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ICSE
Living Science
Chemistry

Class 10

Chapter-4 Analytical Chemistry

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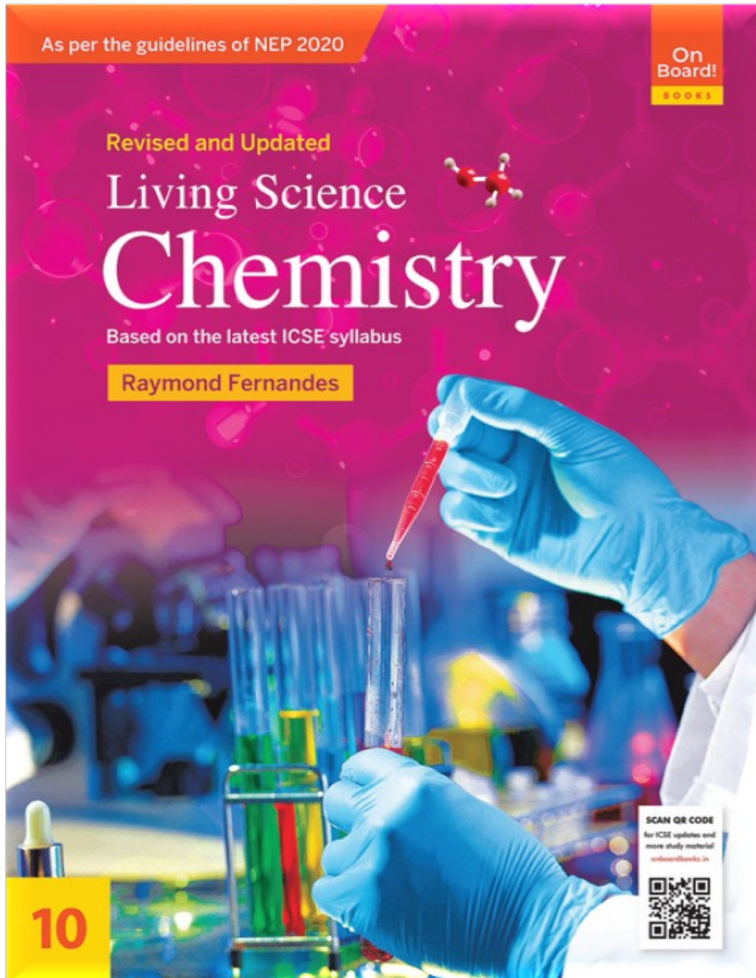

LEARNING OBJECTIVES

Why do compounds have colours?

Action of alkali on solution of metallic salts

- Action of sodium hydroxide on solution of metallic salts
- Action of ammonium hydroxide on solution of metallic salts

Action of alkalis on amphoteric metals

- Action of alkalis on amphoteric metal oxides
- Action of alkalis on amphoteric metal hydroxides

What is Analytical Chemistry?

Analytical Chemistry is a branch of chemistry that deals with the analysis of compounds. Analysis can be qualitative and quantitative.

This chapter deals with qualitative analysis to ascertain the positive radicals (or metal cations) present in compounds by identifying the colours of the precipitates formed.

Why do compounds have colours?

Elements can be classified into normal elements, transition elements, inner transition elements and inert gases. **Transition elements** (ranging from group 3 to 12) usually form coloured compounds. This is because the ions of these elements have a tendency to absorb light of a particular colour in the visible region and reflect or transmit the rest. The light that is transmitted is the colour of the substance.

Colours of salts

The colour of a salt solution depends upon the colour of the cation and anion in solution. Different colours of salt help in the identification of cation during qualitative analysis.

Coloured cations

The colours have varied ranges depending on the type of compounds they form, their valency and oxidation states.

Colourless cations

Ions of normal elements (ranging from Groups 1, 2 to Group 13 to 18) are generally colourless.

Coloured anions

Anions are generally colourless with a few exceptions such as the permanganate ion which is pink, the dichromate ion which is orange and the chromate ion is yellow in colour.

Action of alkali on solution of metallic salts

Metal cations of salts can be identified by using either a strong alkali like sodium hydroxide or a weak alkali like ammonium hydroxide. The action of alkali on metal cations produces hydroxides that appear as insoluble coloured substances called precipitates. Therefore, the formation of coloured **precipitates** helps in the identification of the metal cation that is present in the salt.

