PROSPERITY ACADEMY

AS CHEMISTRY 9701

Crash Course

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GROUP 17

COMPLETE NOTES

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Group 17 :-

- Known as halogens
- Exist as diatomic molecules
- We will focus on Cl_2, Br_2, I_2

Appearance at room temperature :-

Cl_2 ⟶ yellow green gas

Br_2 ⟶ red brown liquid

I_2 ⟶ black solid

1) Colour gets darker
2) M.p./b.p. increases as the no. of electrons increase so temporary dipole forces increase.

Prediction for Fluorine : Yellow gas

Prediction for Astatine : Black solid.

Reactivity of the halogens :-

F_2
Cl_2
Br_2
I_2
At_2

Reactivity decreases as
1) Nuclear charge increases
2) Shielding also increases — cancel each other out
3) Atomic radius increases due to more number of shells so the nucleus cannot attract new electrons easily.

The halogens act as oxidising agents (reduce themselves)

$2Na^{0}_{(s)} + Cl^{0}_{2(g)} \longrightarrow 2Na^{+1}Cl^{-1}_{(s)}$

Cl was reduced
Na was oxidised.

Reducing ability of halides:-

F^-
Cl^-
Br^-
I^-
At^-

reducing ability increases ↓

1) Nuclear charge increases
2) Shielding also increases — cancel each other out
3) Atomic radius increases due to more number of shells so the nucleus can lose control of new electrons easily.

The halide ions act as reducing agents:-

$$\overset{+1\ -1}{2HI} + \overset{+1\ +6\ -2}{H_2SO_4} \longrightarrow \overset{+4\ -2}{SO_2} + \overset{0}{I_2} + \overset{+1\ -2}{2H_2O}$$

I^- was oxidised (-1 to 0)
S was reduced (+6 to +4)

Displacement reactions:- A more reactive halogen (up the group) can displace a less reactive halogen from its salt

1) $Cl_{2(aq)} + 2NaBr_{(aq)} \longrightarrow 2NaCl_{(aq)} + Br_{2(aq)}$ Observation:- Colourless solution turns brown

ionic: $Cl_2 + \cancel{2Na^+} + 2Br^- \longrightarrow \cancel{2Na^+} + 2Cl^- + Br_2$ $\longrightarrow Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$

2) $Cl_{2(aq)} + 2KI_{(aq)} \longrightarrow 2KCl_{(aq)} + I_{2(aq)}$ Observation:- Colourless solution turns brown

ionic: $Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$

3) $Br_{2(aq)} + 2KI_{(aq)} \longrightarrow 2KBr_{(aq)} + I_{2(aq)}$ Observation:- There might be a change in the shade of brown

ionic: $Br_2 + 2I^- \longrightarrow 2Br^- + I_2$

* Iodine is black solid, purple in vapour form and organic solvent, and brown in water.
* Bromine is red brown in liquid, vapour, organic solvent and water
* To differentiate $I_{2(aq)}$ and $Br_{2(aq)}$ add an organic solvent, purple layer will form for iodine while bromine will remain brown.

Reactions with hydrogen and thermal stability of hydrogen halides:-

- F_2 reacts with H_2 explosively under all conditions.
- Cl_2 burns in dark and reacts explosively in presence of U.V light
- Br_2 reacts with hydrogen at 200°C and platinum catalyst
- I_2 reacts with hydrogen at 500 - 600°C and that also only reversibly

Proof that reactivity decreases.

$$H_2 + I_2 \rightleftharpoons 2HI$$

If we insert a hot rod in a container containing the hydrogen halides :-

- H-F : nothing happens (H-F : 562 KJ mol^{-1})
- H-Cl : nothing happens (H-Cl : 431 KJ mol^{-1})
- H-Br : some brown vapour seen (H-Br : 366 KJ mol^{-1})
- H-I : lots of purple vapour seen (H-I : 299 KJ mol^{-1})

Bond enthalpy decreases, thermal stability decreases

- The size of the halogen atom increases
  - ↳ it cannot pull on shared pair as strongly
    - ↳ bond is less polar
  - ↳ orbital overlap becomes less efficient.

