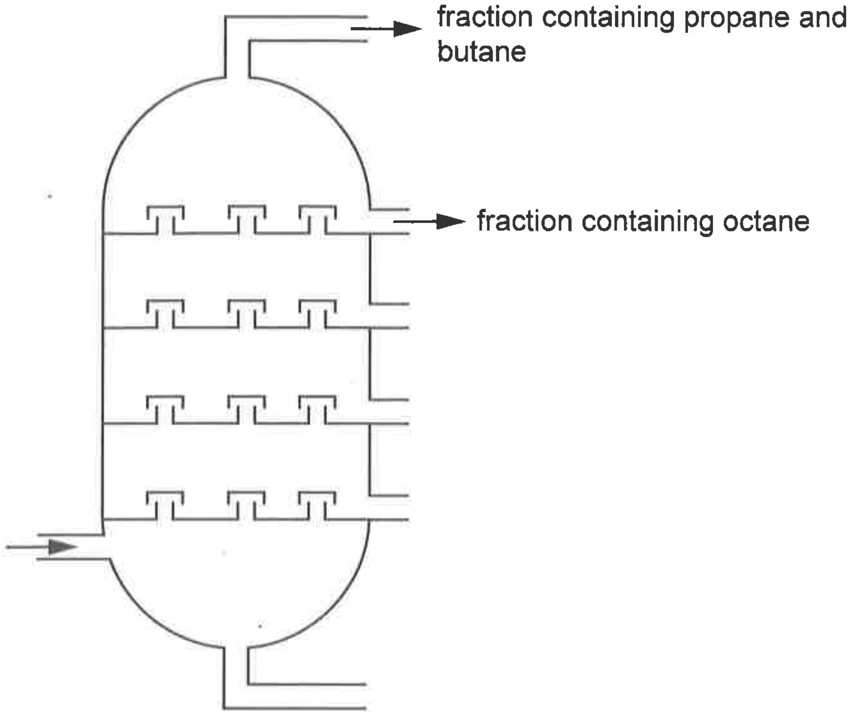


Fig. 2.1

(a) Describe how fractional distillation separates propane from octane.

As all the fractions in crude oil boils and enter as gas, the temperature is the highest at the bottom and lowest at the top of the fractionating column. Fractions like propane with a lower boiling point rises and condense at the top of the column, which octane with a higher boiling point rises and condense at the petrol fraction. As the temperature is different at different parts column, each molecule condenses at different parts of the column through selective condensation. [3]

(b) Explain why propane and butane leave the column in the same fraction.

Both propane and butane have similar low relative molecular masses and their boiling points fall within the range in the fraction. Hence, both molecules condense with the same range of temperature in the same fraction. [1]

(c) Complete Table 2.1 to show the molecular formula and empirical formula of propane and the empirical formula of octane.

Table 2.1

compound	molecular formula	empirical formula
propane	C_3H_8	C_3H_8
octane	C_8H_{18}	C_4H_9

[2]

(d) Octane is the main component in petrol used in cars.

However, some cars use LPG (Liquefied Petroleum Gas) fuel. The main component of LPG fuel is butane.

Table 2.2 shows the enthalpy change of combustion when one mole of octane and one mole of butane are completely burned.

Table 2.2

alkane	enthalpy change of combustion in kJ/mol
octane	–5470
butane	–2880

(i) Suggest reasons why the enthalpy change of combustion of octane is more negative than the enthalpy change of combustion of butane.

Both octane and butane have a negative enthalpy change of combustion as heat energy is released upon combustion. The amount of heat energy released by combustion of octane is higher due to the increase in the number of carbon and hydrogen atoms. As such, the net amount of heat energy released from the increased in the formation of carbon dioxide and water molecules ~~is larger than the amount of energy absorbed from~~ is higher in octane than butane

[2]

(ii) Calculate the mass of butane that gives the same amount of energy when combusted as 50.0 kg of octane.

Give your answer to **three** significant figures.

mol of octane $= \frac{50000}{114}$

$= 438.596$

Energy obtained $= 438.596 \times 5470$

$= 2.39912 \times 10^6$

mol of butane $= \frac{2.39912 \times 10^6}{2880}$

$= 833.03$ mol

mass $= 833.03 \times (58)$

$= 48315$ g

≈ 48.3 kg

mass of butane = 48.3 kg [3]

[Total: 11]

A3 Table 3.1 shows information about some electrolysis experiments.

