Activity 8A: Testing for cations and anions

Ans p. 35

1. When red litmus is added to a solution, it turns blue. On the addition of dilute hydrochloric acid, bubbles of gas are observed. Name the anion in the original solution.
2. A colourless solution formed a white precipitate when barium chloride solution was added. The solution was filtered, and when dilute hydrochloric acid was added to the residue, no reaction took place. Identify the anion present in the colourless solution. Write an ionic equation for the formation of the precipitate.
3. An unknown solution **X** is pale blue in colour. When excess ammonia is added to some of solution **X**, a light-blue precipitate forms which dissolves to give a deep-blue solution. When silver nitrate solution is added to some of solution **X**, nothing happens. When barium chloride solution is added to some of solution **X**, nothing happens. Identify the ions present in the solution. Write balanced ionic equations for the reactions which occur.
4. Four common test solutions are:

   Test **W** – Barium nitrate

   Test **X** – Silver nitrate followed by aqueous ammonia

   Test **Y** – Sodium hydroxide (a small quantity and then excess reagent)

   Text **Z** – Aqueous ammonia (a small quantity, then excess reagent).

   Choose the test (**W**, **X**, **Y** or **Z**) which distinguishes between the ions in each of the following pairs. Give the observation that would be made as each ion pair is tested, with balanced equations for expected reactions.

   Pairs of ions:

   a. Cl^- (chloride ions) and I^- (iodide ions)

   b. SO_4^{2-} (sulfate ions) and NO_3^- (nitrate)

   c. Al^{3+} (aluminium ions) and Zn^{2+} (zinc ions)

   d. Cu^{2+} (copper(II) ions) and Fe^{2+} (iron(II) ions)
5. Sodium hydroxide is added to a colourless solution containing only one type of metal ion. A white precipitate forms.

   a. Give the formulae for five ions which could be present in the solution, and write equations for the precipitation reactions.

   b. Outline further reactions that could be carried out to distinguish between these five ions. Write equations for any reactions which would occur.
6. A white powder was dissolved in water and analysed in the following way.

   Step 1: Aqueous silver nitrate was added and a white precipitate formed.

   Step 2: Excess aqueous ammonia was added to the white precipitate and the precipitate disappeared.

   Step 3: Aqueous sodium hydroxide was added to a fresh sample of the dissolved powder and no precipitate formed.

   a. Identify the ions in the white powder.

   b. Write equations for the reactions which occurred.

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7. A blue powder was dissolved in water and analysed in the following way:
Step 1: Aqueous barium nitrate was added and a precipitate formed
Step 2: Aqueous ammonia was added to a fresh sample and a blue precipitate formed
Step 3: Excess aqueous ammonia was added to the blue precipitate which dissolved, and a deep blue solution was observed.

a. Identify the ions in the blue powder.

b. Write equations for the reactions which occur.

8. Four colourless solutions are unlabelled. They are known to be Na_2CO_3, Na_2SO_4, $MgSO_4$, and NaOH.
Use the reaction schemes for *Identifying cations* and *Identifying anions* to devise a method that could be used to identify each solid.
Describe any observations you would expect to make and write balanced equations for any reactions you would expect to occur.

9. A colourless solution was analysed to determine the cation and anion present. To separate samples of this solution, various tests were carried out and the observations that follow were made.
Identify the cation and anion present. Write balanced equations for the precipitation reactions that occurred and for the formation of any complex ions.

Observations: No reaction to litmus. On addition of barium nitrate, no reaction occurred. No reaction occurred on addition of silver nitrate. A white precipitate formed when a small volume of aqueous sodium hydroxide was added, and this precipitate disappeared when excess sodium hydroxide was added. No precipitate formed with dilute sulfuric acid. A white precipitate formed when a small volume of aqueous ammonia was added, and this remained in the presence of excess ammonia.

10. An orange-brown coloured solution was analysed to determine the cation and anion present. To separate samples of this solution, various tests were carried out and the observations that follow were made.
Identify the cation and anion present. Write balanced equations for the precipitation reactions that occurred and for the formation of any complex ions. Justify your answers.

Observations: No reaction to litmus. On addition of barium nitrate, a white precipitate formed. A red-brown precipitate was formed when a small volume of aqueous sodium hydroxide was added. When potassium cyanate was added to a sample of the solution, a blood-red solution formed.

11. A colourless solution was analysed to determine the cation and anion present. To separate samples of this solution, various tests were carried out and the observations that follow were made.
Identify the cation and anion present. Write balanced equations for the precipitation reactions that occurred and for the formation of any complex ions. Justify your answers.

Observations: No reaction to litmus. On addition of barium nitrate, no reaction occurred. On addition of silver nitrate, a yellow precipitate formed which remained when excess ammonia solution was added. A white precipitate formed when a small volume of aqueous sodium hydroxide was added and this disappeared when excess sodium hydroxide was added. A white precipitate formed when a small volume of aqueous ammonia was added, and this disappeared when excess ammonia was added.