Testing for Halide ions:-

- Dissolve halide salt in water and add dilute HNO_3 (Nitric acid) ⟶ removes other ions that may give a confusing precipitate
- Add $AgNO_3$ solution :-

1) Cl^- ⟶ white ppt 2) Br^- ⟶ Cream ppt 3) I^- ⟶ yellow ppt

not very easily distinguishable

The precipitates are insoluble silver halide salts:-

$$NaCl + AgNO_3 \longrightarrow NaNO_3 + AgCl$$

ionic: $Na^+ + Cl^- + Ag^+ + NO_3^- \longrightarrow Na^+ + NO_3^- + AgCl_{(s)}$

$$\therefore Ag^+ + Cl^- \longrightarrow AgCl_{(s)}$$

To distinguish, we add excess aqueous ammonia :-

$AgCl$ ⟶ dissolves to give colourless solution upon addition of dilute Ammonia ($NH_{3(aq)}$)

$AgBr$ ⟶ dissolves to give colourless solution only upon addition of concentrated ammonia ($NH_{3(aq)}$)

AgI ⟶ does not dissolve in any concentration of ammonia ($NH_{3(aq)}$)

When we add aqueous ammonia, the following complex ion is formed (Not important)

$[H_3N \longrightarrow Ag \longleftarrow NH_3]^+$ → Diammine silver$^+$ ion ⟶ this eventually reacts with Cl^-, I^- or Br^- and either dissolves or not

↳ Acted as a ligand ⟶ used its lone pair to form a dative bond to a metal atom/ion.

Reactions of halide ions with H_2SO_4 :- Proof of reducing ability increasing down the group.

- 2 types of reactions ⟶ 1) Acid - base 2) Redox

1) $NaCl$ + conc. H_2SO_4

Acid Base reaction: $NaCl_{(aq)} + H_2SO_{4(aq)} \longrightarrow NaHSO_{4(aq)} + HCl_{(g)}$ Observation :- Steamy fumes of HCl seen

Redox reaction : ——

2) $NaBr$ + conc. H_2SO_4

Acid Base reaction: $NaBr_{(aq)} + H_2SO_{4(aq)} \longrightarrow NaHSO_{4(aq)} + HBr_{(g)}$ Observation :- Steamy fumes of HBr seen

Redox reaction: $\overset{+1\ -1}{HBr_{(g)}} + \overset{+1\ +6\ -2}{H_2SO_{4(aq)}} \longrightarrow \overset{+4\ -2}{SO_{2(g)}} + \overset{0}{Br_{2(g)}} + \overset{+1\ -2}{H_2O_{(l)}}$ Observation :- Red brown vapour also seen
Pungent smell of SO_2

removal of oxygen

Br: -1 to 0 S: +6 → +4

3) NaI + conc. H_2SO_4 :-

Acid Base reaction: $NaI_{(aq)} + H_2SO_{4(aq)} \longrightarrow NaHSO_{4(aq)} + HI_{(g)}$

Observation :- Few steamy fumes of HI seen

Redox reaction : 1) $2\overset{+1\ -1}{HI}_{(g)} + \overset{+1\ +6\ -2}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{removal of oxygen}}{\overset{+4\ -2}{SO_{2(g)}}} + \overset{0}{I_{2(g)}} + 2\overset{+1\ -2}{H_2O_{(l)}}$

Observation :- Purple vapour also seen
Pungent smell of SO_2

I : -1 to 0 S : +6 to +4

2) $6\overset{+1\ -1}{HI}_{(g)} + \overset{+1\ +6\ -2}{H_2SO_{4(aq)}} \longrightarrow \overset{0}{S_{(s)}} + 3\overset{0}{I_{2(g)}} + 4\overset{+1\ -2}{H_2O_{(l)}}$

Observation :- Yellow solid seen ($S_{(s)}$)

I : -1 to 0 S : +6 to 0

3) $8HI_{(g)} + H_2SO_{4(aq)} \longrightarrow H_2S_{(g)} + 4I_{2(g)} + 4H_2O_{(l)}$

