ChemFactsheet

www.curriculumpress.co.uk Number 63

Answering Questions on Identifying Unknown Inorganic Compounds

Before reading through this Factsheet you should:
- Be confident in assigning ionic formulae;
- Have gained practical experience of inorganic chemistry tests and preparations. (Factsheet 24);
- Know and understand the AS/A2 content on inorganic chemistry (Factsheets 13, 14, 19, 20, 38, 46, 47).

After working through this Factsheet you will be able to:
- Identify unknown inorganic chemicals when supplied with the necessary information in a written exam or practical situation.

The aim of this Factsheet is to provide candidates with the necessary information and experience to tackle questions involving the identification of unknown inorganic compounds.

Such questions are commonplace in both written and practical exam situations, and also practical assessments. In practical situations candidates will most likely be required to carry out simple chemical tests and make observations. In an exam situation the observations may be supplied, or the question may involve selecting the correct reagents for particular situations.

This Factsheet will provides summaries of the common tests (see tables at the end of the Factsheet) and help in making inferences from the test results.

Strategy

Read the question carefully, assume any information about the unknown chemical supplied is important and must be considered. It is worth "ticking off" the information to make sure you have used it all.

Unknown inorganic compounds are likely to be ionic - identification is usually achieved through chemical testing for both the anion and cation. Although some pieces of information can be used in isolation - eg a flame test - be aware that you will often have to make deductions from the results of more than one test - for example, a white precipitate with acidified barium chloride solution indicates a sulphate or hydrogen sulphate, but you will need to combine this with a further test (addition of sodium carbonate solution) to distinguish between the two.

Chemical tests are not the only things to provide useful information. You should also note the colour of the compound, and whether it is soluble or not:-

Colour -
- a coloured compound suggests a transition metal,
- most group 1 and 2 compounds are white

Solubility
- alkali metal, ammonium salts and nitrates are soluble
- halides are soluble except for lead, mercury and silver
- sulphates are soluble except for calcium, strontium, barium, silver, mercury and lead
- carbonates and hydroxides are insoluble except for group 1 and ammonium compounds.

These can provide a useful check on the results of chemical tests - if you think you have a solution of copper carbonate, for example, you cannot be right, as it is insoluble. Likewise, a blue compound is unlikely to be a sodium salt.
The example below indicates how conclusions can be drawn from each piece of information. Further examples are overleaf.

Information given	**Conclusion drawn**
Inorganic compound P is a pale green solid.	*Suggests P contains transition metal cation*
$10cm^3$ of a solution of P was made up in a test tube.	*P is soluble - not a carbonate or hydroxide (it can't be a group 1 carbonate or hydroxide)*
Sodium hydroxide solution was added to $5cm^3$ of this solution A pale green precipitate was produced, which became brown on its surface with standing. The precipitate did not dissolve in excess sodium hydroxide.	*Green ppt could be Fe^{2+}, Cr^{3+}, Ni^{2+}. Insoluble in excess, so not Cr^{3+}* *Brown on surface $\Rightarrow Fe^{2+}$ (brown is from oxidation to Fe^{3+})*
The mixture from the previous test was warmed. A gas was evolved which turned damp red litmus paper blue	*Gas is ammonia $\Rightarrow NH_4^+$ present*
To the remaining $5cm^3$ of P, barium chloride solution was added dropwise, followed by dilute hydrochloric acid. A white precipitate was observed.	*White ppt $\Rightarrow$sulphate or hydrogen sulphate*
On addition of sodium carbonate solution to this mixture, a very slight effervescence was observed	*Only slight effervescence $\Rightarrow Fe^2$sulphate* ***Compound is ammonium iron (II) sulphate $(NH_4)_2Fe(SO_4)_2$***

Practice Questions

1. Use the following information to identify inorganic chemical A:

   Flame test: Yellow-orange flame.
   To 3 cm^3 of a solution of A was added 3 cm^3 2M HNO_3 and 0.1M $AgNO_3$ dropwise.
   A cream precipitate was produced which would not dissolve in dilute NH_3 (aq), but did dissolve in concentrated NH_3 (aq).

2. Use the following information to identify inorganic chemical B:

   4 cm^3 of a solution of B was made up in a test tube. Sodium hydroxide solution was added, and the mixture warmed. A gas was given off which turned damp red litmus paper blue.

   Another sample of B was dissolved in dilute nitric acid, and then barium chloride solution was added dropwise. A white precipitate was observed.
   Sodium carbonate was added to a solution of B, and there was no observable reaction.

3. Use the following information to identify inorganic chemical C:

   Solid C gives a lilac colour in a flame test.
   A solution of C is boiled with sodium hydroxide solution and aluminium powder. Fumes were evolved which turned damp red litmus paper blue.

4. Use the following information to identify inorganic chemical D:

   D is in the form of a blue solution. On addition of ammonia solution dropwise to D, a sky blue precipitate is formed.
   As the ammonia is then added to excess, this precipitate dissolves leaving a deep blue solution.

   Another sample of B is tested with solid sodium carbonate – there is no observable reaction.
   To a different sample of D dilute hydrochloric acid is added, and then barium chloride solution dropwise – a white precipitate forms.