Action of sodium hydroxide on solution of metallic salts

When sodium hydroxide is added to a solution of metallic salts in a dropwise manner, the metal hydroxides get precipitated. Some precipitated metallic hydroxides dissolve in excess of sodium hydroxide to form soluble complex salts. This helps in the identification of the metal ion.

Notes: Refer to Table 4.1, 4.2. 4,3 and 4.4 for some coloured cations, colourless cations, coloured anions and colourless anions.

Following are the observations obtained by the action of sodium hydroxide on certain metallic salt solutions:

1. **For calcium salts (Ca^{2+}):** If a **white precipitate** is formed on reaction with NaOH which is insoluble in excess sodium hydroxide, then the metal cation in the salt solution is calcium ion.

$$CaCl_2 + 2NaOH \longrightarrow Ca(OH)_2\downarrow + 2NaCl$$
$$Ca^{2+} + 2NaOH \longrightarrow Ca(OH)_2\downarrow + 2Na^+$$

2. **For ferrous salts (Fe^{2+}):** If a **dirty green** precipitate is formed which is insoluble in excess sodium hydroxide, then the metal cation in the salt solution is iron(II) or ferrous.

$$FeSO_4 + 2NaOH \longrightarrow Fe(OH)_2\downarrow + Na_2SO_4$$
$$Fe^{2+} + 2NaOH \longrightarrow Fe(OH)_2\downarrow + 2Na^+$$

3. **For ferric salts (Fe^{3+}):** If a **reddish brown** precipitate is formed which is insoluble in excess sodium hydroxide, then the metal cation in the salt solution is iron(III) or ferric.

$$FeCl_3 + 3NaOH \longrightarrow Fe(OH)_3\downarrow + 3NaCl$$
$$Fe^{3+} + 3NaOH \longrightarrow Fe(OH)_3\downarrow + 3Na^+$$

Table 4.5 Addition of NaOH solution (in limited quantity and in excess)

Limited quantity	In excess	Inference
White precipitate	Insoluble	Ca^{2+}
Dirty green precipitate	Insoluble	Fe^{2+}
Reddish brown precipitate	Insoluble	Fe^{3+}
Bluish white precipitate	Insoluble	Cu^{2+}
White gelatinous precipitate	Soluble	Zn^{2+}
Chalky white precipitate	Soluble	Pb^{2+}

Note: For more examples, please refer to pages 71-72 of the textbook.

Following are the observations obtained by the action of ammonium hydroxide on certain metallic salt solutions:

1. **For ferrous salts (Fe^{2+}):** If a **dirty green** precipitate is formed, which is insoluble in excess ammonium hydroxide, then the metal cation in the salt solution is iron(II) or ferrous ion.

$$FeSO_4 + 2NH_4OH \longrightarrow Fe(OH)_2\downarrow + (NH_4)_2SO_4$$
$$Fe^{2+} + 2NH_4OH \longrightarrow Fe(OH)_2\downarrow + 2NH_4^+$$

2. **For ferric salts (Fe^{3+}):** If a **reddish brown** precipitate is formed, which is insoluble in excess ammonium hydroxide, then the metal cation in the salt solution is iron(III) or ferric.

$$FeCl_3 + 3NH_4OH \longrightarrow Fe(OH)_3\downarrow + 3NH_4Cl$$
$$Fe^{3+} + 3NH_4OH \longrightarrow Fe(OH)_3\downarrow + 3NH_4^+$$

3. **For copper salts (Cu^{2+}):** If a **light blue** precipitate is formed, which is soluble in excess ammonium hydroxide forming an ink blue solution, then the metal cation in the salt solution is copper(II) or cupric.

$$CuSO_4 + 2NH_4OH \longrightarrow Cu(OH)_2\downarrow + (NH_4)_2SO_4$$
$$Cu^{2+} + 2NH_4OH \longrightarrow Cu(OH)_2\downarrow + 2NH_4^+$$

TABLE 4.6 Addition of NH_4OH solution (in limited quantity and in excess)

Limited quantity	In excess	Inference
Dirty green precipitate	Insoluble	Fe^{2+}
Reddish brown precipitate	Insoluble	Fe^{3+}
Bluish white precipitate	Soluble in excess forming an ink blue solution	Cu^{2+}
White gelatinous precipitate	Soluble	Zn^{2+}
White precipitate	Insoluble	Pb^{2+}
No precipitate	Clear solution	Ca^{2+}

Note: For more examples, please refer to page 72 of the textbook.