Observation :- H_2S produces smell of rotten eggs

Disproportionation of Chlorine:-

1) Reaction with cold NaOH :-

produces bleach

$$\overset{0}{Cl_2}_{(g)} + 2\overset{+1\ -2\ +1}{NaOH}_{(aq)} \longrightarrow \overset{+1\ -1}{NaCl}_{(aq)} + \overset{+1\ +1\ -2}{NaClO}_{(aq)} + H_2O_{(l)}$$

Cl : 0 → −1 (reduced) and 0 → +1 (oxidised)

ionic: $Cl_2 + \cancel{2Na^+} + 2OH^- \longrightarrow \cancel{Na^+} + Cl^- + \cancel{Na^+} + ClO^- + H_2O$

$$Cl_{2(g)} + 2OH^-_{(aq)} \longrightarrow Cl^-_{(aq)} + ClO^-_{(aq)} + H_2O_{(l)}$$

2) Reaction with hot NaOH:-

$$3\overset{0}{Cl_2}_{(g)} + 6\overset{+1\ -2\ +1}{NaOH}_{(aq)} \longrightarrow 5\overset{+1\ -1}{NaCl}_{(aq)} + \overset{+1\ +5\ -2}{NaClO_3}_{(aq)} + 3\overset{+1\ -2}{H_2O}_{(l)}$$

Cl : 0 → −1 (reduced) and 0 → +5 (oxidised)

ionic: $3Cl_{2(g)} + 6OH^-_{(aq)} \longrightarrow 5Cl^-_{(aq)} + ClO_3^-{}_{(aq)} + 3H_2O_{(l)}$

3) Reaction with water :-

$$\overset{0}{Cl_2}_{(g)} + \overset{+1\ -2}{H_2O}_{(l)} \longrightarrow \overset{+1\ -1}{HCl}_{(aq)} + \overset{+1\ +1\ -2}{HClO}_{(aq)} \longrightarrow \text{reduces pH of water, kills bacteria}$$

Cl : 0 → −1 (reduced) and 0 → +1 (oxidised)

1 Properties of chlorine, iodine and their compounds are compared.

Property **Q** for chlorine is smaller than for iodine.

What is property **Q**?

A oxidising ability of the element

B solubility of the silver halide in $NH_3(aq)$

C strength of van der Waals' forces between the molecules of the element

D thermal stability of the hydrogen halide

2 What happens when chlorine is bubbled through aqueous potassium iodide?

A Chlorine is oxidised to chloride ions. ✗ reduced

$Cl_2^0 + KI^{-1} \longrightarrow KCl^{-1} + I_2^0$

B Hydrochloric acid is formed. ✗

C Iodide ions are oxidised to iodine. ✓

D Potassium iodide is reduced to iodine. ✗

4 Which statement is most likely to be true for astatine, which is below iodine in Group VII of the Periodic Table?

A Astatine and aqueous potassium chloride react to form aqueous potassium astatide and chlorine.

B Potassium astatide and hot dilute sulfuric acid react to form white fumes of only hydrogen astatide.

C Silver astatide reacts with dilute aqueous ammonia in excess to form a solution of a soluble complex.

D Sodium astatide and hot concentrated sulfuric acid react to form astatine.

12 Chile saltpetre, $NaNO_3$, contains sodium iodide as an impurity.

Aqueous silver nitrate is added to an aqueous solution of Chile saltpetre. Concentrated aqueous ammonia is then added.

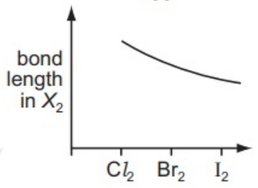
Which observations are made?

	with acidified silver nitrate	with concentrated aqueous ammonia
A	no precipitate	no further reaction
B	no precipitate	precipitate forms
C	precipitate forms	precipitate dissolves
D	precipitate forms	precipitate remains

7 Which graph correctly describes a trend found in the halogen group?

[*X* represents a halogen atom.]

