

Cambridge AS & A Level

CHEMISTRY

Paper 2


Topical Past Paper Questions
+ Answer Scheme

2015 - 2021



Chapter 11

Group 17

 **PapaCambridge**

11.1 Physical properties of the Group 17 elements

62. 9701_m17_qp_22 Q: 2

Hydrogen halides are compounds formed when halogens (Group 17 elements) react with hydrogen. The bond polarity of the hydrogen halides decreases from HF to HI.

Some relevant data are shown in the table.

hydrogen halide	HF	HCl	HBr	HI
boiling point/°C	19	−85	−67	−35
H–X bond energy/kJ mol ^{−1}	562	431	366	299

(a) (i) Explain the meaning of the term *bond polarity*.

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.....

..... [1]

(ii) Suggest why the boiling point of HF is **much** higher than the boiling points of the other hydrogen halides.

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..... [2]

(iii) Describe and explain the relative thermal stabilities of the hydrogen halides.

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..... [3]

- (b) The equation for the preparation of hydrogen chloride using concentrated sulfuric acid is shown.



- (i) Use the Brønsted-Lowry theory of acids and bases to identify the base and its conjugate acid in this reaction. Explain your answer.

Brønsted-Lowry base (base-I) =

conjugate acid (acid-II) =

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.....
.....

[2]

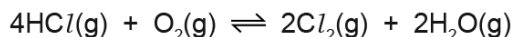
- (ii) Explain why the reaction of concentrated sulfuric acid and sodium iodide is not suitable for the preparation of hydrogen iodide.

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.....

[2]

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(c) Hydrogen chloride undergoes a reversible reaction with oxygen.



The reaction is carried out at 400 °C in the presence of a copper(II) chloride catalyst.

(i) Use the data in the table to calculate the overall enthalpy change of reaction.

compound	enthalpy change of formation / kJ mol ⁻¹
HCl(g)	-92
H ₂ O(g)	-242

enthalpy change of reaction = kJ mol⁻¹ [2]

(ii) State the **type** of catalyst used in this reaction. Explain how a catalyst is able to increase the rate of a chemical reaction.

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..... [2]

(iii) The reaction exists in dynamic equilibrium.

The reaction was repeated at 1000 °C and the same pressure.

State and explain the effect on the composition of the equilibrium mixture of the change in temperature.

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..... [2]

- (iv) When 1.60 mol of HCl are mixed in a sealed container with 0.500 mol of O_2 at 400°C , 0.600 mol of Cl_2 and 0.600 mol of H_2O are formed.

The total pressure inside the container is $1.50 \times 10^5 \text{ Pa}$.

- Calculate the amounts, in mol, of HCl and O_2 in the equilibrium mixture.

$\text{HCl} = \dots\dots\dots \text{ mol}$

$\text{O}_2 = \dots\dots\dots \text{ mol}$

- Calculate the mole fraction of Cl_2 and hence the partial pressure of Cl_2 in the equilibrium mixture.

mole fraction of $\text{Cl}_2 = \dots\dots\dots$

$p_{\text{Cl}_2} = \dots\dots\dots \text{ Pa}$
[3]



- (v) In a separate experiment, an equilibrium reaction mixture was found to contain the four gases at the partial pressures shown in the table.

gas	HCl	O ₂	Cl ₂	H ₂ O
partial pressure/Pa	4.8×10^4	3.0×10^4	3.6×10^4	3.6×10^4

$$K_p = \frac{(p_{Cl_2})^2 \times (p_{H_2O})^2}{(p_{HCl})^4 \times p_{O_2}}$$

Use this information and the expression given for K_p to calculate a value for K_p . State the units of K_p .

$K_p = \dots\dots\dots$

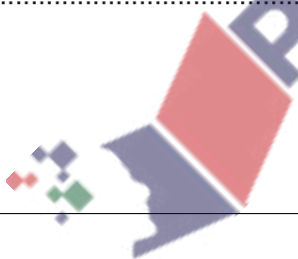
units = $\dots\dots\dots$ [2]

- (vi) The reaction is repeated without a catalyst.

