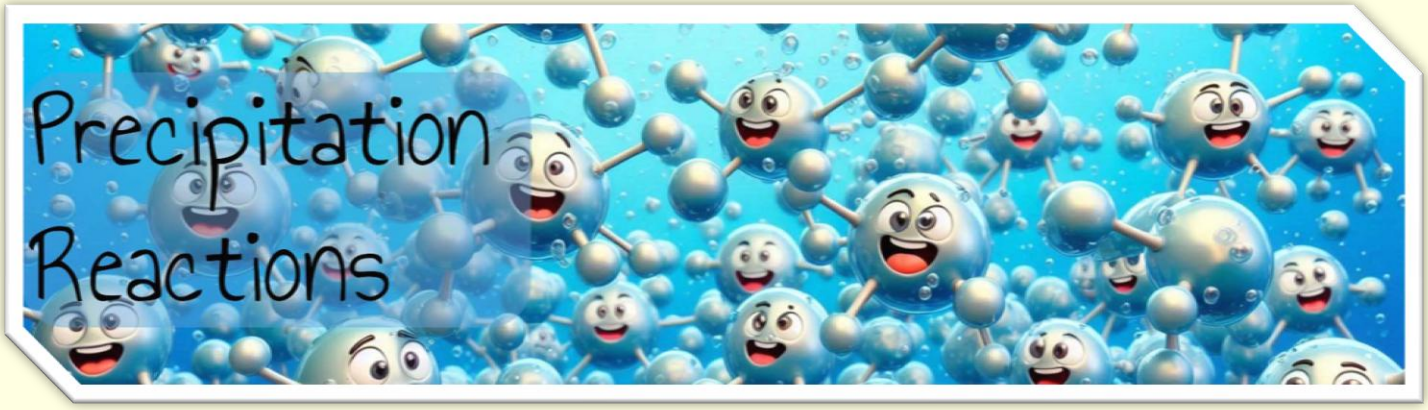


Answer all the questions below as fully as you can then check your answers

1. Which of the following equations correctly represents the first stage of hydrolysis of a hexaaqua metal(III) ion in aqueous solution?

$[M(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [M(H_2O)_5(OH)]^{2+}_{(aq)} + H_3O^+_{(aq)}$

$[M(H_2O)_6]^{3+}_{(aq)} \rightleftharpoons [M(H_2O)_5(OH)]^{3+}_{(aq)} + H^+_{(aq)}$

$[M(H_2O)_6]^{3+}_{(aq)} + OH^-(aq) \rightleftharpoons [M(H_2O)_5(OH)]^{2+}_{(aq)} + H_2O_{(l)}$

$[M(H_2O)_6]^{3+}_{(aq)} \rightleftharpoons [M(H_2O)_5(OH)]^{2+}_{(aq)} + H^+_{(aq)}$

2. When excess sodium hydroxide is added to a solution containing aluminium(III) ions, which of the following species is formed?

a) $Al(OH)_{3(s)}$ b) $Al(H_2O)_3(OH)_{3(aq)}$ c) $[Al(OH)_4]^-_{(aq)}$ d) $[Al(H_2O)_2(OH)_4]^-_{(aq)}$

3. Which of the following metal hydroxides is amphoteric?

a) Copper(II) hydroxide b) Iron(II) hydroxide

c) Aluminium hydroxide d) Iron(III) hydroxide

4. Explain why solutions of hexaaqua metal(III) ions are acidic.

5. Write the balanced ionic equation for the reaction between aqueous copper(II) ions and excess sodium hydroxide.

6. Describe the observations when sodium hydroxide solution is added drop wise to a solution of iron(III) chloride.

7. Explain why the shortened formula of metal hydroxides e.g. $Cu(OH)_2$ is not fully accurate.

8. A solution contains hexaaquachromium(III) ions, $[Cr(H_2O)_6]^{3+}$. Write the equation for the reaction of these ions with water, showing the formation of the first hydrolysis product.

b) Describe what you would observe when sodium hydroxide solution is added drop wise, and then in excess, to the hexaaquachromium(III) solution. Write equations for any reactions that occur.

c) Explain what would happen if acid is added to the solution formed in part b) containing the hexahydroxochromate(III) ion.

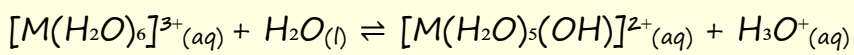
9. A student adds sodium hydroxide solution to solutions of copper(II) sulfate and aluminium sulfate. Describe the observations for each experiment.

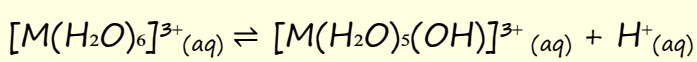
b) Write ionic equations for the reactions that occur.

