11.2 GROUP 17

The chemical properties of the halogen elements and the hydrogen halides

Learning outcomes

Candidates should be able to:

1 describe the relative reactivity of the elements as oxidising agents
2 describe the reactions of the elements with hydrogen and explain their relative reactivity in these reactions
3 describe the relative thermal stabilities of the hydrogen halides and explain these in terms of bond strengths

INTRODUCTION

- When a halogen reacts with a metal atom, the halogen atom gains one electron. Because of this, the halogen elements are oxidising agents (electron acceptors).
- Each halogen atom shares a pair of electrons with the other non-metal atom in a covalent bond, e.g., in hydrogen chloride, HCl.
  $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
- The reactions of fluorine are more **vigorous** than those of chlorine. Bromine reacts less vigorously than chlorine, and iodine is less reactive than bromine.

The halogens get less reactive going down Group 17.

Equation for reaction	Description of reaction
$H_2(g) + F_2(g) \rightarrow 2HF(g)$	reacts explosively even in cool, dark conditions
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$	reacts explosively in sunlight
$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$	reacts slowly on heating
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	forms an equilibrium mixture on heating

1. The hydrogen halides HCl, HBr and HI are all colourless gases at room temperature.
   The hydrogen halides can be formed by reacting the halogens with hydrogen.
   Describe and explain the relative reactivity of the halogens down the group when they react with hydrogen to form HCl, HBr and HI. [2]

A more reactive halogen can displace a less reactive halogen from a halide solution of the less reactive halogen.

When chlorine water, $Cl_2(aq)$, is added to a solution of sodium bromide containing $Br^-(aq)$ ions, the solution changes to a yellowish-brown colour. The colour is caused by the presence of dissolved bromine molecules, $Br_2(aq)$, as found in bromine water. The displacement reaction that takes place is:
$Cl_2(aq) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(aq)$
We say that chlorine has displaced bromine from solution.
This is summarised in the ionic equation for this displacement reaction:
$Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$
The chlorine atoms are more electronegative than bromine atoms so are more likely (have a stronger tendency) to form negatively charged ions.
Likewise, bromine will displace iodine from an iodide solution:
$Br_2(aq) + 2NaI(aq) \rightarrow 2NaBr(aq) + I_2(aq)$
or as an ionic equation:
$Br_2(aq) + 2I^-(aq) \rightarrow 2Br^-(aq) + I_2(aq)$

These displacement reactions show that the oxidising power of the halogens (their ability to gain electrons) **decreases** going down Group 17.

2. An excess of $Cl^-(aq)$ is added to $1cm^3$ of $Br_2(aq)$.
Describe what is observed. Explain your answer. **[1]**

3. A solution of aqueous bromide ions, $Br^-(aq)$, is added to separate samples of $Cl_2(aq)$ and $I_2(aq)$.
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 $Cl_2(aq)$

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observation on addition to $I_2(aq)$

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explanation

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..... [3]

1. Redox reactions are common in the chemistry of Group 17 elements.
Which statement is correct?

A Br^- ions will reduce Cl_2 but not I_2.
B Cl_2 will oxidise Br^- ions but not I^- ions.
C F_2 is the weakest oxidising agent out of F_2, Cl_2, Br_2 and I_2.
D I– ions are the weakest reducing agent out of F^-, Cl^-, Br^- and I^-.

2. X, Y and Z are three elements in Group 17.
X_2 has weaker covalent bonds than Y_2.
X_2 has stronger instantaneous dipole–induced dipole forces between its molecules than Z_2.
Y_2 is a stronger oxidising agent than Z_2.
What could be X, Y and Z?

	X	Y	Z
A	Br	Cl	I
B	Cl	Br	I
C	I	Br	Cl
D	I	Cl	Br

Thermal stability: the resistance of a compound to breakdown by heating

Hydrogen iodide can be decomposed by inserting a red-hot wire into a sample of hydrogen iodide gas. The **purple** fumes seen are iodine vapour:
$2HI(g) \rightarrow H_2(g) + I_2(g)$
By contrast, hydrogen fluoride and hydrogen chloride are not decomposed in temperatures up to 1500 °C.
Hydrogen bromide is not as stable as HF and HCl, but it is more resistant to decomposition than hydrogen iodide. At 430 °C in a closed container, 10% of a sample of HBr will decompose, whereas around 20% of HI decomposes at that temperature.