State the effect of this on K_p .

$\dots\dots\dots$ [1]

[Total: 22]



63. 9701_w17_qp_22 Q: 3

The elements in Group 2 show trends in their properties that are typical of metals.
 The elements in Group 17 show trends in their properties that are typical of non-metals.

(a) State and explain the trend in ionisation energy down Group 2.

.....

 [2]

(b) (i) State and explain the trend in melting point down Group 17.

.....

 [2]

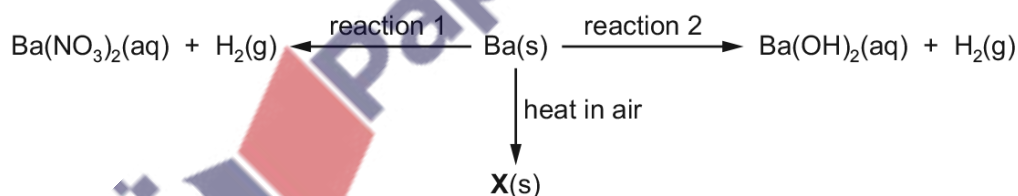
(ii) The melting point decreases down Group 2.

Explain this trend.

.....

 [2]

(c) Some reactions based on the Group 2 metal barium, Ba, are shown.



(i) State the reagent needed for each of reactions 1 and 2.

reaction 1
 reaction 2 [2]

(ii) Name X and write an equation for its formation.

name
 equation [2]

- (iii) The $\text{Ba}(\text{NO}_3)_2(\text{aq})$, produced by reaction 1, is heated to dryness. The anhydrous solid is then heated strongly and decomposes. Barium oxide is produced, together with two other products.

Identify the **two** other products of this decomposition reaction and state what would be observed.

.....
..... [2]

- (iv) State what would be observed when excess $\text{MgSO}_4(\text{aq})$ is added to the $\text{Ba}(\text{OH})_2(\text{aq})$ produced in reaction 2. Explain your answer.

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

[Total: 15]

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11.2 The chemical properties of the elements and their hydrides

64. 9701_s19_qp_22 Q: 2

Group 17 elements are commonly referred to as the halogens.

(a) State and explain the trend in volatility of chlorine, bromine and iodine down the group.

.....

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.....

..... [3]

Hydrogen gas reacts with the different halogens under different conditions.

(b) (i) State the conditions required for chlorine to react with hydrogen at room temperature.

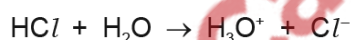
..... [1]

(ii) On heating, iodine reacts with hydrogen in a reversible reaction.

Give the equation for this reaction. Include state symbols.

..... [2]

(c) Hydrogen chloride reacts with water.



(i) In this reaction, one of the reactants behaves as a Brønsted-Lowry acid.

What is meant by the term *Brønsted-Lowry acid*?

.....

..... [1]

(ii) Identify the reactant behaving as an acid and its conjugate base.

acid

conjugate base [1]

(iii) Name the type of bond formed between H^+ and H_2O to make H_3O^+ .

..... [1]

(iv) For H_3O^+ , predict its shape and the H–O–H bond angle.

shape

bond angle [2]

[Total: 11]

65. 9701_s16_qp_22 Q: 2

The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

element	bond energy /kJ mol ⁻¹	standard enthalpy change of atomisation, $\Delta H_{\text{at}}^{\ominus}$ /kJ mol ⁻¹	boiling point of element /K	boiling point of hydrogen halide /K
fluorine, F–F	158	79	85	293
chlorine, Cl–Cl	242	121	238	188
bromine, Br–Br	193	112	332	206
iodine, I–I	151	107	457	238

(a) (i) Explain the meaning of the term *standard enthalpy change of atomisation*.

.....

 [3]

(ii) For fluorine and chlorine, the enthalpy changes of atomisation are half the value of the bond energies.

For bromine and iodine, the enthalpy changes of atomisation are much more than half the value of the bond energies.