Table 3.1

experiment	negative electrode	positive electrode	electrolyte	substance formed at negative electrode	substance formed at positive electrode
1	carbon	carbon	dilute aqueous sodium chloride	hydrogen	oxygen
2	carbon	carbon	concentrated aqueous sodium chloride	hydrogen	chlorine
3	silver	silver	dilute aqueous copper(II) sulfate	copper	oxygen
4	copper	copper	dilute aqueous copper(II) sulfate	copper	copper(II) ions

(a) Complete Table 3.1 by filling in the missing information. [2]

Silver

(b) Use examples from the table to explain the difference between an inert electrode and an electrode that is not inert.

In experiments 1 and 2, inert electrodes of carbon are used where the electrodes do not participare in the electrolytic cell. However in experiments 3 and 4, the reactive/non-inert electrodes take part in the electrolytic experiment as the positive electrode dissolves to form positive ions (Ag^+ in experiment 3) and (Cu^{2+} in experiment 4) [2]

(c) **(i)** Describe the change that would be **seen** at the negative electrode during experiment 3.

Reddish-brown deposit were found on the silver electrode and the electrode increases in size [1]

(ii) Write an ionic equation for the reaction at the positive electrode in experiment 3.

$$4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$$

[1]

(iii) Describe and explain the colour change of the solution during experiment 3.

Blue colour solution fades away due to the preferential discharge of Cu^{2+} ions in the solution at the negative electrode, lowering concentration of Cu^{2+} ions. Cu^{2+} ions are responsible for the blue solution. [2]

[Total: 8]

A4 Iron is extracted from iron ore in a blast furnace.

Fig. 4.1 shows the substances that enter and leave a blast furnace.

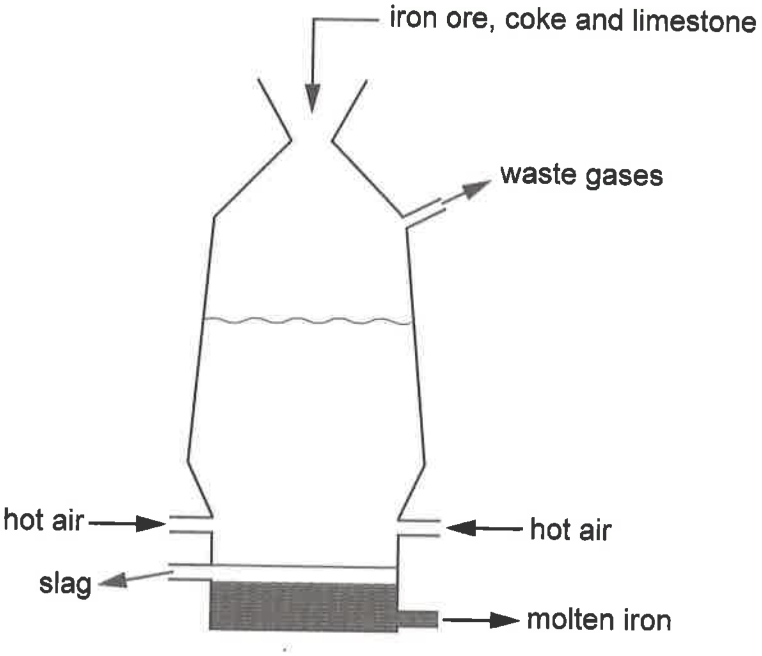


Fig. 4.1

(a) Give the name and the formula for the main compound in the slag.

name ....calgium sillcate........

formula ....$CaSiO_3$........

[1]

(b) Iron ore contains iron(III) oxide, Fe_2O_3.

(i) Calculate the maximum mass of iron that could be produced from 14 000 tonnes of iron(III) oxide.

1 tonne = 1 000 kg

Moles of $Fe_2O_3 = \frac{14000 \times 10^6}{160}$

$= 8.75 \times 10^7$ mol

1mol Fe_2O_3 : 2 mol Fe

Mass of Fe $= 2 \times 8.75 \times 10^7 \times 56$

$= 9800 \times 10^9$ g

[3]

(ii) 14 000 tonnes of iron ore produce much less iron than the value calculated in **(b)(i)**.

Suggest reasons why.