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1. carbonate
2. SO_4^{2-}
   $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$
3. Cu^{2+}, NO_3^-
   $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$
   $Cu^{2+}(aq) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq)$
4. **a.** Test X: Cl^- ions give a white precipitate which then dissolves in $NH_3(aq)$; I^- ions give a yellow precipitate which will not dissolve.
   $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ $Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$
   $AgCl(s) + 2NH_3(aq) \longrightarrow [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$
   b. Test W: SO_4^{2-} ions give a white precipitate; NO_3^- ions do not give a precipitate.
   $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$
   c. Test Z: Al^{3+} ions give a white precipitate which does not dissolve in excess NH_3; Zn^{2+} ions give a white precipitate which dissolves.
   $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$
   $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$
   $Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$
   d. Test Y: Cu^{2+} ions give a pale blue gelatinous precipitate which does not dissolve in excess OH^-, Fe^{2+} ions give a pale green gelatinous precipitate (which does not dissolve and which turns brown if left in air).
   $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$
   $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$
5. **a.** Mg^{2+}, Ba^{2+}, Al^{3+}, Zn^{2+}, Pb^{2+}
   $Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s)$
   $Ba^{2+}(aq) + 2OH^-(aq) \longrightarrow Ba(OH)_2(s)$
   $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$
   $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$
   $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$
   b. Add excess NaOH – if precipitate remains, ion is Mg^{2+} or Ba^{2+};
   if precipitate dissolves, ion is Al^{3+}, Zn^{2+} or Pb^{2+}
   $Al^{3+}(aq) + 4OH^-(aq) \longrightarrow [Al(OH)_4]^-(aq)$ *or*
   $Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH)_4]^-$
   $Zn^{2+}(aq) + 4OH^-(aq) \longrightarrow [Zn(OH)_4]^{2-}(aq)$ *or*
   $Zn(OH)_2(s) + 2OH^-(aq) \longrightarrow [Zn(OH)_4]^{2-}$
   $Pb^{2+}(aq) + 4OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$ *or*
   $Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}$

   To distinguish between Al^{3+}, Zn^{2+}, or Pb^{2+}: to the original solution, add NH_3 solution dropwise and then excess – if a white precipitate forms and dissolves in excess, the ion is Zn^{2+}; if the precipitate remains, the ion is Al^{3+} or Pb^{2+}

   $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$
   $Zn^{2+}(aq) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq)$ *or*
   $Zn(OH)_2(s) + 2OH^-(aq) \longrightarrow [Zn(OH)_4]^{2-}(aq)$

   To the original sample add dil. H_2SO_4 – if a white precipitate forms, the ion is Pb^{2+}.
   $Pb^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow PbSO_4(s)$

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To distinguish between Mg^{2+} or Ba^{2+}: add dil H_2SO_4 to the original solution – if a white precipitate forms, ion is Ba^{2+}

$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

6. **a.** Na^+, Cl^-

b. $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

$AgCl(s) + 2NH_3(aq) \longrightarrow [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$

or $Ag^+(aq) + 2NH_3(aq) \longrightarrow [Ag(NH_3)_2]^+(aq)$

7. **a.** Cu^{2+}, SO_4

b. $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$

or $Cu^{2+}(aq) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq)$

8. Add red litmus paper to the solutions – the ones which turn the litmus blue are NaOH and Na_2CO_3. Add a few drops of dilute HCl to a sample of each of these solutions. The sample that 'fizzes' is Na_2CO_3

$CO_3^{2-} + 2H^+ \longrightarrow H_2O + CO_2$

Add NaOH to the other two solutions – a white precipitate forms with $MgSO_4$

$Mg^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s)$

The remaining solution is Na_2SO_4

9. Anion NO_3^- no reaction with any of the anion testing solutions

Cation Al^{3+} $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$

$Al(OH)_3(s) + OH^-(aq) \longrightarrow Al(OH)_4^-(aq)$

10. Anion SO_4^{2-} $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

Cation Fe^{3+} $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$

$Fe^{3+}(aq) + SCN^-(aq) \longrightarrow [Fe(SCN)]^{2+}(aq)$

Justification for answer.

Cation is Fe^{3+}: A red-brown precipitate forms on the addition of NaOH to the solution. Solubility rules state $Fe(OH)_3$ is insoluble and it is the only likely precipitate that is red-brown in colour. Fe^{3+} ions are known to give a blood-red colour on the addition of SCN^- as a complex ion is formed.

Anion is SO_4^{2-}: Sulfate ions are neutral in aqueous solution. On addition of Ba^{2+} ions a white precipitate of $BaSO_4$ would be observed because barium sulfate is one of the few insoluble sulfate compounds. All the other possible anions form soluble compounds with barium ions.

11. Anion I^- $Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$

Cation Zn^{2+} $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$

$Zn(OH)_2(s) + 2OH^-(aq) \longrightarrow [Zn(OH)_4]^{2-}(aq)$

$Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$

$Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$

Justification for answer.

Cation is Zn^{2+}. Since a white precipitate formed on addition of NaOH solution and dissolved when excess was added, the possible cations would be either Zn^{2+} or Al^{3+} as both these ions can give white precipitates with NaOH. Each of these precipitates can be dissolved with the addition of excess NaOH as a complex ion forms. When NH_3 solution is added, both Zn^{2+} and Al^{3+} initially give a white precipitate of their

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ISBN 978-0-947504-92-2

hydroxides ($Zn(OH)_2$ or $Al(OH)_3$) but the Zn^{2+} ions are able to form complex ions with NH_3 molecules – thus dissolving the $Zn(OH)_2$ precipitate.

Anion is I^-: Iodide ions are neutral in solution, so there is no reaction to litmus. There is no reaction with Ba^{2+} ions, as from solubility rules BaI_2 will be soluble. When $AgNO_3$ solution is added, a yellow precipitate can result from the presence of I^- ions as AgI is insoluble. AgI is not soluble in excess ammonia solution as a complex ion is unable to form. (This will confirm the anion as I^- rather than Cl^-.)

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