Action of alkalis on amphoteric metals

Hot and concentrated caustic alkalis (NaOH, KOH) react with amphoteric metals like aluminium, zinc and lead to liberate hydrogen gas.

$$2Al + 2NaOH + 2H_2O \xrightarrow{\Delta} 2NaAlO_2 + 3H_2\uparrow$$

(conc.) sodium meta aluminate

$$Zn + 2NaOH \xrightarrow{\Delta} Na_2ZnO_2 + H_2\uparrow$$

(conc.) sodium zincate

$$Pb + 2NaOH \xrightarrow{\Delta} Na_2PbO_2 + H_2\uparrow$$

(conc.) sodium plumbite

Action of alkalis on amphoteric metal oxides

Hot and concentrated alkalis also react with amphoteric metal oxides to form salt and water.

$$ZnO + 2NaOH \xrightarrow{\Delta} Na_2ZnO_2 + H_2O$$

sodium zincate

$$Al_2O_3 + 2NaOH \xrightarrow{\Delta} 2NaAlO_2 + H_2O$$

sodium meta aluminate

Action of alkalis on amphoteric metal hydroxides

$$Zn(OH)_2 + 2NaOH \xrightarrow{\Delta} \underset{\text{sodium zincate}}{Na_2ZnO_2} + 2H_2O$$

$$Al(OH)_3 + NaOH \xrightarrow{\Delta} \underset{\text{sodium meta aluminate}}{NaAlO_2} + 2H_2O$$

$$Pb(OH)_2 + 2NaOH \xrightarrow{\Delta} \underset{\text{sodium plumbite}}{Na_2PbO_2} + 2H_2O$$

$$Zn(OH)_2 + 2KOH \xrightarrow{\Delta} \underset{\text{potassium zincate}}{K_2ZnO_2} + 2H_2O$$

$$Pb(OH)_2 + 2NaOH \xrightarrow{\Delta} \underset{\text{potassium plumbite}}{Na_2PbO_2} + 2H_2O$$

$$Zn(OH)_2 + 2KOH \xrightarrow{\Delta} \underset{\text{potassium zincate}}{K_2ZnO_2} + 2H_2O$$

$$Pb(OH)_2 + 2KOH \xrightarrow{\Delta} \underset{\text{potassium plumbite}}{K_2PbO_2} + 2H_2O$$

Note: The oxides and hydroxides of zinc, aluminium and lead being amphoteric can react with both acids as well as bases to form salt and water.

$$ZnO + 2HCl \longrightarrow \underset{\text{zinc chloride}}{ZnCl_2} + H_2O$$

$$Zn(OH)_2 + 2HCl \longrightarrow ZnCl_2 + 2H_2O$$

$$ZnO + 2NaOH \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2} + H_2O$$

$$Zn(OH)_2 + 2NaOH \longrightarrow Na_2ZnO_2 + 2H_2O$$

SUMMARY

1. Action of sodium hydroxide on metallic salts

Ion	Salt	Reaction involved	Colour of precipitate	Solubility of precipitate in excess of NaOH
Ca^{2+}	$CaCl_2$	$CaCl_2 + 2NaOH \longrightarrow Ca(OH)_2\downarrow + 2NaCl$ Calcium hydroxide	White	Insoluble
Fe^{2+}	$FeSO_4$	$FeSO_4 + 2NaOH \longrightarrow Fe(OH)_2\downarrow + Na_2SO_4$ Ferrous or iron(II) hydroxide	Dirty green	Insoluble
Fe^{3+}	$FeCl_3$	$FeCl_3 + 3NaOH \longrightarrow Fe(OH)_3\downarrow + 3NaCl$ Iron(III) hydroxide	Reddish brown	Insoluble
Cu^{2+}	$CuSO_4$	$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + Na_2SO_4$ Copper hydroxide	Light (pale) blue	Insoluble
Zn^{2+}	$ZnSO_4$	$ZnSO_4 + 2NaOH \longrightarrow Zn(OH)_2\downarrow + Na_2SO_4$ Zinc hydroxide	White gelatinous	Soluble due to zincate formation $Zn(OH)_2 + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2O$
Pb^{2+}	$Pb(NO_3)_2$	$Pb(NO_3)_2 + 2NaOH \longrightarrow Pb(OH)_2\downarrow + 2NaNO_3$ Lead hydroxide	Chalky white	Soluble due to plumbite formation $Pb(OH)_2 + 2NaOH \rightarrow Na_2PbO_2 + 2H_2O$
NH_4^+	NH_4NO_3	$NH_4NO_3 + NaOH \longrightarrow NH_3\uparrow + H_2O + NaNO_3$	No ppt but NH_3 gas is evolved	NH_3 turns moist red litmus blue