Suggest a reason for this difference.

.....

 [1]

(iii) The standard enthalpy of formation of iodine monochloride, ICl, is $-24.0 \text{ kJ mol}^{-1}$.

◆ Use this information and the bond energies of iodine and chlorine to calculate the I–Cl bond energy.

I–Cl bond energy = kJ mol⁻¹ [2]

- (b) (i) Explain the trend in the boiling points of the hydrogen halides, HCl, HBr and HI.

.....
.....
..... [2]

- (ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HCl, HBr and HI.

.....
.....
..... [2]

- (c) In an experiment, two of the halogens are represented as P_2 and Q_2 .

P_2 combines with hydrogen on heating to form HP, which can be easily broken down into its elements. A solution of HP in water reacts with aqueous silver ions to form a yellow precipitate that is insoluble in dilute aqueous ammonia.

Q_2 combines explosively with hydrogen in sunlight to form HQ, which is stable to heat. A solution of HQ in water reacts with aqueous silver ions to form a white precipitate that is soluble in dilute aqueous ammonia.

- (i) Identify the halogens P_2 and Q_2 .

P_2 = Q_2 = [1]

- (ii) HP readily decomposes into its elements when heated but HQ is stable to heat. Explain this with reference to bond energies.

.....
.....
..... [2]

- (iii) Write an equation for the thermal decomposition of HP.

..... [1]

(iv) Write ionic equations, including state symbols, for

1. the formation of the white precipitate on addition of aqueous silver ions to aqueous HQ,
.....

2. the subsequent dissolving of this precipitate in dilute aqueous ammonia.
.....

[2]

(d) Chlorine reacts directly with many elements to form chlorides. Three such compounds are $MgCl_2$, $AlCl_3$ and $SiCl_4$.

(i) State and explain the pattern shown by the formulae of these three chlorides.

.....
.....
..... [2]

(ii) Write equations to show the behaviour of each of these chlorides when added to water.

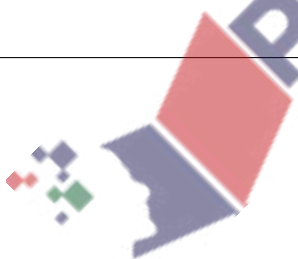
$MgCl_2$

$AlCl_3$

$SiCl_4$

[3]

[Total: 21]



11.3 Some reactions of the halide ions

66. 9701_s21_qp_21 Q: 3

Sodium halide salts react with concentrated sulfuric acid at room temperature.

(a) (i) Write an equation to represent the reaction of NaCl(s) with concentrated sulfuric acid.

..... [1]

(ii) Name this type of reaction.

..... [1]

(b) NaI(s) reacts with concentrated sulfuric acid, at room temperature, to form steamy fumes.

(i) Identify the chemical responsible for the steamy fumes.

..... [1]

(ii) The reaction of NaI(s) with concentrated sulfuric acid continues, forming several other products, including a dark grey solid.

Identify the chemical responsible for the dark grey solid and **one** other product of this further reaction.

dark grey solid

other product

[2]

(c) Explain the differences in observations, at room temperature, when NaI(s) reacts with concentrated sulfuric acid compared to those for NaCl(s).

.....
.....
..... [2]

(d) Complete the equation for the reaction of Br⁻ with excess concentrated H₂SO₄ at room temperature.

.....Br⁻ +H⁺ +H₂SO₄ → [1]

[Total: 8]

67. 9701_s21_qp_22 Q: 1

A Group 2 metal combines with bromine to form a crystalline solid, MBr_2 .

Excess aqueous AgNO_3 is added to a solution of MBr_2 and a precipitate forms. The mixture is filtered. The precipitate is dried and the mass of the precipitate is recorded.

(a) State the formula and colour of the precipitate.

..... [2]

(b) Complete the equation to represent the reaction between MBr_2 and AgNO_3 .

..... MBr_2 + AgNO_3 → [1]

(c) A 0.250 g sample of pure MBr_2 contains 8.415×10^{-4} mol MBr_2 .