Iron ore contains impurities like SiO_2. As such, the number of moles of Fe_2O_3 is lower than expected, leading to a lower moles and mass of Fe obtained [1]

Pure oxygen that are blown into molten iron to oxidise the impurities, might react with molten iron, leading to lower mass of iron obtained [1]

[2]

(c) Table 4.1 shows the composition of the main waste gases that leave the furnace.

Table 4.1

gas	percentage composition
nitrogen	55
carbon dioxide	21
carbon monoxide	20

Describe and explain the source of each of these gases.

Nitrogen comes from the hot air blasts in the blast furnace which did not react with any substance. Carbon monoxide is produced from the reduction of carbon dioxide with coke, and the excess CO leaves the furnace. Carbon dioxide is produced from the combustion of coke, decomposition of limestone and reduction of haematite ore

[3]

(d) Molten iron from the blast furnace contains carbon. The carbon is removed from the iron.

Carefully controlled amounts of carbon are then added to make steel.

[Explain why carbon is added to iron] and [why the amounts added must be carefully controlled.]

Carbon is added to iron for alloying to make steel, which is harder and stronger than pure iron [1]

Careful amounts of carbon are added to iron as low amount of carbon are softer, more easily shaped while high amounts of carbon are stronger and harder but more brittle [1]

[2]

[Total: 11]

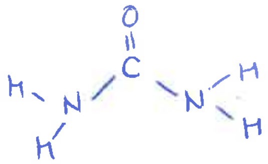
A5 A new system for treating the exhaust emissions of diesel cars has been developed.

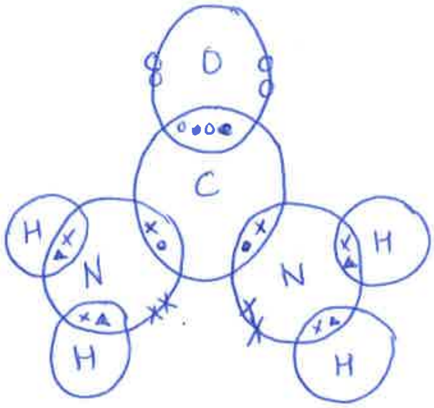
The system injects a fluid called DEF (Diesel Exhaust Fluid) into the hot exhaust gases.

DEF contains an aqueous solution of urea, $(NH_2)_2CO$.

(a) Draw a 'dot-and-cross' diagram for urea, $(NH_2)_2CO$.

Show outer electrons only.





[3]

(b) When the DEF is injected into the hot exhaust gases, the high temperature causes the reaction shown in equation 1.

equation 1 ✓ $(NH_2)_2CO + H_2O \rightarrow \underline{2NH_3} + CO_2$ × 4

The ammonia formed reacts with nitrogen oxides in the exhaust gases.

equation 2 $4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$

equation 3 ✓ $\underline{8NH_3} + 6NO_2 \rightarrow 7N_2 + 12H_2O$

(i) The DEF is stored in a tank in the car away from the hot engine.

If this tank becomes too hot, it could cause an explosion.

Use equation 1 to explain why.

~~When the temperature is too high~~, DEF decomposes to form 3 moles of gas. When the temperature gets too high, more moles of gaseous products leading to a larger volume of gases are formed in the tank. This larger volume of gases lead to a buildup in pressure, causing the risk of explosion.

[1]

(ii) State, with reasons, **two** benefits to the environment of using DEF to treat exhaust gases.

Refer to the reactants and products of equation 2 and equation 3 in your answer.

DEF helps to remove the ~~reactants~~ in air pollutants of NO and NO_2 in reactants in equations 2 and 3. This is important as oxides of nitrogen can react with oxygen and rainwater to form acid rain, corroding limestone buildings [1]

Using DEF produces N_2 and H_2O in the products, which are clean gases and do not pollute the environment [1] [2]

(iii) Suggest and explain **one** reason why using DEF does **not** solve all environmental problems caused by the exhaust gases.

In equation 1, carbon dioxide gas is produced. As carbon dioxide is a greenhouse gas, it traps heat. Large volumes of carbon dioxide gas will lead to an increase in average temperature causing global warming, causing polar ice caps to melt. [2]

(iv) Write an overall equation for the reaction of urea with NO_2.

$$4(NH_2)_2CO + 6NO_2 \rightarrow 7N_2 + 8H_2O + 4CO_2$$

[2]

(c) A motorist buys a 500 cm^3 bottle of DEF.

