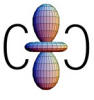
Lesson 4

Reactions of Group 2 metals

Objectives

- Describe the reactions of group two metals
- Write half equations for the reaction of group 2 metals with oxygen and water
- Describe the reactions of group two metal oxides
- Describe the reactions of group two metal hydroxides



Reactivity of group 2 elements

Group 2 elements are strong REDUCING agents

When they react they are OXIDISED

OIL – RIG

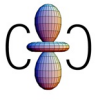
$M \rightarrow M^{2+} + 2e^-$

Predict the trend in reactivity going down the group

Reaction with oxygen

$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$

What are the oxidation numbers for each element before and after the reactions?



Reaction with water

$Ca(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + H_2(g)$

What are the oxidation numbers for each element before and after the reactions?

Group 2 oxides and hydroxides are bases and neutralise acids. When dissolved in water they have a high pH (10-11)

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$

$Ca(OH)_2(s) + 2HCl(aq) \rightarrow CaCl_2 + 2H_2O(l)$

AfL

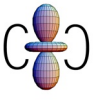
When you dissolve MgO in water it has a high pH. Explain why this is?

Answer

To have a high pH there must be hydroxide ions present.

When MgO is dissolved in water it reacts with the water to produce $Mg(OH)_2$

$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2\ (aq)$



Past paper question

4 Calcium hydroxide is used in agriculture but the amounts used must be carefully controlled.

(a) State **one** use of calcium hydroxide in agriculture **and** suggest why the amount of calcium hydroxide used should not be excessive.

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

Past paper question

4 Calcium hydroxide is used in agriculture but the amounts used must be carefully controlled.

(a) State **one** use of calcium hydroxide in agriculture **and** suggest why the amount of calcium hydroxide used should not be excessive.

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.....

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

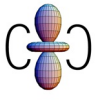
(b) A student knew that calcium hydroxide could be made by adding calcium to water.

The student added 0.00131 mol of calcium to a beaker containing about 100 cm^3 of water.
A reaction took place as shown by the equation below.
All the calcium hydroxide formed was soluble.

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

(i) Calculate the mass of calcium that the student added.

mass of calcium = ... g **[1]**



Past paper question

(ii) Calculate the volume of hydrogen gas, in dm^3, produced in this reaction at room temperature and pressure, RTP.

volume of hydrogen gas = ... dm^3 **[1]**

(iii) The student transferred the contents of the beaker to a 250 cm^3 volumetric flask and water was added to make the solution up to 250 cm^3.

Calculate the concentration, in mol dm^{-3}, of **hydroxide ions** in the 250 cm^3 solution.

concentration = ... mol dm^{-3} **[2]**

Past paper question

(c) The student repeated the experiment using the same mass of pure barium.

The student found that a smaller volume of hydrogen gas was produced, measured at RTP.

(i) Explain why.

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

(ii) Suggest **one** other difference the student would observe between the reactions of water with calcium and of water with barium.

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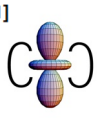
..... **[1]**



Mark scheme

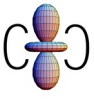
4	(a)		Used to neutralise **acidic** soils ✓ Excess will result in soils becoming **too** alkaline (to sustain crop growth) ✓	2	**ALLOW** raises the pH of the soil **IGNORE** references to fertilisers **ALLOW** pH becomes **too** high **IGNORE** 'harmful' **IGNORE** 'corrosive'
	(b)	(i)	0.00131 × 40.1 = 0.0525 g **OR** 5.25 × 10^{-2} ✓	1	**ALLOW** 0.053 **OR** 0.05253 **OR** 0.052531 g **IGNORE** 0.05 **if correct answer seen in working** **DO NOT ALLOW** 0.052 **OR** 0.0524
		(ii)	0 00131 × 24.0 = 0.0314 dm^3 **OR** 3.14 × 10^{-2} ✓	1	**ALLOW** 0.031 **OR** 0.03144 dm^3 **IGNORE** 0.03 **if correct answer seen in working** **DO NOT ALLOW** 31.4
		(iii)	Mol of OH^- ions = 0.00131 × 2 = 0.00262 **OR** 2.62 × 10^{-3} ✓ Mol of OH^- ions in 1 dm^3 = 0.00262 × $\frac{1000}{250}$ = 0.0105 mol dm^{-3} ✓	2	**ALLOW** 0.0026 **ALLOW** 0.01048 **OR** 0.01(0) **ALLOW ECF** from incorrect mol of OH^- **DO NOT ALLOW** 2nd mark as **ECF** if 0.0525 is used as no of mol of OH^- ions **DO NOT ALLOW** 2nd mark as **ECF** if 0.0314 is used as no of mol of OH^- ions 0.00524 mol dm^{-3} is a likely **ECF** as a result of not multiplying 0.00131 by 2, but 0.00131 must be seen in working
	(c)	(i)	**Fewer** moles of Ba (in 0.0525 g) **OR Fewer** atoms of Ba (in 0.0525) ✓	1	**ORA** Assume candidate is referring to Ba if not stated **IGNORE** A_r Ba > A_r Ca
		(ii)	Idea of Ba having a quick**er** rate **OR more** vigorous reaction ✓	1	**ALLOW more** exothermic **OR** gets hot**ter OR** fizzes more Assume candidate is referring to Ba if not stated Comparison is essential **IGNORE** 'Ba more reactive'

