1

Carbon capture is the name given to some processes used to prevent carbon dioxide entering the atmosphere. Carbon capture is carried out because carbon dioxide is a greenhouse gas.

Flue gases in chimneys contain carbon dioxide produced from burning fossil fuels. Various different compounds can be used to react with the carbon dioxide to capture it. Alternatively, carbon dioxide can be separated from other gases by a physical process.

Many sources of natural gas contain carbon dioxide, which can be removed by freezing.

Captured carbon dioxide must then be stored to prevent it entering the atmosphere. It can be injected into depleted oil and gas formations, or into porous rocks full of salt water. These are usually over 1 km below the Earth's surface and have non-porous rocks above them. Eventually the carbon dioxide dissolves, forming carbonate ions and then new minerals.

(a) Greenhouse gases can absorb infrared radiation. Explain why carbon dioxide absorbs infrared radiation but oxygen cannot.

(2)

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(b) A solution of the compound aminoethanol, $H_2NCH_2CH_2OH$, can be used to absorb carbon dioxide.

$$2H_2NCH_2CH_2OH + CO_2 + H_2O \rightleftharpoons (H_3NCH_2CH_2OH)_2CO_3$$

(i) Explain why aminoethanol is soluble in water.

(1)

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(ii) The position of this equilibrium moves to the left on heating. This frees the captured carbon dioxide for storage. Use this information to decide whether the forward reaction is exothermic or endothermic. Explain your answer.

(2)

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(c) The composition of a sample of natural gas and the melting temperatures of four of its components are shown below.

	Percentage	Melting temperature / K
Methane	95.2	91.1
2-methylpropane	0.8	113.7
Butane	0.9	134.7
Other hydrocarbons	2.4	
Carbon dioxide	0.7	216.5

(i) Draw a dot and cross diagram for carbon dioxide.

(2)

(ii) The London forces between molecules of carbon dioxide are stronger than the London forces between molecules of methane. Suggest a reason for this.

(1)

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(iii) Use your knowledge of intermolecular forces to suggest why butane has a higher melting temperature than 2-methylpropane.

(2)

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(d) When carbon dioxide dissolves, it may eventually form minerals such as magnesium carbonate and calcium carbonate.

(i) State the results of flame tests carried out on these two minerals.

(2)

Magnesium carbonate .....

Calcium carbonate .....

*(ii) Magnesium carbonate and calcium carbonate both undergo thermal decomposition, but they have different stability to heat. The difference in stability to heat can be compared in an experiment.

Suggest how this experiment could be carried out. You should indicate

- how to detect when the thermal decomposition occurs
- the measurement you would make to compare the stability to heat
- how to make the comparison fair.

You may include a diagram if you wish but it is not essential.

(4)

*(iii) State and explain which of the two carbonates is more stable to heat.

(3)

(Total for Question = 19 marks)

2 The melting temperatures of the elements of Period 3 are given in the table below. Use these values to answer the questions that follow.

Element	Na	Mg	Al	Si	P (white)	S (monoclinic)	Cl	Ar
Melting temperature / K	371	922	933	1683	317	392	172	84

(a) Explain why the melting temperature of sodium is very much less than that of magnesium.

(3)

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(b) Explain why the melting temperature of silicon is very much greater than that of white phosphorus.

(3)

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(c) Explain why the melting temperature of argon is the lowest of all the elements of Period 3.

(1)

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(d) Explain why magnesium is a good conductor of electricity whereas sulfur is a non-conductor.

(2)

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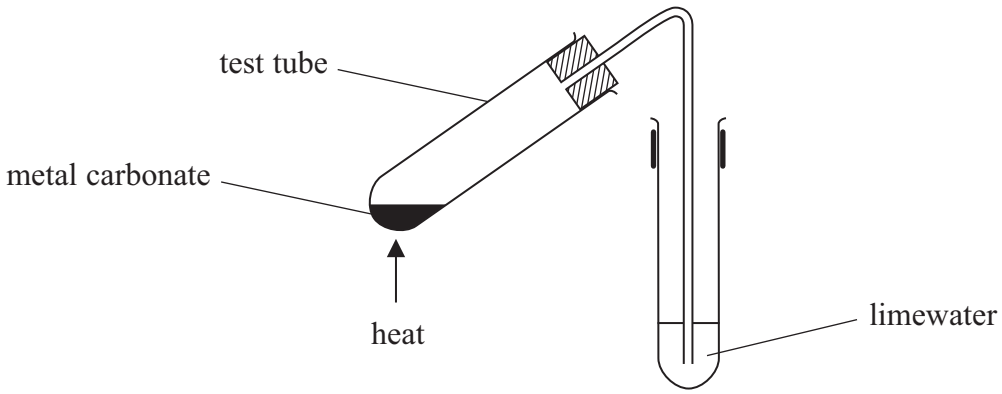
(Total for Question 9 marks)