The label says that the bottle contains 160 g of urea.

Calculate the concentration of urea in mol / dm^3.

M_r of urea $= 2\times(14+2)+12+16$

$= 32+12+16$

$= 60$

mole of urea $= \frac{160}{60}$

$= 2.6667$

Concentration $= \frac{2.6667}{\frac{500}{1000}} = 5.33$ mol/dm^3

concentration of urea = 5.33 mol / dm^3 [2]

[Total: 12]

Section B

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

The last question is in the form of an either/or and only one of the alternatives should be attempted.

B6 Acids and pH

Solutions of different acids of the same concentration (in mol / dm^3) have different properties. The concentration of hydrogen ions, the pH and the rate of reaction with metals and carbonates may be different, even when the initial concentration of the acid is the same.

Table 6.1 gives information about solutions of acids at different concentrations.

Table 6.1

name of acid	concentration of acid in mol / dm^3	concentration of hydrogen ions in solution in mol / dm^3	pH
hydrochloric acid	0.01 ✓	0.01	2.0 ✓
	0.10	0.10	1.0
	0.20	0.20	0.7
sulfuric acid	0.01 ✓	0.02	1.7 ✓
	0.02	0.04	1.4
ethanoic acid	0.01 ✓	0.0004	3.4 ✓
	0.05	0.0009	3.0
	0.10	0.0013	2.9

General Equations for Reactions of Acids

Some sources, such as text books and websites, represent the general formula of an acid as HA, where A is an anion. HA can be used to give general equations for the reactions of acids.

For example, the reaction of acids with Group II metal hydroxides may be shown as:

equation 1 $2HA + M(OH)_2 \longrightarrow MA_2 + 2H_2O$

And the reaction of acids with any metal can be shown as:

equation 2 $xHA + M \longrightarrow MA_x + \frac{x}{2}H_2$

where x is the value of the positive charge on the metal ion.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

(a) **(i)** Which acids in Table 6.1 fit the general formula HA and which do not?

Explain your reasoning with reference to the ions present in each acid.

Hydrochloric acid and ethanoic acid [1] fits the geneal formula Hydrochloric acid completely ionises in water to form H^+ and Cl^- ions, while ethanoic acid ionises partially in water to form H^+ and CH_3COO^- ions Both acids produces positively chaged H^+ ions and negatively charged of $^{1-}$ anions Sulfuric acid do not fit the formula as the $SO_4{}^{2-}$ anion has charged of 2-. [2]

(ii) Construct a general equation for the reaction of an acid with Group I carbonates.

Use HA as the general formula for an acid and M as the symbol for a Group I metal.

$$2HA + M_2CO_3 \longrightarrow 2MA + H_2O + CO_2$$

[1]

(iii) Write an equation for the reaction of calcium with ethanoic acid.

Show, with reference to the value of *x*, why equation 2 agrees with your equation.

$$Ca + 2CH_3COOH \rightarrow (CH_3COO)_2Ca + H_2 \quad [1]$$

equation 2:

$$xHA + M \rightarrow MA_x + \frac{x}{2}H_2$$

when $x = 2$ where M is Group II,

$$2HA + M \rightarrow MA_2 + H_2$$

This is similar when A is equals to CH_3COO^-.

[2]

(b) **(i)** A student looks at the data in Table 6.1 and suggests the following relationship.

$$\text{pH} \propto \frac{1}{\text{initial concentration of the acid}}$$

Use the data to show that this relationship is incorrect.

when the initial concentrations of hydrochloric acid, sulfuric acid and ethanoic acid were 0.01 mol/dm^3, the pH of the acids were 2.0, 1.7 and 3.4 respectively which proves that the relationship is incorrect. Based on the relationship, if the initial concentration of acid were all 0.01 mol/dm^3, the pH of all 3 acids should be the same. [2]

(ii) State and explain the factors that affect the pH of an acid using information from Table 6.1.

1. The strength of acid affects the pH. Strong acids like HCl and H_2SO_4 ionises completely in water to give a high concentration of H^+ ions, resulting in low pH of 2.0 or lower whereas weak acids like CH_3COOH ionises partially to give a low concentration of H^+ ions, resulting in higher pH > 2.0.