Group 2 carbonates

Thermal decomposition by heat – more difficult going down the group

$MgCO_3(s) \longrightarrow MgO\ (s) + CO_2\ (g)$

In other words THERMAL STABILITY increases as you go down the group.



Past paper question

(c) Group 2 elements and compounds show periodic trends. One trend is shown by the effect of heat upon Group 2 carbonates.

A student carried out an experiment to find out the volume of carbon dioxide obtained by heating a weighed sample of magnesium carbonate.

The student placed a 1.47 g sample of $MgCO_3$ into a test-tube and heated it until there was no further change in mass.

The following reaction took place.

$$MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$$

(i) What type of reaction is this?

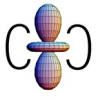
..... **[1]**

Past paper question

(ii) What volume of CO_2, in dm^3, would have been given off when measured at room temperature and pressure?

The molar mass of $MgCO_3$ = 84.3 g mol^{-1}

answer = ...dm^3 **[2]**



Mark scheme

c	i	**Thermal** decomposition ✓	1	**DO NOT ALLOW** just 'decomposition' or 'thermodecomposition'
	ii	1.47 = 0.0174 mol of $MgCO_3$ ✓ 84.3 $0.0174 \times 24.0 = 0.418\ dm^3$ **OR** (Calculator value × 24.0) = $0.419\ dm^3$ ✓	2	**ALLOW** mol of $MgCO_3$ as calculator value of 0.017437722 or correct rounding to 2 sig figs or more **DO NOT ALLOW** 0.0175 (this has taken M_r of $MgCO_3$ as 84) **ALLOW**, for 2nd mark **calculated moles of $MgCO_3$** × 24(.0) as calculator value or correct rounding to 2 sig figs or more [e.g. 0.017 × 24(.0) = 0.408] **DO NOT ALLOW** 84.3 or 1.47 × 24(.0) as no mole calculation has been done **ALLOW** two marks for correct answer with no working shown

Past paper question

(iii) The student repeated the experiment a further three times, using the same number of moles of $CaCO_3$, $SrCO_3$ and $BaCO_3$.

What trend in the behaviour of the Group 2 carbonates would be observed by the student?

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

Mark scheme

4	c	iii	The ease of (thermal) decomposition decreases (down the group) ora ✓	1	**ALLOW** (thermal) stability increases **IGNORE** more heat would be needed **IGNORE** 'takes longer' or 'is slower' **IGNORE** reference to trend in reactivity **IGNORE** answers which include 'more / less mol of CO_2'

How to write "half-equations"

A half equation shows the reagent being oxidised OR the reagent being reduced separately.

It shows what is happening to the electrons

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

$O_2 + 4e^- \rightarrow 2O^{2-}$

Attempt the half equation for the the reaction of Ca with H_2O

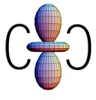
Plenary – reaction web

Using pages 88-91 of the text book to guide you draw a reaction web for the reactions of magnesium.

Complete question 4 on page 98 for homework.