3 The carbonates of Group 2 in the Periodic Table decompose on heating to form the corresponding metal oxide and carbon dioxide. A general equation for the reaction is

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

The thermal stability of these carbonates can be compared in the laboratory using the apparatus in the diagram below. The test tube on the left contains a sample of a metal carbonate and the tube on the right contains limewater.



(a) (i) State the measurement that you would make in this experiment.

(1)

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(ii) Suggest **three** ways to make sure that, when carrying out this experiment, the thermal stabilities of the different carbonates are compared fairly.

(3)

1 .....

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2 .....

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3 .....

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(b) (i) State the trend in the thermal stability of the metal carbonates as the group is descended.

(1)

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*(ii) Explain this trend in stability.

(3)

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(Total for Question 8 marks)

4 Magnesium nitrate, $Mg(NO_3)_2$, decomposes when it is heated. One product is the brown gas, nitrogen dioxide.

(a) (i) Write an equation for this reaction. State symbols are **not** required.

(2)

(ii) Calcium nitrate decomposes in a similar way to magnesium nitrate, but at a higher temperature.

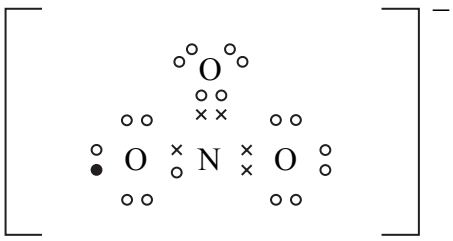
Explain why the two nitrates have different stability to heat.

(2)

(b) Sodium nitrate decomposes to give different products to magnesium nitrate. Write an equation for the decomposition of sodium nitrate. State symbols are **not** required.

(1)

(c) A student suggested that the structure of the nitrate ion, NO_3^-, is



Scientists have found that the bonds between nitrogen and oxygen in the nitrate ion are all the same length. Is the student's suggestion supported by this evidence? Explain your answer.

(1)

(d) Nitrogen dioxide gas can dimerize to dinitrogen tetroxide, N_2O_4, a very pale yellow gas, as shown in the equation below.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ mol}^{-1}$$

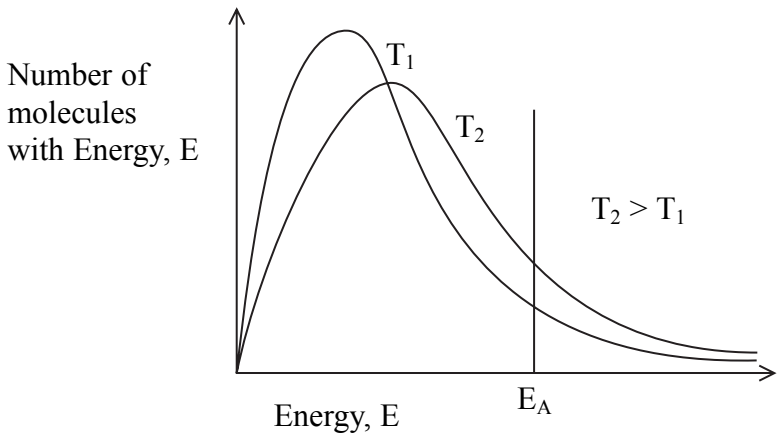
(i) What would you see when an equilibrium mixture of these gases is warmed gently? Explain your answer.

(2)

(ii) Explain why an equilibrium mixture of these gases eventually becomes paler in colour when the pressure on it is increased.

(2)

(e) Two Maxwell-Boltzmann distributions showing the energy of particles in a gas at different temperatures, T_1 and T_2, are shown below. The activation energy for the reaction is labelled E_A.



Use the distributions to explain why gases react faster when the temperature is increased.

(2)

(Total for Question = 12 marks)