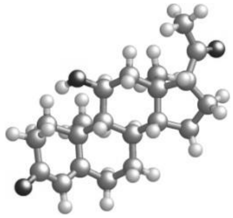

Chem!stry

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Identification of Gases

Gas	Observations
Ammonia, $NH_3(g)$	Colourless. Pungent. Damp red litmus paper turns blue. White fumes of $NH_4Cl(s)$ are observed when a glass rod dipped in concentrated hydrochloric acid is brought near the gas.
Chlorine, $Cl_2(g)$	Pale green-yellow. Pungent. Damp blue litmus paper turns red and is then bleached white.
Water vapour, $H_2O(g)$	Colourless. Odourless. Anhydrous copper(II) sulfate paper changes colour from white to blue. Anhydrous cobalt(II) chloride paper changes colour from blue to pink.
Sulphur dioxide, $SO_2(g)$	Colourless. Pungent. Acidified potassium manganate(VII) changes colour from purple to colourless.
Carbon dioxide, $CO_2(g)$	Colourless. Odourless. White precipitate of $CaCO_3(s)$ forms when the gas is bubbled into limewater. **Note:** Colourless solution of $Ca(HCO_3)_2(aq)$ formed if excess $CO_2(g)$ is used.
Oxygen, $O_2(g)$	Colourless. Odourless. Relights a glowing splint.
Hydrogen, $H_2(g)$	Colourless. Odourless. Lighted splint is extinguished with a '*pop*' sound.
Hydrogen chloride, $HCl(g)$	Colourless. Pungent. Damp blue litmus paper turns red. White fumes of $NH_4Cl(s)$ are observed when a glass rod dipped in aqueous ammonia is brought near the gas.

Identification of Cations Part #1 – Test-tube Reactions

Cation	Using aqueous sodium hydroxide – $NaOH(aq)$	*Using aqueous ammonia – $NH_3(aq)$
Aluminium cation, $Al^{3+}(aq)$	White precipitate of $Al(OH)_3(s)$ – soluble in excess $NaOH(aq)$ giving a colourless solution.	White precipitate of $Al(OH)_3(s)$ – insoluble in excess $NH_3(aq)$.
Calcium cation, $Ca^{2+}(aq)$	White precipitate of $Ca(OH)_2(s)$ – insoluble in excess $NaOH(aq)$.	No observed reaction. No precipitate formed.
Zinc cation, $Zn^{2+}(aq)$	White precipitate of $Zn(OH)_2(s)$ – soluble in excess $NaOH(aq)$ giving a colourless solution.	White precipitate of $Zn(OH)_2(s)$ – soluble in excess $NH_3(aq)$ giving a colourless solution.
Lead(II) cation, $Pb^{2+}(aq)$	White precipitate of $Pb(OH)_2(s)$ – soluble in excess $NaOH(aq)$ giving a colourless solution.	White precipitate of $Pb(OH)_2(s)$ – insoluble in excess $NH_3(aq)$.
Iron(II) cation, $Fe^{2+}(aq)$	Green precipitate of $Fe(OH)_2(s)$ – insoluble in excess $NaOH(aq)$. Turns red-brown on standing.	Green precipitate of $Fe(OH)_2(s)$ – insoluble in excess $NH_3(aq)$. Turns red-brown on standing.
Iron(III) cation, $Fe^{3+}(aq)$	Red-brown precipitate of $Fe(OH)_3(s)$ – insoluble in excess $NaOH(aq)$.	Red-brown precipitate of $Fe(OH)_3(s)$ – insoluble in excess $NH_3(aq)$.
Copper(II) cation, $Cu^{2+}(aq)$	Blue precipitate of $Cu(OH)_2(s)$ – insoluble in excess $NaOH(aq)$.	Blue precipitate of $Cu(OH)_2(s)$ – soluble in excess $NH_3(aq)$ to give a dark blue solution.
Ammonium cation, $NH_4^+(aq)$	No precipitate – ammonia gas produced on warming (turns damp red litmus paper blue).	Test not applicable.

***Note:** In balanced chemical equations, aqueous ammonia should be written as $NH_4OH(aq)$, **not** $NH_3(aq)$.

Identification of Cations Part #2 – Flame Tests

Cation	Observation
Sodium, Na^{+}	Yellow / orange flame colour.
Potassium, K^{+}	Lilac flame colour.
Calcium, Ca^{2+}	Brick red flame colour.
Barium, Ba^{2+}	Apple green flame colour.
Copper(II), Cu^{2+}	Green flame colour.