2. The higher the concentration of acid, the lower the pH value. As concentration of HCl increases from 0.01 to 0.2 mol/dm^3, pH decreases from 2 to 0.7 due to higher concentration of H^+ ions produced. [3]

(iii) Complete Table 6.2.

Use the data in Table 6.1 to help you.

Table 6.2

acid	concentration of acid in mol/dm^3	concentration of hydrogen ions in solution in mol/dm^3	predicted pH
hydrochloric acid	0.04	0.04	1.4
sulfuric acid	0.05	0.10	1.0

[2]

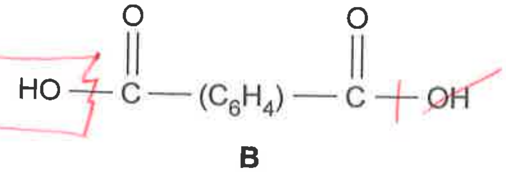
3. The higher the concentration of H^+ ions in solution, the lower the pH as shown in ethanoic acid, as concentration of H^+ increases from 0.0004 to 0.0013, pH decreases from 3.4 to 2.9.

[Total: 12]

B7 **(a)** Molecule **A** and molecule **B** react together to make a condensation polymer.

$HO-(CH_2)_4-OH$

A

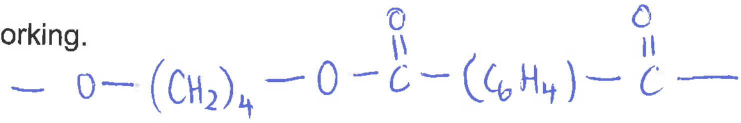


$HO-\overset{\overset{O}{\|}}{C}-(C_6H_4)-\overset{\overset{O}{\|}}{C}-OH$

B

(i) What is the relative molecular mass of the repeating unit of the polymer formed from molecules **A** and **B**?

Show your working.



$-O-(CH_2)_4-O-\overset{\overset{O}{\|}}{C}-(C_6H_4)-\overset{\overset{O}{\|}}{C}-$

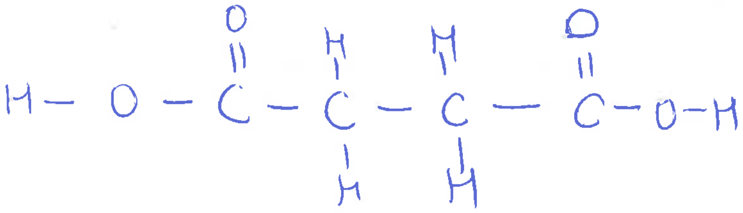
$M_r = 16 + 4(14) + 16 + 12 + 16 + (6\times12 + 4) + 12 + 16$

$= 220$

[2]

(ii) Molecule **A** has two alcohol groups. Each alcohol group can be oxidised by acidified potassium manganate(VII).

Draw the structure of the compound formed when molecule **A** is oxidised using excess acidified potassium manganate(VII).



$H-O-\overset{\overset{O}{\|}}{C}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{O}{\|}}{C}-O-H$

[2]

(b) Fig. 7.1 shows how molecule **C** polymerises to make another condensation polymer.

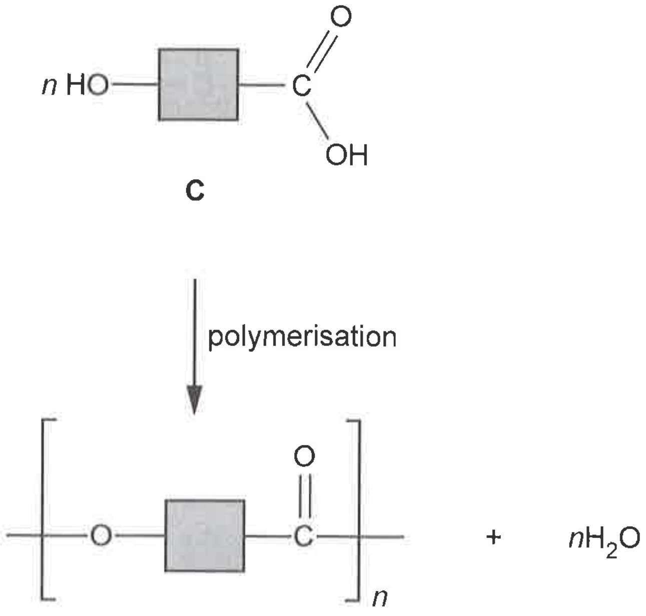


Fig. 7.1

(i) The polymer formed from molecule **C** is a type of polyester.