A



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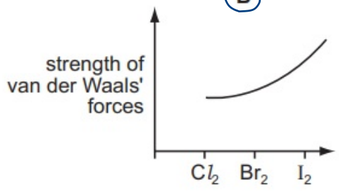

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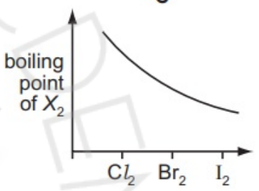
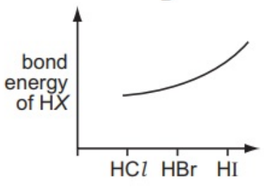


D



15 The following report appeared in a newspaper.

Drums of bromine broke open after a vehicle crash on the motorway. Traffic was diverted as purple gaseous bromine drifted over the road (it is denser than air), causing irritation to drivers' eyes. Firemen sprayed water over the scene of the accident, dissolving the bromine and washing it away.

What is **wrong** with the report?

A Bromine does not dissolve in water.

B Bromine does not vapourise readily.

C Bromine is less dense than air.

D Bromine is not purple.

19 In black and white photographic film, light converts silver chloride into metallic silver. After the film has been developed, the unexposed silver chloride is removed by reaction with sodium thiosulphate to produce a 'fixed' negative.

$$\overset{+1\ -1}{AgCl} + 2\overset{+1\ +2\ -2}{Na_2S_2O_3} \longrightarrow \overset{+1}{4Na^+} + \overset{-1}{Cl^-} + \overset{+1\ +2\ -2}{[Ag(S_2O_3)_2]^{3-}}$$

What is the function of thiosulphate?

$6(-2) + 4x + 1 = -3$

$x = +2$

A to make the silver ions soluble

B to oxidise the silver ions ✗

C to oxidise the silver metal ✗

D to reduce silver ions ✗

20 X, Y and Z represent different halogens. The table shows the results of nine experiments in which aqueous solutions of X_2, Y_2 and Z_2 were separately added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	$X^-(aq)$	$Y^-(aq)$	$Z^-(aq)$
$X_2(aq)$	no reaction	no reaction	no reaction
$Y_2(aq)$	X_2 formed	no reaction	Z_2 formed
$Z_2(aq)$	X_2 formed	no reaction	no reaction

I Cl Br

Which row in the following table contains the ions X^-, Y^- and Z^- in order of their decreasing strength as reducing agents?

	strongest ⟶		weakest
A	X^-	Y^-	Z^-
B	X^-	Z^-	Y^-
C	Y^-	Z^-	X^-
D	Z^-	X^-	Y^-

24 A student observed the reactions when sodium chloride and sodium iodide were each reacted separately with concentrated sulfuric acid and with concentrated phosphoric acid. The observations are recorded in the table.

	sodium chloride	sodium iodide
conc. H_2SO_4	colourless acidic gas formed	purple vapour formed
conc. H_3PO_4	colourless acidic gas formed	colourless acidic gas formed

Which deduction can be made from these observations?

A Concentrated phosphoric acid is a stronger oxidising agent than concentrated sulfuric acid.

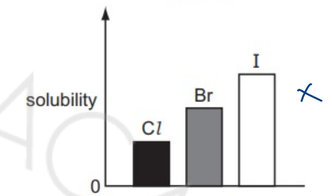
B Concentrated phosphoric acid is a stronger oxidising agent than iodine.

C Concentrated sulfuric acid is a stronger oxidising agent than chlorine.

D Concentrated sulfuric acid is a stronger oxidising agent than iodine.

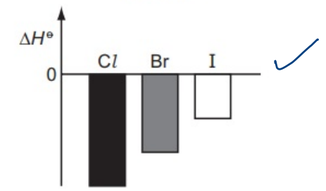
49 Two students, P and Q, were asked to draw bar charts to represent how some properties of the halogens and their compounds differ in magnitude. Their diagrams are shown.

student P



solubility of AgX(s) in $NH_3(aq)$

student Q



ΔH° for $H_2(g) + X_2(g) \rightarrow 2HX(g)$

Which of the student's diagrams are correct?

A both P and Q

B P only

C Q only

D neither P nor Q

2 The gaseous hydrogen halides HC*l*, HBr and HI, may be prepared by reacting the corresponding sodium salt with anhydrous phosphoric(V) acid, H_3PO_4.

When the sodium halide Na*X* was used, the following reaction occurred and a sample of gaseous H*X* was collected in a gas jar.

$$NaX + H_3PO_4 \rightarrow NaH_2PO_4 + HX$$

A hot glass rod was placed in the sample of H*X* and immediately a red/orange colour was observed.