Periodicity

Lesson 5 – practical experiments to investigate group 2 reactions

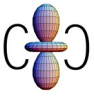


Objectives

- *Plan* and execute a practical experiment to investigate the reactions of group 2 metals oxides and hydroxides
- *Identify* the reactions taking place using the worksheet provided
- *Write-up* your practical including method, results and conclusion – this should include a description of how your results support or contrast with chemical theory

Periodicity

Lesson 6 - Halide ions



Must (C grade)
- Recognise that halogens react by gaining electrons to become halide ions
- Use the precipitation of silver halide as a test for halide ions
- Know some of the uses of halides

Should (B grade)
- Recap the reactivity series of halides – that halogens become less reactive down the group
- Interpret the tests for halide to determine whether a given solution is a chloride, bromide or iodide
- Write half equations for the reduction of halogens to form halide ions

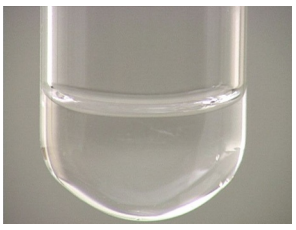
Could (A grade)
- Describe the displacement of halogens from halide salts according to the reactivity series of the halogens
- Write equations to show the disproportionation of chlorine in water and sodium hydroxide

Halide salts

NaI

NaBr

NaCl



Silver halides are solids and form a precipitate when silver nitrate is added

$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

White precipitate

$NaBr + AgNO_3 \longrightarrow AgBr + NaNO_3$

Cream precipitate

$NaI + AgNO_3 \longrightarrow AgI + NaNO_3$

Yellow/cream precipitate

How to write ionic equations

$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

Has the ionic equation

$Cl^-(aq) + Ag^+(aq) \rightarrow AgCl(s)$

We call the highly soluble Na^+ and NO_3^- ions SPECTATOR ions

Don't forget the state symbols (aq) (s) (l) (g)

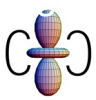
Is it cream, or is that yellow?

Confirming the tests when colour is not conclusive

AgCl dissolves in **dilute/conc ammonia**

AgBr dissolves in **conc ammonia**

AgI **does not dissolve**



Trend in reactivity

Fluorine is the most reactive halogen. **It is such a powerful oxidising agent it will even oxidise oxygen in water.**

In group 7 reactivity (oxidising power) decreases as you go down the group.

This is because **group 7 halogens react by reduction** gaining electrons to form negative ions. As the atomic radius, shielding and so the attractive force of the nucleus increases going down the group, reactivity decreases.

Past paper question

(d) The halogen fluorine is too reactive to use in a school or college laboratory. Fluorine is a powerful oxidising agent. It will react with water as shown below.

(i) Complete and balance the equation for the reaction of fluorine with water.

$F_2(g)$ + $H_2O(l)$ → ..... + $O_2(g)$ **[1]**

(ii) Using oxidation numbers, show what has been oxidised and what has been reduced in this reaction.

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

Mark scheme

(i)	$2F_2 + 2H_2O \rightarrow 4HF + O_2$ ✓	1	**ALLOW** correct multiples, including use of ½ O_2 **ALLOW** 4FH **IGNORE** state symbols
(ii)	Oxygen has been oxidised as (oxidation number has increased from) O = –2 to O = 0 ✓ Fluorine has been reduced as (oxidation number has decreased from) F = 0 to F = –1 ✓	2	**IGNORE** references to oxygen in any incorrect products **DO NOT ALLOW** O_2 = –2 → O = 0 but **ALLOW** F_2 = 0 → F = –1 **ALLOW** 'F is reduced from 0 to –1' regardless of product (or no product) in **5d(i)** except **ALLOW ECF** for F = –2 **if** H_2F is seen **ALLOW** one mark for O = –2 and O_2 = 0 **AND** F_2 = 0 and F = –1 if **no reference OR incorrect reference** to oxidation / reduction is seen Look at equation in **5d(i)** for oxidation numbers **if not seen in 5d(ii)** **IGNORE** reference to electron loss / gain if correct **DO NOT ALLOW** incorrect reference to electron loss / gain