2. Action of ammonium hydroxide on metallic salts

Ion	Salt	Reaction involved	Colour of precipitate	Solubility of precipitate in excess of NH_4OH
Ca^{2+}	$Ca(NO_3)_2$	No precipitate formation takes place	No precipitate	No change as concentration of OH^- ions is low and cannot precipitate $Ca(OH)_2$
Fe^{2+}	$FeSO_4$	$FeSO_4 + 2NH_4OH \longrightarrow Fe(OH)_2\downarrow + (NH_4)_2SO_4$	Dirty green	Insoluble
Fe^{3+}	$FeCl_3$	$FeCl_3 + 3NH_4OH \longrightarrow Fe(OH)_3\downarrow + 3NH_4Cl$	Reddish brown	Insoluble
Zn^{2+}	$ZnSO_4$	$ZnSO_4 + 2NH_4OH \longrightarrow Zn(OH)_2\downarrow + (NH_4)_2SO_4$	White gelatinous	Soluble due to tetramine zinc complex formation $Zn(OH)_2 + 4NH_4OH \rightarrow [Zn(NH_3)_4](OH_2) + 4H_2O$
Pb^{2+}	$Pb(NO_3)_2$	$Pb(NO_3)_2 + 2NH_4OH \longrightarrow Pb(OH)_2\downarrow + 2NH_4NO_3$	White	Insoluble

3. Action of alkalis on amphoteric metals

$$\text{Metal} + \text{Alkali} \longrightarrow \text{Salt} + \text{Hydrogen gas}$$

Metal	Alkali (hot and concentrated)	Reaction involved
Zn	NaOH	$Zn + 2NaOH \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2} + H_2\uparrow$
Zn	KOH	$Zn + 2KOH \longrightarrow \underset{\text{potassium zincate}}{K_2ZnO_2} + H_2\uparrow$
Al	$NaOH + H_2O$	$2Al + 2NaOH + 2H_2O \longrightarrow \underset{\text{sodium aluminate}}{2NaAlO_2} + 3H_2\uparrow$

4. Action of alkalis on amphoteric metal oxides and hydroxides:

$$\text{Metal oxide} + \text{Alkali} \longrightarrow \text{Salt} + H_2O$$

Oxide	Alkali	Reaction involved
ZnO	$NaOH$	$ZnO + 2NaOH \longrightarrow Na_2ZnO_2 + H_2O$
PbO	$NaOH$	$PbO_2 + 2NaOH \longrightarrow Na_2PbO_3 + H_2O$
Al_2O_3	$NaOH$	$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$

$$\text{Metal hydroxide} + \text{Alkali} \longrightarrow \text{Salt} + H_2O$$

Hydroxide	Alkali	Reaction involved
$Zn(OH)_2$	$NaOH$	$Zn(OH)_2 + 2NaOH \longrightarrow Na_2ZnO_2 + 2H_2O$
$Pb(OH)_2$	$NaOH$	$Pb(OH)_2 + 2NaOH \longrightarrow Na_2PbO_2 + 2H_2O$
$Al(OH)_3$	$NaOH$	$Al(OH)_3 + NaOH \longrightarrow NaAlO_2 + 2H_2O$
$Al(OH)_3$	KOH	$Al(OH)_3 + KOH \longrightarrow KAlO_2 + 2H_2O$

5. The oxides and hydroxides of certain metals like zinc and aluminium exhibit both basic and acidic behaviour and are called **amphoteric**. The oxides and hydroxides of zinc react with hot caustic alkali to form **zincates**. The oxide and hydroxides of aluminium forms **aluminates** while those of lead form **plumbites** when treated with caustic alkalis.

THANK YOU