(a) What is the identity of Na*X*?

NaBr [1]

(b) What gas, other than H*X*, would be formed if concentrated sulfuric acid were used with Na*X* instead of phosphoric(V) acid?

SO_2 [1]

(c) Suggest why phosphoric(V) acid rather than concentrated sulfuric acid is used to make samples of H*X* from the corresponding sodium salt.
Explain your answer.

conc. H_2SO_4 is a stronger oxidising agent than conc. H_3PO_4 and so produces many more products using up HX. [1]

6 **(a)** In this question, **K**, **L** and **M** refer to a halogen atom or halide ion.
For each part question, read the information and complete the answer lines below.

(i) When concentrated sulfuric acid is added to solid Na**K**, white fumes are produced that turn damp blue litmus paper red. No other colour changes are observed.

identity of **K** = Cl

equation for reaction $NaCl_{(aq)} + H_2SO_{4(aq)} \longrightarrow NaHSO_{4(aq)} + HCl_{(g)}$

explanation The fumes are HCl gas

[3]

(ii) When silver nitrate solution is added to an aqueous solution of Na**L**, a precipitate forms that remains after the addition of concentrated ammonia solution.

identity of **L** = I

colour of precipitate yellow

equation for reaction $NaI_{(aq)} + AgNO_{3(aq)} \longrightarrow AgI_{(s)} + NaNO_{3(aq)}$ [3]

(iii) $\mathbf{M}_2$ is a liquid at room temperature with a boiling point higher than that of chlorine but lower than that of iodine.

identity of **M** = Br

explanation Br has more electrons than chlorine but less than iodine so the temporary dipole forces in Br are stronger than chlorine but less than iodine.

[2]

5 The elements of Group VII of the Periodic Table show variation in their properties.

(a) (i) Complete the table below, stating the colour of each element in its normal state at room temperature.

halogen	melting point / °C	colour
chlorine	–101	yellow-green
bromine	–7	reddish-brown
iodine	114	black

(ii) Briefly explain why the melting points of the halogens increase from chlorine to iodine.

Down the group, the number of electrons increase hence the strength of the temporary dipole forces get stronger

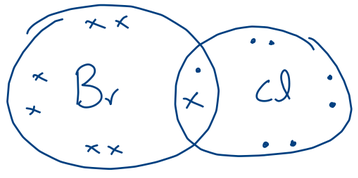
[4]

(b) The halogens form many interhalogen compounds in which two different halogens are combined. One such compound is bromine monochloride, BrCl.

(i) Complete the electronic configurations of chlorine and bromine.

chlorine	$1s^2 2s^2 2p^6 3s^2 3p^5$
bromine	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$

(ii) Draw a 'dot-and-cross' diagram of the BrCl molecule.
Show outermost electrons only.



(c) Interhalogen compounds like BrCl have similar properties to the halogens.

(i) By considering your answers to **(a)** and **(b)**, predict the physical state of BrCl at room temperature. Explain your answer.

physical state Gas

explanation Number of electrons in BrCl are less than Br_2 so weaker temporary dipole forces.

(ii) Suggest the colour of BrCl.

orange

[4]

(d) Cl_2 and BrCl each react with aqueous KI.

(i) Describe what would be seen when Cl_2 is bubbled through aqueous KI for several minutes.

initially Brown solution formed

after several minutes black solid forms

(ii) Construct an equation for the reaction that occurs.

$Cl_{2(g)} + KI_{(aq)} \longrightarrow KCl_{(aq)} + I_{2(aq)}$

(iii) Suggest an equation for the reaction that occurs between BrCl and aqueous KI.