Calculate the relative formula mass, M_r , of MBr_2 . Use this to identify **M**.

Show your working.

M_r =

M = [3]

(d) A sample of MBr_2 is dissolved in water. Chlorine gas is then bubbled into the solution.

(i) Describe the observations for this reaction.

..... [1]

(ii) Name the type of reaction that occurs when MBr_2 reacts with chlorine gas.

..... [1]

(e) Compound Y is a pure **insoluble** solid which contains halide ions.

A single reagent is added directly to compound Y to determine the halide ion present.

Identify the reagent added. State the observation which would confirm that Y contains bromide ions.

reagent

observation

[2]

(f) Separate 1.0g samples of three different magnesium salts are tested in order to identify the anion present in each sample.

(i) Explain how the action of heat is used to identify which sample is:

- $MgCO_3$
- $Mg(NO_3)_2$
- MgO .

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

(ii) Complete the electron configuration of the magnesium cation present in these salts.

$1s^2$ [1]

(g) A sample of $MgCO_3(s)$ is distinguished from a sample of $Mg(OH)_2(s)$ by adding a small amount of each solid to $HCl(aq)$.

State **one** similarity and **one** difference in these two reactions.

similarity

difference

[2]

[Total: 16]

68. 9701_m20_qp_22 Q: 2

The Group 17 elements, chlorine, bromine and iodine, are non-metals that show trends in their physical and chemical properties.

(a) Describe the trend in the colour of the Group 17 elements down the group.

.....
..... [1]

(b) The Group 17 elements can oxidise many metals to form halides.

(i) Describe the relative reactivity of the elements in Group 17 as oxidising agents.

.....
..... [1]

(ii) Chlorine reacts with hot tin metal to form tin(IV) chloride, SnCl_4 .

SnCl_4 is a colourless liquid at room temperature that reacts vigorously with water to form an acidic solution.

Suggest the type of structure and bonding shown by SnCl_4 . Explain your answer.

.....
.....
.....
.....
..... [2]

(c) The Group 17 elements form soluble halides with sodium.

(i) Describe what is seen when dilute $\text{AgNO}_3(\text{aq})$ is added to $\text{NaBr}(\text{aq})$ followed by aqueous ammonia.

.....
.....
..... [2]

- (ii) NaCl reacts with concentrated H_2SO_4 to form HCl and NaHSO_4 .

Explain the difference between the reactions of concentrated H_2SO_4 with NaCl and with NaI . Your answer should refer to the role of the sulfuric acid in each reaction.

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.....
.....
.....

[3]

- (d) The hydrogen halides are useful reagents in organic and inorganic reactions.

- (i) Describe and explain the trend in the boiling points of the hydrogen halides, HCl , HBr and HI .

.....
.....
.....
.....

[2]

- (ii) Describe and explain the trend in the thermal stabilities of the hydrogen halides, HCl , HBr and HI .

.....
.....
.....
.....

[2]

- (e) Lucas's reagent is a mixture of HCl and ZnCl_2 . Primary, secondary and tertiary alcohols can be distinguished by their reaction with Lucas's reagent.

Alcohols react with the HCl in Lucas's reagent to form halogenoalkanes.

ZnCl_2 acts as a homogeneous catalyst for these reactions.

- (i) Explain the meaning of the term *homogeneous*.

.....
 [1]

- (ii) Pentan-3-ol, $\text{C}_2\text{H}_5\text{CH}(\text{OH})\text{C}_2\text{H}_5$, reacts slowly with HCl to form a secondary halogenoalkane.

Complete the equation for this reaction using structural formulae.

$\text{C}_2\text{H}_5\text{CH}(\text{OH})\text{C}_2\text{H}_5 + \dots\dots\dots$ [1]

- (iii) The fastest reaction shown by Lucas's reagent is with a tertiary alcohol.

Draw the structure of the tertiary alcohol that is an isomer of pentan-3-ol.

[1]

- (iv) Tertiary alcohols tend to react with Lucas's reagent using the same mechanism as in their reaction with HCl .