Reactivity and displacement

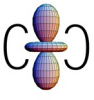
Halogens react by gaining an electron

$Cl_2 + 2e^- \rightarrow 2Cl^-$

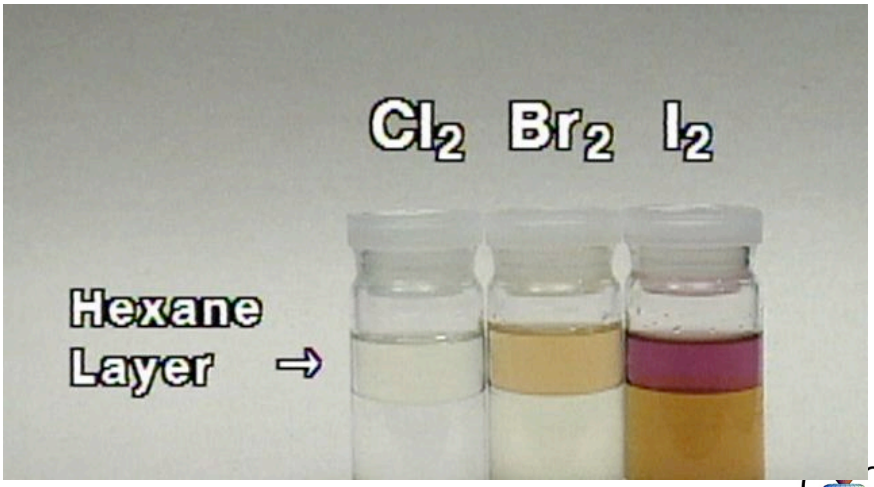
Halogens are more reactive the higher they are in the group

More reactive halogens can displace less reactive halogens from solution

$I^-(aq) + Cl_2(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$



Displacement reactions



Past-paper question

(c) A student investigated the reactivity of halogens by attempting some redox reactions.

(i) The student added bromine water to aqueous solutions of sodium chloride and sodium iodide in separate test-tubes. The student then added an organic solvent, cyclohexane, to each test-tube and these were shaken.

- State what colour you would see in the cyclohexane in each test-tube after shaking.
- Write **ionic** equations for any chemical reactions that take place.
- State and explain the trend in reactivity shown by these observations.

In your answer you should use appropriate technical terms spelled correctly.

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[6]

Mark scheme

(i)	***Colours:*** (Add Br_2 to $NaCl_{(}$) (Cyclohexane layer) turns orange **OR** yellow ✓ (Add Br_2 to $NaI_{(}$) (Cyclohexane layer) turns purple **OR** lilac **OR** violet **OR** pink **OR** mauve ✓ ***Equation:*** $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓ ***Reactivity:*** Reactivity decreases down the group **OR** Oxidising power decreases down the group ✓ ***Explanations:*** Chlorine will gain electron easiest **OR** form negative ion easiest ✓ Because chlorine (atom) is smallest **OR** Outer(most) shell of chlorine least shielded **OR** Nuclear attraction on electrons of chlorine is greatest ✓	6	**Use annotations with ticks, crosses ECF etc. for this part** **ALLOW** any combination of these but no others **ALLOW** any combination of these but no others **DO NOT ALLOW** 'precipitate' with either colour **DO NOT ALLOW** equation mark if incorrect equation(s) also seen **IGNORE** $Br_2 + 2Cl^- \rightarrow Br_2 + 2Cl^-$ **IGNORE correct** non-ionic version of equation **IGNORE** state symbols **ALLOW** Chlorine is the most reactive **ALLOW** Cl for chlorine etc. **ALLOW** Iodine is the least reactive **ALLOW** chlorine is best at electron capture **ALLOW** chlorine has 'greatest' electron affinity **IGNORE** chlorine is most electronegative **DO NOT ALLOW** explanations in terms of displacement ***Quality of Written Communication –*** *Electron(s)* ***OR*** *negative spelled correctly at least* ***ONCE*** *for marking point 5* **ALLOW** Chlorine atom has fewest shells **ALLOW** outer(most) shell closest to the nucleus **ALLOW** Chlorine atom has lowest shielding **ORA** for marking points 4, 5 and 6

Past paper question

4 In the Periodic Table, the chemistry of elements in a group can often be predicted from the chemistry of just one element in the group.

(a) Ions of Group 7 elements take part in displacement reactions. These reactions can be used to compare the reactivities of the elements within Group 7.

A student adds aqueous solutions of halogens to test-tubes containing solutions of halide ions. The resulting mixtures are then shaken with cyclohexane, an organic solvent.

One of the student's results is shown in the table.

experiment number	experiment details	colour seen within the organic solvent
1	addition of Cl_2(aq) to I^-(aq) ions	
2	addition of Cl_2(aq) to Br^-(aq) ions	orange
3	addition of Br_2(aq) to Cl^-(aq) ions	

(i) Complete the table to show the expected colours. **[2]**

(ii) Write the ionic equation for the reaction taking place in experiment 2.