IMPORTANT

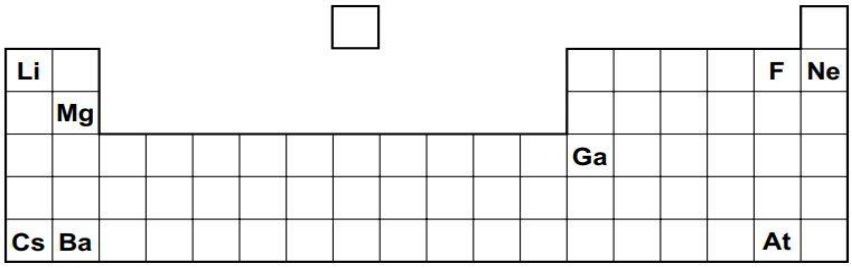
The hydrogen halides get less thermally stable going down Group 17.

most thermally stable HF
HCl
HBr
least thermally stable HI

4. The halide ions, X^- (where X = C**l**, Br, I), show clear trends in their physical and chemical properties.
State and explain the relative thermal stabilities of the hydrogen halides, HX. [2]

5. When heated with a Bunsen burner, HC**l** does not decompose, whereas HI forms H_2 and I_2.
Explain the difference in the effect of heating on HC**l** and HI. [1]

6. The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements in the Periodic Table.
(a) The positions of some elements are shown.



(i) Using Fig. 1.1 identify the element that forms a soluble hydroxide and an insoluble sulfate. [1]

(ii) Using Fig. 1.1 identify the most volatile element in a group that contains elements in all three states of matter at room temperature and pressure. [1]

(iii) Using Fig. 1.1 identify the element that forms the largest cation. [1]

7. Bleach is used as a cleaning product to kill bacteria. It is made by adding compounds like sodium chlorate(**I**), NaClO, to water.

(i) Identify the formula of the ion present in bleach that kills bacteria. [1]

(ii) Sodium chlorate(**I**), NaClO, reacts with hydrogen peroxide to produce sodium chloride, water and oxygen gas. Construct an equation for this reaction. [1]

(iii) A sample of bleach **W** contains an unknown concentration of sodium chlorate(I).
10.0cm^3 of **W** is diluted with distilled water to make a total volume of 100cm^3 of bleach solution. 25.0cm^3 of this diluted bleach solution is added to an excess of hydrogen peroxide and the volume of gas produced measured under room conditions.
The experiment is repeated and on average 25.0cm^3 of diluted bleach solution produces 42.0cm^3 of gas.
Calculate the concentration, in gdm^{-3}, of sodium chlorate(I) in **W**.

8. 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]

9. 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 H**I**. [2]

(ii) Describe and explain the trend in the thermal stabilities of the hydrogen halides, HCl, HBr and H**I**. [2]

10. Tennessine, Ts, is an unstable man-made element. It is found below astatine, At, in Group 17.
The chemical properties of Ts and its compounds have only been predicted.
(i) Suggest an equation for the reaction of NaTs and Br_2. Assume that Ts follows the same trends as the other elements in Group 17. Explain your answer. [2]

(ii) Some scientists predict that Ts has properties typical of metals like copper.
Complete the following table with:
- the predicted melting point of tennessine
- the lattice structure of solid chlorine, bromine and tennessine.

Assume that Ts has properties typical of metals like copper. [2]

element	chlorine	bromine	tennessine
melting point/°C	–101	–7.2	
lattice structure of crystalline solid			

3. When descending Group 17 from chlorine to iodine, which statement is correct?

A The hydrides become less thermally stable as they become weaker reducing agents.
B The hydrides become more thermally stable as the reactivity of the elements decreases.
C The volatility of the elements decreases as the van der Waals' forces increase.
D The volatility of the elements increases as the size of the molecules increases.

4. The table refers to the hydrogen halides.
Which row is correct?

	oxidation	thermal stability
A	easier to oxidise down the group	increases down the group
B	more difficult to oxidise down the group	increases down the group
C	easier to oxidise down the group	decreases down the group
D	more difficult to oxidise down the group	decreases down the group

5. In reaction 1, concentrated sulfuric acid is added to potassium chloride and the fumes produced are bubbled into aqueous potassium iodide solution.
In reaction 2, potassium chloride is dissolved in aqueous ammonia and this is then added to aqueous silver nitrate.
What are the observations for reactions 1 and 2?

observation for reaction 1 observation for reaction 2
A brown solution colourless solution
B brown solution white precipitate
C colourless solution colourless solution
D colourless solution white precipitate

6. U, V and W represent different halogens. The table shows the results of nine experiments in which aqueous solutions of U2, V2 and W2 were separately added to separate aqueous solutions containing U–, V – and W – ions.

	U–(aq)	V –(aq)	W –(aq)
U2(aq)	no reaction	no reaction	no reaction
V2(aq)	U2 formed	no reaction	W2 formed
W2(aq)	U2 formed	no reaction	no reaction

Which row contains the ions U–, V – and W – in order of their **decreasing** strength as reducing agents?

	Strongest weakest		
A	U–	V –	W –
B	U–	W –	V –
C	V –	W –	U–
D	W –	U–	V –

*****This is not a complete note. It is to guide you. It is recommended to study the prescribed textbooks along with this material. *****