Suggest the type of reaction shown by tertiary alcohols with Lucas's reagent.

..... [1]

[Total: 17]

69. 9701_s17_qp_23 Q: 2

The halogens, chlorine, bromine and iodine, and their compounds, show a variety of similarities and trends in their physical and chemical properties.

(a) (i) Give the colours and states of chlorine, bromine and iodine at room temperature and pressure.

halogen	colour	state
chlorine		
bromine		
iodine		

[2]

(ii) The halogens become less volatile down the group.

Explain this trend in volatility.

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.....
..... [2]

(b) The halogens are oxidising agents.

State and explain the trend in oxidising power of the halogens.

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..... [3]

(c) Concentrated sulfuric acid reacts with solid sodium halides.

(i) State any observations that would be made on addition of concentrated sulfuric acid to

- solid sodium chloride,
- solid sodium iodide.

[2]

- (ii) Give reasons for the difference in the observations in (i).

.....
.....
..... [2]

- (iii) The addition of concentrated sulfuric acid to solid sodium bromide, NaBr, produces brown fumes and an acidic gas that decolourises acidified potassium manganate(VII) solution. This acidic gas is a significant contributor to acid rain.

Write the equation for the reaction of concentrated sulfuric acid with sodium bromide.

..... [2]

- (d) An aqueous solution, Z, contains a mixture of sodium chloride and sodium iodide.

- (i) Excess aqueous silver nitrate is added to Z in a test-tube. A yellow precipitate forms.

Explain the colour of this precipitate.

.....
..... [1]

- (ii) Aqueous ammonia is then added to the test-tube in (i). The mass of precipitate decreases.

Explain this observation.

.....
..... [1]

[Total: 15]



11.4 The reactions of chlorine with aqueous sodium hydroxide

70. 9701_s21_qp_23 Q: 1

The elements in Group 17 are known as the halogens.

(a) Between the molecules of Group 17 elements van der Waals' forces exist.

(i) State the trend in the relative strength of van der Waals' forces down Group 17.

..... [1]

(ii) State the physical state of each of the halogens under room conditions.

chlorine

bromine

iodine

[1]

(b) A solution of aqueous bromide ions, $\text{Br}^-(\text{aq})$, is added to separate samples of $\text{Cl}_2(\text{aq})$ and $\text{I}_2(\text{aq})$.

Describe what is observed in each reaction. Explain your answer in terms of the relative reactivity of these elements as oxidising agents.

observation on addition to $\text{Cl}_2(\text{aq})$

observation on addition to $\text{I}_2(\text{aq})$

explanation

[3]

(c) Bleach is made by reacting Cl_2 with cold $\text{NaOH}(\text{aq})$.

Write an equation for the reaction of Cl_2 with cold NaOH .

..... [1]

(d) When ClO^- (aq) is added to water, it behaves as a Brønsted-Lowry base.

(i) Define the term *Brønsted-Lowry base*.

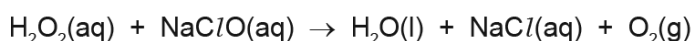
..... [1]

(ii) Write an ionic equation for the reaction between ClO^- and H_2O .

..... [1]

(e) The concentration of NaClO in bleach **S** is $x \text{ g dm}^{-3}$.

NaClO reacts with H_2O_2 (aq) as shown.



A 5.00 cm^3 sample of **S** completely reacts with H_2O_2 (aq). The volume of O_2 (g) produced is 24.0 cm^3 under room conditions.

Assume that only the NaClO in **S** reacts with H_2O_2 (aq).

Calculate x . Show your working.

$x = \dots\dots\dots \text{ g dm}^{-3}$
[3]

(f) Sodium chlorate(I), NaClO , oxidises dilute hydrochloric acid to form three products. The products which contain chlorine have chlorine species with oxidation number -1 or 0 .

No other species changes its oxidation number during the reaction.

Use this information to complete the ionic equation.



