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O-level chemistry

Introduction

This is a branch of chemistry that requires the use of known chemicals and reagents called **bench reagents** to identify unknown chemical or reagents based on changes in color and other observable reactions that take place when one chemical is added to another. As part of the school curriculum, students are expected to be understand the use the bench reagents to identify the simple cations and anions.

The syllabi

For the purpose of the examinations, Ordinary level students should familiar with the use reagent such as:

Dilute sodium hydroxide solution,

Dilute ammonia solution

Dilute hydrochloric acid solution

Dilute Nitric acid solution

Dilute sulphuric acid

Potassium iodide solution

Sodium carbonate solution

Potassium hexacyanoferrate (II) solution

Potassium hexacyanoferrate (III) solution

Lime water

Barium chloride/nitrate solution

Silver nitrate solution

Lead nitrate/ethanoate solution

Copper turning

Litmus paper

Ammonium thiocyanate

To identify the following cations and anions

Cations: Cu^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} Al^{3+}, NH_4^+ and Fe^{3+}

Anions: SO_4^{2-}, Cl^-, NO_3^-, and CO_3^{2-}

Identification of cations

1. The color of a compound gives a clue about a cation present in a compound.

   The table common colors of cations are shown in the table below

Color of compounds	Suspected cations
White	Pb^{2+}, Zn^{2+} Al^{3+}, NH_4^+
Blue	Cu^{2+}
Green	Fe^{2+}, Cu^{2+}
Brown	Fe^{3+}

2. Observation when cations are reacted with dilute sodium hydroxide dropwise until in excess.

Cations in solution	Observation	Comment
NH_4^+	No observable change	On boiling the resultant mixture, a gas that turns red litmus paper blue is given off. This is the only way of showing that a compound contains ammonium ion.
Zn^{2+}	White precipitate soluble in excess	Not that Al^{3+}., Zn^{2+} and Pb^{2+} show the

	Equation $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ Then $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$	same observation with sodium hydroxide solution When sodium hydroxide solution is added to a colourless solution and a white precipitate soluble in excess is obtained: we deduce presence of Al^{3+}. Zn^{2+} and Pb^{2+} A precipitate is a solid formed when solutions are added together.
Pb^{2+}	White precipitate soluble in excess Equation $Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$ Then $Pb(OH)_2(s) + 2OH^-(aq) \rightarrow Pb(OH)_4^{2-}(aq)$	
Al^{3+}	White precipitate soluble in excess Equation $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ Then $Al(OH)_3(s) + 2OH^-(aq) \rightarrow Al(OH)_4^-(aq)$	
Cu^{2+}	Blue precipitate insoluble in excess $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$	Formation of blue precipitate is an indication of presence of Cu^{2+} ions but this is not a confirmatory test for Cu^{2+}.
Fe^{2+}	Dirty green precipitate insoluble in excess. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$	Formation of dirty green precipitate is an indication of presence of Fe^{2+} ions at O-level but this is not a confirmatory test for Fe^{2+}.
Fe^{3+}	Brown precipitate insoluble in excess	Formation of brown precipitate is an indication of presence of Fe^{3+} ions but this is not a confirmatory test for Fe^{3+}.

3. Observation when cations are reacted with dilute ammonia dropwise until in excess.

Cations in solution	Observation	Comment

NH_4^+	No observable change	This is not a significant test for NH_4^+
Zn^{2+}	White precipitate soluble in excess Equation $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ Then $Zn(OH)_2(s) + 4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}(aq)$	This test distinguishes Zn^{2+} ions from Al^{3+} and Pb^{2+} ions that form white precipitates with ammonia solution insoluble in excess. The test is thus used to confirm presence of Zn^{2+} ions
Pb^{2+}	White precipitate soluble in excess Equation $Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$	Not that Al^{3+} and Pb^{2+} show the same observation with ammonia solution. The insolubility of the precipitate in excess distinguishes Al^{3+} and Pb^{2+} ions from Zn^{2+} ion whose precipitate is soluble in excess ions.
Al^{3+}	White precipitate soluble in excess Equation $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$	
Cu^{2+}	Blue precipitate soluble in excess to give deep blue solution $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ Then $Cu(OH)_2(aq) + 4NH_3(aq) \rightarrow Cu(NH_3)_4^{2+}(aq)$	Formation of blue precipitate soluble in excess ammonia is an indication of presence of Cu^{2+} ions. At O-level this this test is used to confirm presence of Cu^{2+} ions I solution
Fe^{2+}	Dirty green precipitate insoluble in excess. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$	Formation of dirty green precipitate is an indication of presence of Fe^{2+} ions at O-level but this is not a confirmatory test for Fe^{2+}.
Fe^{3+}	Brown precipitate insoluble in excess	Formation of brown precipitate is an indication of presence of Fe^{3+} ions but this is not a confirmatory test for Fe^{3+}.