Explain how the structure of the polymer shows that it is a polyester.

The polymer structure contains more than one/ multiple/ ester linkages $-\overset{O}{\overset{\|}{C}}-O$ which resembles a polyester.

[1]

(ii) The condensation polymerisation of molecule **C** can be compared with the addition polymerisation of ethene.

Outline **one** similarity and **two** differences between the condensation polymerisation of molecule **C** and the addition polymerisation of ethene.

One similarity is that both types of polymerisation involves only one type of monomer, $HO-\square-\overset{O}{\overset{\|}{C}}-OH$ for C and C_2H_4 for ethene.

In addition polymerisation of ethene, there is no loss of atoms or molecules in the products whereas in condensation polymerisation of C, small molecules like H_2O is lost in the products.

[3]

In addition polymerisation of ethene, only one functional group of C=C double bond is involved, whereas in condensation polymerisation of C, two functional groups $-OH$ and $\overset{O}{\overset{\|}{C}}-OH$ are involved in the formation of polyester.

[Total: 8]

EITHER

B8 Some cars have components made from an alloy of aluminium and silicon.

Silicon is extracted from silicon dioxide in sand by heating the sand to 2000 °C in a furnace with carbon. The reaction is shown.

$$SiO_2 + 2C \rightarrow Si + 2CO$$

Sand also contains small amounts of aluminium oxide. Aluminium oxide remains in the silicon after the reaction with carbon and further processes are needed to remove it.

(a) What conclusions can you make from this information about the relative reactivity of carbon, silicon and aluminium?

Use ideas about reduction to explain your answer.

Carbon is more reactive than silicon as it is able to reduce Sillion in SiO_2 to Si. Oxidation state of Si in SiO_2 decreases from +4 to 0 in Si. As aluminium oxide remains, this shows that carbon is less reactie than aluminium as it is unable to reduce Al in Al_2O_3. Oxidation state of Al in Al_2O_3 remains +3. Hence relative reactivity increases from Si to C to Al, with Al being most reactive [2]

(b) Table 8.1 shows information about some oxides of carbon, silicon and aluminium.

Table 8.1

oxide	melting point / °C	boiling point / °C	density at room temperature and pressure in g / cm^3	electrical conductivity
carbon monoxide	–205	–192	0.002	Does not conduct in any state.
silicon dioxide	1600	2230	2.65	Does not conduct in any state.
aluminium oxide	2000	2980	3.99	Conducts when molten.

Use ideas about bonding and structure to explain the differences between the properties of the oxides of carbon, silicon and aluminium.

Bonding [3]

Carbon monoxide has very low melting and boiling points whereas silicon dioxide and aluminium oxide both have high melting and boiling points. Carbon monoxide has a simple covalent structure with discrete molecules while silicon dioxide has a giant covalent structure and aluminium oxide has a giant ionic structure. The low melting and boiling point in CO is due to little amount of energy required to overcome the weak intermolecular forces of attraction between CO molecules. The high melting and boiling point in SiO_2 is due to a large amount of energy required to break the network of strong covalent bonds between Si and O atoms

The high melting and boiling point in Al_2O_3 is due to large amount of energy required to overcome the strong electrostatic forces of attraction between oppositely charged ions

Electrical conducting [1]

CO and SiO_2 do not conduct electricity at any state because there are no mobile ions or mobile electrons available to function as charged carriers. However, in molten Al_2O_3, the ionic structure is broken down and there are mobile Al^{3+} and O^{2-} ions to function charged carries

density [1]

CO has a low density because it exists as a gas at room temperature, occupying a much larger volume in the same given mass. SiO_2 and Al_2O_3 have a much larger density because they exist as solids at room tempeature, occupying a smaller volume in the same given mass compared to CO.

[5]

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

(c) Aluminium–silicon alloys contain aluminium mixed with silicon and other elements.

Table 8.2 shows information about the composition of some aluminium–silicon alloys.

Table 8.2

alloy	percentage by mass of silicon	percentage by mass of elements other than silicon and aluminium
X	<16	7
Y	16–19	8
Z	22–24	6

100 g of an aluminium–silicon alloy is analysed and found to contain 2.8 mol of aluminium.