[Total: 13]

71. 9701_s18_qp_23 Q: 3

The elements in Group 17, the halogens, show trends in both their chemical and physical properties. The elements and their compounds have a wide variety of uses.

(a) At room temperature fluorine and chlorine are gases, bromine is a liquid and iodine is a solid.

(i) State the trend in the volatility of the Group 17 elements down the group.

..... [1]

(ii) Explain this trend.

.....

 [2]

(b) Iodine, I_2 , can be displaced from $NaI(aq)$, by chlorine, Cl_2 .

Write an equation for this reaction.

..... [1]

(c) Silver nitrate solution, $AgNO_3(aq)$, is added to separate solutions of NaI and $NaCl$. Precipitates form. An excess of aqueous ammonia is then added to both precipitates.

(i) Complete the table to give the colour and name of the precipitate formed in each reaction and the effect of the addition of an excess of aqueous ammonia to each of the precipitates formed.

	$NaI(aq) + AgNO_3(aq)$	$NaCl(aq) + AgNO_3(aq)$
colour of precipitate		
name of precipitate		
effect of addition of an excess of aqueous ammonia to the precipitate		

[3]

(ii) Write an ionic equation, including state symbols, to show the reaction occurring when $AgNO_3(aq)$ is added to $NaI(aq)$.

..... [1]

- (d) Solid NaI reacts with concentrated sulfuric acid to form purple fumes of $I_2(g)$ and hydrogen sulfide gas, $H_2S(g)$.
However, when solid NaCl reacts with concentrated sulfuric acid the only gas produced is $HCl(g)$.

Explain the difference in the reactions of concentrated sulfuric acid with NaI and with NaCl. Your answer should refer to the role of the sulfuric acid in each reaction.

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..... [3]

- (e) Chlorine is commonly used in water purification. When chlorine is added to water it reacts to produce a mixture of acids, one of which is chloric(I) acid, $HClO$, a powerful oxidising agent.

- (i) Explain the meaning of the term *oxidising agent*, in terms of electron transfer.

.....

.....

.....

..... [1]

- (ii) Suggest an equation for this reaction of chlorine with water.

..... [1]

- (iii) Write an equation for the reaction of chlorine with **hot** aqueous sodium hydroxide.

Use oxidation numbers to explain why this is a redox reaction.

equation

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.....

..... [2]

[Total: 15]

11.5 Some important uses of the halogens and of halogen compounds

72. 9701_s19_qp_22 Q: 3

Period 3 elements react with chlorine gas, $\text{Cl}_2(\text{g})$, to form chlorides.

(a) The table shows the differences in observations which occur when two Period 3 chlorides are added to water.

Period 3 chloride	observations when added to water	pH of solution formed with water
NaCl	White solid disappears. Colourless solution made.	7
SiCl_4	Pale yellow solution forms. Bubbles form and the test-tube feels hot. White precipitate forms.	1–2

(i) Write an equation for the reaction occurring when SiCl_4 is added to cold water. Include state symbols.

..... [1]

(ii) Name the type of reaction occurring when SiCl_4 is added to water. Ignore the exothermic/endothermic nature of the reaction.

..... [1]

(iii) Explain, in terms of bonding, why NaCl and SiCl_4 behave differently when added to water.

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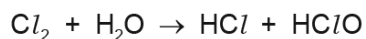
 [2]

(iv) Explain, in terms of electronegativity, why the bonding in NaCl is different from the bonding in SiCl_4 .

.....

 [3]

(b) $Cl_2(g)$ dissolves in cold water and reacts with it.



(i) Identify the oxidation number of chlorine in each of the chlorine-containing species in this reaction.

chlorine-containing species	Cl_2	HCl	$HClO$
oxidation number of chlorine			

[2]

(ii) Name the type of reaction occurring.

..... [1]

(iii) Explain why chlorine is used in the purification of water.

.....
 [1]

(c) A mixture of HCl and $HClO$ is added to cold dilute $NaOH$. One of the products behaves as a bleach.

Suggest the equation for the reaction occurring.

..... [2]

[Total: 13]