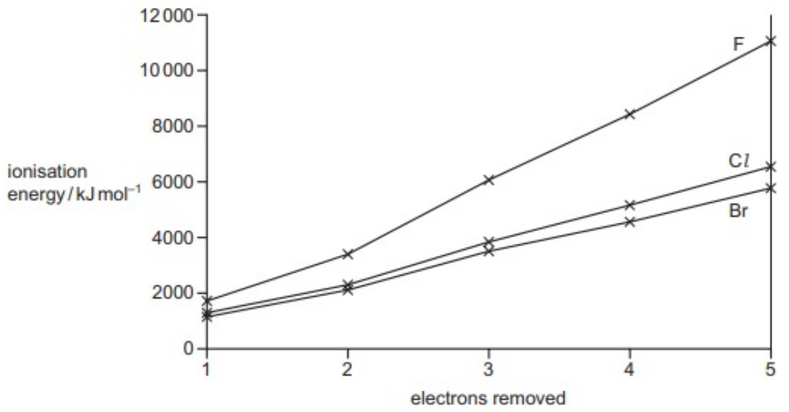
$BrCl + 2KI \longrightarrow KCl + KBr + I_2$

(iv) How do Cl_2 and BrCl behave in these reactions?

oxidising agents

[5]

8 **(a)** Successive ionisation energies for the elements fluorine, F, to bromine, Br, are shown on the graph.



(i) Explain why the first ionisation energies decrease down the group.

The nuclear charge increases as well as the shielding by inner shell electrons which counteract each other. The atomic radius increases due to increased number of shells and therefore it becomes easier to lose an electron as there is less attraction to it by the nucleus [3]

(ii) Explain why there is an increase in the successive ionisation energies of fluorine.

As electrons are removed, the protons per electron increases and repulsion between existing electrons increases so the atomic radius decreases and so it becomes harded to remove electrons. [2]

(b) Group VII is the only group in the Periodic Table containing elements in all three states of matter at room conditions.

State and explain, in terms of intermolecular forces, the trend in the boiling points of the elements down Group VII.

Already done

[4]

(c) Compounds containing different halogen atoms covalently bonded together are called interhalogen compounds.

(i) One interhalogen compound can be prepared by the reaction between iodine and fluorine. This compound has M_r = 222 and the percentage composition by mass: F, 42.8; I, 57.2.

Calculate the molecular formula of this interhalogen compound.

	F	:	I
moles	$\frac{42.8}{19}$		$\frac{57.2}{127}$
	= (2.2526	:	0.45075) ÷ 0.45075
	5	:	1

Emp. F = IF_5

$n = \frac{222}{221.9}$

$n \simeq 1$

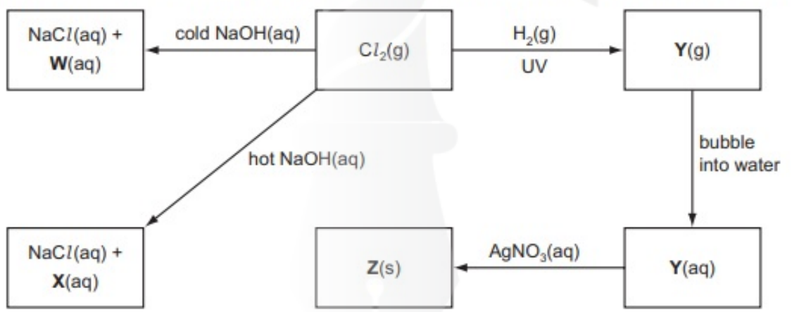
molecular formula IF_5 [3]

(ii) Another interhalogen compound has the formula IC*l*.

Draw a 'dot-and-cross' diagram of a molecule of this compound, showing outer shell electrons only. Explain whether or not you would expect this molecule to be polar.

It would be polar as Cl is much more electronegative than I [2]

(d) Some reactions involving chlorine and its compounds are shown in the reaction scheme below.



(i) Give the **formulae** of **W**, **X**, **Y** and **Z**.

W NaClO

X $NaClO_3$

Y HCl

Z AgCl

[4]

(ii) Write an equation for the reaction of chlorine with **hot** NaOH(aq).

$3Cl_2 + 6NaOH \longrightarrow 5NaCl + NaClO_3 + 3H_2O$ [2]

(iii) State the oxidation numbers of chlorine at the start and at the end of the reaction in **(ii)**.

start: 0 end: +5 and -1 [2]

(iv) Write an **ionic** equation for the reaction of **Y** with $AgNO_3$(aq). Include state symbols.

$Cl^-_{(aq)} + Ag^+_{(aq)} \longrightarrow AgCl_{(s)}$ [1]