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

(iii) These three experiments alone are unable to confirm the order of reactivity for Cl_2, Br_2 and I_2.

Suggest **one** further displacement reaction which could be carried out to confirm the order of reactivity of Cl_2, Br_2 and I_2.

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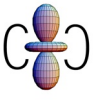
..... **[1]**



Mark scheme

4	a	i	1 = purple / lilac / violet / pink / mauve ✓ 3 = orange ✓	2	**ALLOW** any combination of these but no others for 1 **ALLOW** yellow as an alternative for 3 **DO NOT ALLOW** 'precipitate' in either
		ii	$Cl_2 + 2Br^- \longrightarrow 2Cl^- + Br_2$ ✓	1	**IGNORE** state symbols **ALLOW** correct multiples, including fractions
		iii	Addition of $Br_2(aq)$ to $I^-(aq)$ ions ✓	1	**ALLOW** Addition of bromine to iodide (i.e. aqueous not needed) **DO NOT ALLOW** Addition of bromine to iodine **ALLOW** Addition of I_2 to Br^-, but NOT if accompanied by description of displacement of bromine **ALLOW** $Br_2 + I^-$ even if seen in an unbalanced equation

Past-paper question

(c) Displacement reactions can be used to detect bromide ions in solution.

A student has a solution that contains bromide ions. The student carries out the following experiment.

Step 1

- She bubbles some chlorine gas through a sample of the solution.
- The mixture changes colour.

Step 2

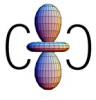
- The student then adds an organic solvent, cyclohexane, to the mixture.
- She shakes the contents and allows the layers to separate.

(i) Write the **ionic** equation for the reaction that takes place in **step 1**.

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

(ii) What colour does the cyclohexane layer turn in **step 2**?

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



Mark scheme

(c)	(i)	$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓	1	**IGNORE** state symbols **ALLOW** any correct multiple including fractions
	(ii)	Yellow / orange / red / brown ✓	1	**ALLOW** any combination of these, but no others

Disproportionation in water

When halogens dissolve in water they are oxidised and reduced at the same time this is called disproportionation

Eg Cl_2 (aq) + H_2O (l) → HCl (aq) + HOCl (l)

0 -1 +1

Past paper question

(b) Chlorine gas reacts with water as shown below.

$$Cl_2(g) + H_2O(l) \rightarrow HClO(aq) + HCl(aq)$$

(i) Using oxidation numbers, explain why this reaction is an example of disproportionation.

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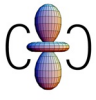
..... **[3]**

Mark scheme

b	**i**	Cl_2 is 0 **AND** HCl is –1 **AND** HClO is (+)1 ✓ Chlorine has been both oxidised and reduced **OR** Chlorine's oxidation state has increased and decreased ✓ Chlorine has been oxidised (from 0) to +1 **AND** chlorine has been reduced (from 0) to –1 ✓ (These two points together subsume the second marking point)	3	**ALLOW** 1– **ALLOW** 1+ Oxidation states may be seen above the equation **DO NOT ALLOW** Cl^- in HCl **DO NOT ALLOW** Cl^+ in HClO in text of answer **DO NOT ALLOW** chlor**IDE** in place of 'chlorine' **IF CORRECT OXIDATION STATES ARE SEEN, ALLOW** second **and** third marking points for: Chlorine is oxidised to form HClO Chlorine is reduced to form HCl **ALLOW** Cl or Cl_2 for 'chlorine' **IGNORE** reference to electron loss / gain if correct **DO NOT ALLOW** 3rd mark for reference to electron loss / gain if incorrect **ALLOW** one mark for 'disproportionation is when a species is both oxidised and reduced' if chlorine / chloride is not mentioned



Disproportionation in NaOH dilute

The reaction of Cl_2 with dilute aqueous NaOH makes bleach (NaClO)

Cl_2 (aq) + 2NaOH (aq) → NaCl (aq)+ NaClO (aq) + H_2O (l)

① Can you give the oxidation numbers of the Cl atoms?
② Can you write an ionic equation?