4. Confirmatory test: After testing the solution with sodium hydroxide and then ammonia solution, a confirmatory test is carried out to tell whether the suspected ion is the exact one.

Suspected ion in solution	Confirmatory test	Observation/comment
NH_4^+	When sodium hydroxide is added and solution boiled	A gas that turns damp red litmus paper blue is given of
Zn^{2+}	Addition of ammonia solution	A white precipitate soluble in excess This distinguishes Zn^{2+} from Pb^{2+} Al^{3+} ion whose precipitate with ammonia are insoluble in excess
Pb^{2+}	Potassium iodide solution	A yellow precipitate of PbI_2.
Al^{3+}	Potassium iodide solution	No observable change. Al^{3+} is confirmed by a negative test distinguishing it from Pb^{2+} that form a yellow ppt
Cu^{2+} Additional test	Ammonia solution	Blue precipitate soluble in excess to form deep solution
	Potassium hexacyanoferrate II	Brown precipitate
	Potassium iodide	Brown suspension: note that a solution of Pb^{2+} is colorless and gives yellow precipitate while that of Cu^{2+} is blue.
Fe^{2+}	Potassium hexacyanoferrate III	Deep blue solution Note that potassium hexacyanoferrate III confirms Fe^{2+} while potassium hexacyanoferrate II confirms Fe^{3+} but the observations are the same: deep blue solution
Fe^{3+}	Potassium hexacyanoferrate II	Deep blue solution

	Ammonium thiocyanate	Red solution

Identification of anions

1. Texture
   a. Salts containing SO_4^{2-}, Cl^- or NO_3^- or usually crystalline
   b. Carbonates are usually in powder form
2. Solubility in water
   a. Salts containing SO_4^{2-}, Cl^- or NO_3^- or usually soluble
   b. Carbonates are usually insoluble
3. Effect on heat
   a. Sulphate, SO_4^{2-}, decompose to release acid gas that turns damp blue litmus red and turn damp potassium dichromate paper from orange to green. The gas is SO_2
   b. Nitrates, NO_3^-, decompose to release brown fumes of nitrogen dioxide, NO_2. This test is used to confirm presence of nitrate ions.
   c. Carbonates, CO_3^{2-}, decompose to give a gas (CO_2) that change damp blue litmus paper pink and lime water milky.
   Note that, every time you are required to heat a compound in a test tube, test the gas given using both blue and red litmus papers. Compounds containing ammonium ions, NH_4+ give off a gas that turns damp red litmus paper blue.
4. Testing the solution with lead nitrate solution
   a. Sulphate ions, SO_4^{2-}, give white precipitates insoluble on boiling the final mixture
   b. Chloride ion, Cl^-, form white precipitate soluble on boiling
   c. Nitrates, NO_3^-, give no observable change
5. Distinguishing solution containing sulphate ions, SO_4^{2-}, from those containing Chloride ions, Cl^-.
   a. Sulphate ions, SO_4^{2-}, form white precipitate with barium chloride insoluble in dilute nitric acid.
   b. Chloride ions, Cl^-, form white precipitate with silver nitrate solution insoluble in dilute nitric acid soluble in excess ammonia
6. Testing for carbonates
   a. Most carbonates used in qualitative analysis are insoluble in water and are usually remain as residues on the filter paper
   b. Addition of an acid to a carbonate, effervescence is observed, a gas that turns limewater milky is produced.