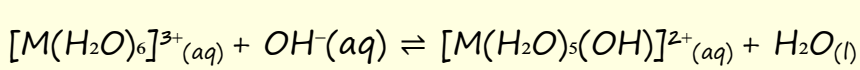
c) Explain why the aluminium hydroxide dissolves in excess sodium hydroxide, but the copper(II) hydroxide does not.

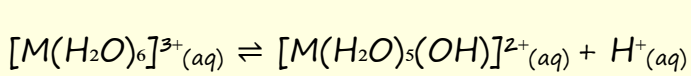
Answers

1. Which of the following equations correctly represents the first stage of hydrolysis of a hexaaqua metal(III) ion in aqueous solution?









Answer: a)

2. When excess sodium hydroxide is added to a solution containing aluminium(III) ions, which of the following species is formed?

a) $Al(OH)_{3(s)}$ b) $Al(H_2O)_3(OH)_{3(aq)}$ c) $[Al(OH)_4]^-_{(aq)}$ d) $[Al(H_2O)_2(OH)_4]^-_{(aq)}$

Answer: c)

3. Which of the following metal hydroxides is amphoteric?

a) Copper(II) hydroxide b) Iron(II) hydroxide

c) Aluminium hydroxide d) Iron(III) hydroxide

Answer: c)

4. Explain why solutions of hexaaqua metal(III) ions are acidic.

Answer: The highly charged metal ion polarises the O-H bonds in the coordinated water ligands, weakening them. This enables the release of a proton (H^+), which is then accepted by another water molecule to form H_3O^+, making the solution acidic.

5. Write the balanced ionic equation for the reaction between aqueous copper(II) ions and excess sodium hydroxide.

Answer: $[Cu(H_2O)_6]^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(H_2O)_4(OH)_{2(s)} + 2H_2O_{(l)}$

6. Describe the observations when sodium hydroxide solution is added drop wise to a solution of iron(III) chloride.

Answer: Initially, a reddish-brown precipitate of iron(III) hydroxide forms. This precipitate does not dissolve in excess sodium hydroxide.

7. Explain why the shortened formula of metal hydroxides e.g. $Cu(OH)_2$ is not fully accurate.

Answer: It does not show the coordinated water ligands that are also part of the complex. The accurate formula is $[Cu(H2O)_4(OH)_2]$.

8. A solution contains hexaaquachromium(III) ions, $[Cr(H_2O)_6]^{3+}$. Write the equation for the reaction of these ions with water, showing the formation of the first hydrolysis product.

Answer: $[Cr(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+}_{(aq)} + H_3O^+_{(aq)}$

b) Describe what you would observe when sodium hydroxide solution is added drop wise, and then in excess, to the hexaaquachromium(III) solution. Write equations for any reactions that occur.

Answer: Initially, a green precipitate of chromium(III) hydroxide, $[Cr(H_2O)_3(OH)_3]_{(s)}$ forms. With excess sodium hydroxide, this precipitate dissolves to form a green solution containing the hexahydroxochromate(III) ion, $[Cr(OH)_6]^{3-}_{(aq)}$.

$[Cr(H_2O)_6]^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow [Cr(H_2O)_3(OH)_3]_{(s)} + 3H_2O_{(l)}$
$[Cr(H_2O)_3(OH)_3]_{(s)} + 3OH^-_{(aq)} \rightarrow [Cr(OH)_6]^{3-}_{(aq)} + 3H_2O_{(l)}$

c) Explain what would happen if acid is added to the solution formed in part b) containing the hexahydroxochromate(III) ion.

Answer: The reverse reaction would occur. Initially, a green precipitate of chromium(III) hydroxide would form, and with further addition of acid, this precipitate would dissolve to reform the green hexaaquachromium(III) ions.

9. A student adds sodium hydroxide solution to solutions of copper(II) sulfate and aluminium sulfate. Describe the observations for each experiment.

Answer: Copper(II) sulfate: A blue precipitate forms.

Aluminium sulfate: A white precipitate forms, which dissolves in excess NaOH to form a colourless solution.

b) Write ionic equations for the reactions that occur.

Answer:

Copper(II) sulfate: $[Cu(H_2O)6]^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(H2O)_4(OH)_{2(s)} + 2H_2O_{(l)}$
Aluminium sulfate: $[Al(H_2O)6]^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Al(H_2O)_3(OH)_3 + 3H_2O(l)$
$Al(H_2O)_3(OH)_{3(s)} + OH^-_{(aq)} \rightarrow [Al(OH)_4]^-_{(aq)} + 3H_2O_{(l)}$

c) Explain why the aluminium hydroxide dissolves in excess sodium hydroxide, but the copper(II) hydroxide does not.

Answer: Aluminium hydroxide is amphoteric, meaning it reacts with both acids and bases. In excess sodium hydroxide, it reacts to form the soluble tetrahydroxoaluminate(III) ion, $[Al(OH)_4]^-$. Copper(II) hydroxide is not amphoteric and does not react with excess sodium hydroxide.