Cl_2 (aq) + $2OH^-$ (aq) → Cl^- (aq)+ ClO^- (aq) + H_2O (l)

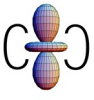
Disproportionation in NaOH

The reaction of Cl_2 with concentrated NaOH makes the weedkiller $NaClO_3$

$3Cl_2$ + 6NaOH → $NaClO_3$ + 5NaCl + $3H_2O$

① Can you give the oxidation numbers of the Cl atoms?
② Can you write an ionic equation?

$3Cl_2$ (aq) + $6OH^-$ (aq) → $5Cl^-$ (aq)+ ClO_3^- (aq) + $3H_2O$ (l)



Past paper question

(d) Chlorine reacts differently with dilute and concentrated aqueous solutions of sodium hydroxide.

- When chlorine reacts with dilute sodium hydroxide, one of the products is sodium chlorate(I). This is the reaction that is used to manufacture bleach.
- When chlorine is reacted with hot concentrated sodium hydroxide, a different reaction takes place. One of the products is $NaClO_3$, used as a weedkiller.

In each reaction, chlorine has been both oxidised and reduced.

(i) What term is used to describe a redox reaction in which an element is both oxidised and reduced?

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

Past paper question

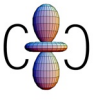
(ii) Write equations for these two reactions of chlorine with sodium hydroxide:

equation for reaction with **dilute** sodium hydroxide,

.....

equation for reaction with **hot concentrated** sodium hydroxide.

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



Past paper question

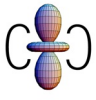
(iii) Chlorine forms another chlorate called sodium chlorate(VII), used in the manufacture of matches.

Suggest the formula of sodium chlorate(VII).

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

Mark scheme

(d)	(i)	Disproportionation ✓	1	**ALLOW** versions which sound the same **DO NOT ALLOW** disproportional **OR** disproportionate **OR** disproportion
	(ii)	$Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$ ✓ $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$ Cl_2 and NaOH as reactants **AND** $NaClO_3$ and NaCl as products✓ Rest of the equation ✓	3	**ALLOW** multiples for either equation **ALLOW** $3Cl_2 + 6NaOH \rightarrow 2NaClO_3 + 4NaCl + 3H_2$
	(iii)	$NaClO_4$ ✓	1	**ALLOW** Na_3ClO_5 etc



Chlorine and drinking water

- Addition of chlorine to drinking water is beneficial because it **kills bacteria** making water safe to drink.

However

- **Chlorine is toxic** and using it is hazardous

Past paper question

(ii) State **one** benefit for public health, of the reaction between chlorine gas and water.

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

Mark scheme

ii	Kills bacteria **OR** 'kills germs' kills micro-organisms **OR** makes water safe to drink **OR** sterilises water ✓ **OR** 'disinfects'	1	**ALLOW** to make water potable **ALLOW** 'removes' for 'kills' **IGNORE** 'virus' **IGNORE** 'purifies water'

Past paper question

4 Chlorine and bromine are elements in Group 7 of the Periodic Table.

(a) Chlorine is used in water treatment.

State **one** advantage and **one** disadvantage of using chlorine in water treatment.

advantage: .....

.....

disadvantage: .....

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

Mark scheme

4	(a)	*Advantage* removes or kills bacteria **OR** kills germs **OR** kills micro-organisms **OR** make it safe to drink **OR** sterilises water **OR** disinfects water ✓ *Disadvantage* it is toxic **OR** poisonous **OR** could form chlorinated hydrocarbons ✓	2	**ALLOW** to make water potable **IGNORE** virus **IGNORE** 'purifies water' **DO NOT ALLOW** 'antiseptic' **ALLOW forms** carcinogens **OR** forms toxins **IGNORE** harmful **DO NOT ALLOW** 'it causes cancer' **DO NOT ALLOW** "It kills you"

Plenary – text book questions

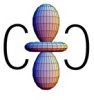
- Attempt question 7 on page 97 (past exam paper question).

Periodicity

Lesson 7 – the reactions of halogens practical

Objectives

- *Plan* and execute a practical experiment to investigate the reactions of halogens
- *Identify* the REDOX reactions taking place using the worksheet provided
- *Write-up* your practical including method, results and conclusion – this should include a description of how your results support or contrast with chemical theory



More practice writing ionic equations

Practical work on REDOX on the worksheet.

REDOX means something is oxidised and something is reduced.

1) Conduct the experiments

2) As you are doing the experiments read through the equations and try and work out what is being oxidised and what is being reduced.

3) Have a go at identifying oxidation numbers.