Exercise

1. Which one of the following cations when with sodium hydroxide solution would form a green precipitate that would turn brown on standing?
   A. Cu^{2+} B. Al^{3+} C. Fe^{2+} D. Pb^{2+}
2. Which of the following hydroxide will form a dark brown solid when heated strongly?
   A. $Zn(OH)_2$ B. $C(OH)_2$ C. $Mg(OH)_2$ D. $Pb(OH)_2$
3. Which one of the following oxides will dissolve in dilute nitric acid but not in dilute sodium hydroxide?
   A. Lead (II) hydroxide B. Zinc hydroxide
   B. aluminium hydroxide D. iron (III) oxide
4. Which one of the following pairs of metal ions form a precipitate that is soluble in aqueous ammonia solution?
   A. Pb^{2+} and Zn^{2+}
   B. Al^{3+} and Cu^{2+}
   C. Zn^{2+} and Cu^{2+}
   D. Pb^{2+} and Al^{3+}
5. Which one of the following oxides can react with potassium hydroxide?
   A. CuO B. CaO C. FeO D. PbO
6. Which one of the following ions when reacted with aqueous lead (II) ions form a precipitate which dissolve on heating?
   A. OH- (aq) B. $SO_4^{2-}(aq)$ C. $Cl^-(aq)$ D. CO_3^{2-}
7. Which one of the following pairs of cations when in solution can be distinguished using, potassium iodide solution?
   A. Pb^{2+} and Al^{3+}
   B. Zn^{2+} and Al^{3+}
   C. Zn^{2+} and Fe^{2+}
   D. Fe^{2+} and Fe^{3+}
8. Which one of the following pairs of ions can be distinguished using acidified barium nitrate solution?
   A. CO_3^{2-} (aq) and $SO_3^{2-}(aq)$
   B. CO_3^{2-} (aq) and SO_4^{2-} (aq)
   C. CO_3^{2-} (aq) and HCO_3^- (aq)
   D. $Cl^-(aq)$ and $I^-(aq)$
9. Which one of the following ions will react with sodium hydroxide to form a green precipitate which will dissolve to form a reddish- brown solution when reacted with concentrated nitric acid?
   A. $Cu^{2+}(aq)$
   B. $Fe^{2+}(aq)$
   C. $Pb^{2+}(aq)$
   D. $Fe^{3+}(aq)$

10. Which one of the following ions is the formula of the complex formed when aluminium ions?
    A. $[Al(OH)_4]^+$
    B. $[Al(OH)_4]^-$
    C. $[Al(OH)_4]^{3+}$
    D. $[Al(OH)_4]^{3+}$
11. Which of the following cations when in solution will not form a precipitate when reacted with sodium hydroxide solution?
    A. Ca^{2+} B. Pb^{2+} C. Ba^{2+} D. Zn^{2+}
12. Which of the following pairs of ions consist of ions that react with aqueous ammonia to form precipitates which are soluble in excess ammonia?
    A. Zn^{2+} and Al^{3+}
    B. Zn^{2+} and Fe^{2+}
    C. Cu^{2+} and Zn^{2+}
    D. Al^{3+} and Fe^{3+}
13. Which one of the following cations when treated with aqueous sodium hydroxide will give a precipitate that does not dissolve in excess alkali?
    A. Al^{3+}
    B. Pb^{2+}
    C. Zn^{2+}
    D. Fe^{3+}
14 Which one of the following anions will react with lead (II) nitrate solution to form a yellow precipitate?
    A. $Cl^-(aq)$
    B. $I^-(aq)$
    C. CO_3^{2-}
    D. $SO_4^{2-}(aq)$
15. Which one of the following hydroxides will react with both dilute hydrochloric acid and aqueous sodium hydroxide?
    A. $Fe(OH)_3$
    B. $Al(OH)_3$
    C. $Cu(OH)^2$
    D. $Mg(OH)^2$
16. Which of the following when reacted with aqueous sodium hydroxide will form a precipitate that is soluble in excess sodium hydroxide solution is
    A. $Fe^{2+}(aq)$
    B. $Al^{3+}(aq)$
    C. $Cu^{2+}(aq)$
    D. $Fe^{2+}(aq)$
17. Which one of the following ions reacts with ammonia to form a precipitate which dissolves in excess ammonia to form a colorless solution?
    A. Zn^{2+}
    B. Mg^{2+}
    C. Cu^{2+}
    D. Fe^{3+}