Identify the alloy, **X**, **Y** or **Z**, using the information in Table 8.2.

Show your working.

Alloy Y

mass of Al $= 2.8 \times 27$
$= 75.6\text{g}$ [1]

% by mass of Si and other elements $= \frac{100 - 75.6}{100} \times 100\%$
$= 24.4\%$ [1]

In alloy Y:
% by mass of Si and other elements ranges from 24% to 27%

16 + 8 to 19 + 8

In alloy Z; % by mass of Si and other elements ranges from 28% - 30%

In alloy X, % by mass of Si and other elements ranges from <23%.

[3]

[Total: 10]

OR

B8 The ‘iodine clock’ reaction is an experiment that is used to investigate rates of reaction.

Aqueous iodide ions are mixed with other reactants and a series of reactions takes place to produce iodine.

The solution turns blue-black when a fixed amount of iodine has been produced.

The conditions of the reaction are changed by changing the concentration of iodide ions or temperature or by adding a catalyst.

These changes affect the time taken for the solution to turn blue-black.

Table 8.3 shows the conditions and results for a series of experiments.

Table 8.3

experiment	concentration of iodide ions used in mol / dm^3	temperature / °C	catalyst added to reaction mixture	time taken for blue-black colour to appear / s
1	0.1	20	none	50
2	0.2	20	none	27
3	0.2	40	none	15
4	0.2	20	Cu^{2+} ions	20

(a) One of the experiments is used as a reference to compare the effect of the variables.

Which experiment is used as a reference?

Explain how you made your choice.

Experiment 2.

Experiment 2 was used as a reference with experiment 1 to compare the effect of changing concentration of I^- on the time taken for solution to turn blueblack

Experiment 2 was used as a reference with experiment 3 to compare the effect of changing temperature of mixture on the time taken [2]

Experiment 2 was used as a reference with experiment 4 to compare the effect of adding catalyst of Cu^{2+} ions on the time taken.

(b) Use ideas about collisions between particles to explain why changing the conditions shown in Table 8.3 changes the time taken for the blue-black colour to appear.

When concentration was decreased from 0.2 to 0.1 mol/dm^3 in experiment 1, the number of I^- ions per unit volume decreases. As such, the particles collide less frequently and the frequency of effective collisions decreases, causing the rate of reaction to decrease, shown ~~the~~ by the increase in time taken from 27 to 50 s. [2]

When temperature was increased from 20°C to 40°C in experiment 3, particles gain more kinetic energy and move faster. There are more particles with energy greater or equals to activation energy, leading to the increase in the frequency of effective collisions, causing the rate of reaction to increase, shown by the decrease in time taken from 27 to 15 s. [2]

[5]

When a catalyst Cu^{2+} ions was added in experiment 4, an alternative pathway of lower activation energy was provided, allowing more particles with energy greater or equals to activation energy, leading to an increase in frequency of effective collisions, causing the rate to increase, shown by the decrease in time from 27 s to 20 s. [1]

(c) The equation shows the reaction that produces iodine.

$$2I^-(aq) + H_2O_2(aq) + 2H^+(aq) \longrightarrow I_2(aq) + 2H_2O(l)$$

In every experiment the volume of aqueous iodide ions used is 10 cm^3 and acid is added in excess.

In every experiment 30 cm^3 of 0.05 mol/dm^3 aqueous hydrogen peroxide is used.

Which is the limiting reactant at the start of each experiment?

Show your working.

No. of mols of H_2O_2 $= \frac{30}{1000} \times 0.05$
$= 1.50 \times 10^{-3}$ mol [1]

Mols of I^- required $= 1.50 \times 10^{-3} \times 2$
$= 3.00 \times 10^{-3}$ mol [1]

In experiment 2, 3 and 4

mols of I^- used $= 0.2 \times \frac{10}{1000}$
$= 2.00 \times 10^{-3}$ mol

In experiment 1

mols of I^- used $= 0.1 \times \frac{10}{1000}$
$= 1.00 \times 10^{-3}$ mol [1]

Since the ~~concentrat~~ no. of mols of I^- used in experiments 1, 2, 3 and 4 are less than the no. of mols of I^- needed (3.00×10^{-3}), I^- is the limiting reactant.

[3]

[Total: 10]