Identification of Anions

Anion	Observation
Carbonate, $CO_3^{2-}(aq)$	Add dilute acid. Effervescence is observed. Carbon dioxide gas is produced (carbon dioxide gas produces a white precipitate of $CaCO_3(s)$ when bubbled through limewater).
Chloride, $Cl^{-}(aq)$	Add dilute nitric acid followed by dilute aqueous silver nitrate. A white precipitate of $AgCl(s)$, which is soluble in aqueous ammonia, but insoluble in dilute nitric acid, confirms chloride ions. **Note:** $Pb(NO_3)_2$ can be used in place of $AgNO_3$. A white precipitate of $PbCl_2(s)$ will be observed.
Iodide, $I^{-}(aq)$	Add dilute nitric acid followed by dilute aqueous silver nitrate. A yellow precipitate of $AgI(s)$, which is insoluble in aqueous ammonia and insoluble in dilute nitric acid confirms iodide ions. **Note:** $Pb(NO_3)_2$ can be used in place of $AgNO_3$. A yellow precipitate of $PbI_2(s)$ will be observed.
Nitrate, $NO_3^{-}(aq)$	Add aqueous sodium hydroxide followed by $Al(s)$ or $Zn(s)$ and warm the mixture. Ammonia gas is produced (turns damp red litmus paper blue). **Note:** Should exclude NH_4^{+} before testing for NO_3^{-}.
Sulfate, $SO_4^{2-}(aq)$	Add dilute nitric acid followed by either dilute aqueous barium chloride or dilute aqueous barium nitrate. A white precipitate of $BaSO_4(s)$ indicates the presence of sulfate ions.

Summary of Tests

• **Test for Cations:** The tests for the cations (positive ions) relies on the fact that all hydroxides are **insoluble** in water, except NaOH, KOH and NH_4OH. Aqueous sodium hydroxide and aqueous ammonia are the two reagents that are used to test for cations. One essential difference between using aqueous sodium hydroxide and aqueous ammonia is that 1.0 mol/dm^3 aqueous sodium hydroxide has a higher $OH^{-}(aq)$ concentration compared to 1.0 mol/dm^3 aqueous ammonia. If the solution of the unknown salt contains the cation of a **transition metal** (Cu^{2+}, Fe^{2+}, Fe^{3+}) then the hydroxide that precipitates will be **coloured**. If the solution of the unknown salt contains the cation of an **amphoteric** element (Al^{3+}, Pb^{2+}, Zn^{2+}) then the white hydroxide that precipitates will **dissolve** in excess aqueous sodium hydroxide to give a colourless solution. Only the white precipitate of $Zn(OH)_2(s)$ and the blue precipitate of $Cu(OH)_2(s)$ dissolve in excess aqueous ammonia to give a colourless solution and dark blue solution respectively. Calcium ions are unique because they give a white precipitate with aqueous sodium hydroxide that is insoluble in excess reagent. Ammonium ions are unique because they react with aqueous sodium hydroxide to produce gaseous ammonia (turns damp red litmus paper blue): ammonium salt + base $\rightarrow$ salt + water + ammonia. Al^{3+} ions can be distinguished from Pb^{2+} ions by adding a solution of sodium chloride or potassium iodide. If Pb^{2+} ions are present in solution, then either a white precipitate of $PbCl_2$ or a yellow precipitate of PbI_2 will be observed (there will be no observed reaction if aluminium ions are present in the solution).

• **Test for Anions:** Testing for anions (negative ions) relies on the reactions of acids and solubility rules. The presence of a carbonate is tested by adding an acid to produce a salt, water and carbon dioxide gas (gives a white precipitate when bubbled through limewater): acid + carbonate $\rightarrow$ salt + water + carbon dioxide. All sulfates are soluble, except for $BaSO_4$ (and $CaSO_4$ and $PbSO_4$) so adding *acidified* $Ba(NO_3)_2(aq)$ to the solution of an unknown salt will give a white precipitate of $BaSO_4(s)$ if $SO_4^{2-}(aq)$ are present in solution. All chlorides are soluble, except for $AgCl$ and $PbCl_2$, so adding either *acidified* $AgNO_3(aq)$ or acidified $Pb(NO_3)_2(aq)$ will give white precipitates of $AgCl(s)$ and $PbCl_2(s)$ respectively if $Cl^{-}(aq)$ are present in solution. Iodides follow the same solubility rules as chlorides, so the test for $I^{-}(aq)$ is similar to the test for $Cl^{-}(aq)$, except the precipitates are yellow.