18. Which one of the anions does not form a precipitate with Pb^{2+} (aq)?
    A. CO_3^{2-}(aq)
    B. OH^-(aq)
    C. NO_3^-(aq)
    D. SO_4^{2-}(aq)
19. Which one of the following ion s react with Cl^-(aq) to form a precipitate which dissolve on heating?
    A. Cu^{2+}(aq)
    B. Fe^{2+}(aq)
    C. Pb^{2+}(aq)
    D. Ca^{2+}(aq)
20 White precipitate was formed when an aqueous solution of a salt was reacted with aqueous barium nitrate. The white precipitate dissolved in nitric acid. The anion is the salt is
    A. SO_3^{2-}
    B. NO_3^-
    C. SO_4^{2-}
    D. Cl^-
21 Which one of the following ion can be confirmed by the brown ring test?
    A. Cl^-
    B. NO_3^-
    C. CO_3^{2-}
    D. SO_4^{2-}
22 Which one of the following ions forms a green precipitate with excess sodium hydroxide?
    A. Fe^{3+}
    B. Fe^{2+}
    C. Cu^{2+}
    D. Zn^{2+}

In each of the questions 23 to 26 one or more of the answers given may be correct. Read each question carefully and then indicate the correct answer according to the following

A. If 1, 2, 3, only are correct
B. If 1 and 3 only are correct
C. If 2 and 4 only are correct
D. If 4 only is correct

23. Which one(s) of the following oxides dissolve(s) in both aqueous sodium hydroxide and nitric acid
    1. Magnesium oxide
    2. Aluminium oxide
    3. Copper (II) oxide
    4. Lead (II) oxide
24 The hydroxide(s) which is/are soluble in excess ammonia solution is/are
    1. Lead (II) hydroxide
    2. Zinc hydroxide
    3. Aluminium hydroxide
    4. Copper (II) hydroxide

25 Which of the following ions in solution will react with lead (II) nitrate solution to form a white precipitate?

1. CO_3^{2-}
2. SO_4^{2-}
3. Cl^-
4. I^-

26. Which of the following ions react with sodium hydroxide solution to form a precipitate that is soluble in excess sodium hydroxide solution?

1. $Cu^{2+}(aq)$
2. $Al^{3+}(aq)$
3. $Fe^{3+}(aq)$
4. $Pb^+(aq)$

Section B

27 (a) Dilute ammonia solution was added to a solution containing Lead (II)s. write an ionic equation for the reaction that took place. (1mark)

(b) To the resultant mixture in (a) was added dilute sodium hydroxide solution drop wise until in excess.

(i) State what is observed (1mark)

(ii) Give a reason for your answer in (b)(i) (1marks)

(c) Zinc powder was added to aqueous solution of lead (II) nitrate and mixture allowed to stand.

(i) Write ionic equation for the reaction that took place (01marks)

(ii) State any conclusion that can be drawn from the equation you have written in (c)(i)

28. A mixture containing copper (II) sulphate and copper (II) carbonate was shaken with excess water and filtered

(a) Identify the residue

(b) The dry residue was heated strongly

(i) State what was observed

(ii) Write an equation for the reaction

(C) (i) Name a reagent that can be used to identify the anion in the filtrate

(ii) write ionic equation for the anion and reagent you have named in (c)(i)

29. Name one reagent that can be used to distinguish between the following pairs of ions. In each case state what is observed when each ion is treated with the reagent.

(a) $Pb^{2+}(aq)$ and $Al^{3+}(aq)$

Reagent ……..

Observation

……

……

(b) $SO_4^{2-}(aq)$ and $CO_3^{2-}(aq)$

Reagent ……..

Observation

……

……

Answers

1	C	6	C	11	D	16	B	21	B	26	B
2	D	7	A	12	C	17	A	22	B		
3	D	8	B	13	D	18	C	23	C		
4	C	9	B	14	B	19	C	24	C		
5	D	10	B	15	B	20	A	25	A		

27 (a) $Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$

(b) (i) White precipitate soluble in excess

(ii) White precipitate of lead (II) hydroxide formed dissolved to form soluble complex.

$Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$

Then

$Pb(OH)_2(s) + 2OH^-(aq) \rightarrow Pb(OH)_4^{2-}(aq)$

(c) (i) $Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$

(ii) Zinc displaces lead ions from solution

28 (a) Copper (II) carbonate, $CuCO_3$

(b) (i) Green solid turned black

(ii) $CuCO3(s) \xrightarrow{heat} CuO(s) + CO_2(g)$

(c) (i) Addition of an acid, effervescence is observed, the gas turns lime water milky.

(ii) $2H^+(aq) + CO_3^{2-}(s) \rightarrow H_2O(l) + CO_2(g)$

29 (a) Reagent: KI solution

Pb^{2+}: yellow ppt

Al^{3+}: No observable change

(b) Reagent: acidified barium chloride solution
SO_4^{2-}: white precipitate
CO_3^{2-} : effervescence