5. a) Use the following information to suggest possible identities for inorganic chemical E:

   E produces a brick red flame in a flame test.
   On addition of dilute hydrochloric acid to solid E there is effervescence.
   The gas produced is bubbled through lime water, which turns cloudy white.

   b) Describe an additional chemical test that could be used to determine the identity of E

6. Use the following information to identify inorganic chemical F

   F is a white solid.
   On heating, F evolves a brown gas which turns damp blue litmus paper red.
   On addition of sodium carbonate solution to a solution of F, a white precipitate is formed.
   A flame test produces an apple-green flame

Answers

1. Yellow-orange flame ⇒ sodium
   Silver nitrate test⇒ halide

   cream ppt, soluble in conc NH_3 ⇒ bromide
   Note that a cream ppt can be difficult to distinguish from white or yellow - the solubility in conc ammonia is essential to be certain it is bromide

   A is sodium bromide (NaBr)

2. Sodium hydroxide test for cations
   No ppt ⇒no cation with insoluble hydroxide present
   Gas given off is ammonia (alkaline gas)
   Ammonium ions present

   Barium chloride test for sulphate or hydrogen sulphate
   No effervescence with sodium carbonate ⇒sulphate
   Note that if the barium chloride was not acidified, carbonates would also produce a white ppt

   B is ammonium sulphate $(NH_4)_2SO_4$)

3. Lilac flame ⇒ potassium

   Gas evolved is ammonia (from reduction of nitrate ion) ⇒ nitrate

   C is potassium nitrate. (KNO_3)

4. Blue solution suggests compound of a transition metal

   Blue ppt with ammonia solution ⇒ Cu^{2+} or Co^{2+}
   Dissolves to give deep blue solution ⇒ Cu^{2+}

   No reaction with sodium carbonate ⇒ not acidic (eg not hydrogen sulphate)

   White ppt with barium chloride ⇒ sulphate (cannot be hydrogen sulphate from previous test)

   D is copper (II) sulphate ($CuSO_4$)

5.a) Brick red flame ⇒ calcium

   Gas evolved on addition of acid is carbon dioxide ⇒ carbonate or hydrogen carbonate

   E is either calcium carbonate, $CaCO_3$ or calcium hydrogen carbonate, $Ca(HCO_3)_2$

   b) Add $MgSO_4$ (aq) dropwise to solution.
   White ppt indicates CO_3^{2-}, no ppt indicates HCO_3^-

6. White solid suggests not a transition metal

   Brown gas is nitrogen dioxide - thermal decomposition of nitrate

   White ppt with sodium carbonate ⇒ cation has insoluble carbonate, so not group 1

   Apple-green flame ⇒ barium

   F is barium nitrate

Tests for simple anions

Anion	Test	Expected Observation
Choride, Cl^-	To solution add dilute HNO_3 then $AgNO_3$ (aq).	White ppt of AgCl, soluble in dilute NH_3 (aq)
Bromide, Br^-	To solution add dilute HNO_3 then $AgNO_3$ (aq).	Cream ppt of AgBr, soluble in conc. NH_3 (aq)
Iodide, I^-	To solution add dilute HNO_3 then $AgNO_3$ (aq).	Yellow ppt of AgI, insoluble in conc. NH_3 (aq)
Nitrate, NO_3^-	Boil with sodium hydroxide solution and aluminium powder	Fumes of ammonia gas
Nitrite, NO_2^-	Add acidified potassium iodide solution	Colour of solution turns brown as iodine is liberated
Carbonate, CO_3^{2-} and hydrogen carbonate, HCO_3^-	Add dilute HCl to solid or solution	Effervesence, CO_2 produced (turns limewater cloudy white)
To differentiate between CO_3^{2-} and HCO_3^-	Add $MgSO_4$ (aq) dropwise to solution	White ppt indicates CO_3^{2-}, no ppt indicates HCO_3^-
Sulphate, SO_4^{2-} and hydrogen sulphate HSO_4^-	Add dilute HCl then BaCl (aq) to solution.	White ppt of $BaSO_4$
To differentiate between SO_4^{2-} and HSO_4^-	Add Na_2CO_3 to solution	Vigorous effervescence of CO_2 indicates HSO_4^-, slight or no effervescence indicates SO_4^-
Sulphite, SO_3^{2-}	Add dilute HCl to solid or solution and warm	Pungent SO_2 evolved, which turns acidified dichromate from orange to green

Cation tests using NaOH(aq)

Cation	Addition of NaOH (aq) dropwise	Addition of excess NaOH (aq)
Ammonium, NH_4^+	On warming, ammonia gas evolved, turning red litmus paper blue	
Chromium, Cr^{3+}	Green ppt	Green solution
Manganate, Mn^{2+}	Buff ppt, darkens in air	Precipitate does not dissolve
Iron (II), Fe^{2+}	Pale green ppt, browns on surface	Precipitate does not dissolve
Iron (III), Fe^{3+}	Red brown ppt	Precipitate does not dissolve
Cobalt, Co^{2+}	Blue ppt, turns brown in air	Precipitate does not dissolve
Nickel, Ni^{2+}	Pale green ppt	Precipitate does not dissolve
Copper, Cu^{2+}	Pale blue ppt	Precipitate does not dissolve
Zinc, Zn^{2+}	White ppt	Colourless solution

Cation tests using NH_3(aq)

Cation	Addition of NH_3(aq) dropwise	Addition of excess NH_3 (aq)
Chromium, Cr^{3+}	Green ppt	Precipitate does not dissolve
Manganate, Mn^{2+}	Buff ppt, darkens in air	Precipitate does not dissolve
Iron (II), Fe^{2+}	Pale green ppt, browns on surface	Precipitate does not dissolve
Iron (III), Fe^{3+}	Red brown ppt	Precipitate does not dissolve
Cobalt, Co^{2+}	Blue ppt, turns brown in air	Precipitate does not dissolve
Nickel, Ni^{2+}	Pale green ppt	Blue solution
Copper, Cu^{2+}	Pale blue ppt	Deep blue solution
Zinc, Zn^{2+}	White ppt	Colourless solution

Flame Tests

Cation	Expected observation
Sodium, Na^+	Yellow-orange flame
Potassium, K^+	Lilac flame
Calcium, Ca^{2+}	Brick red flame
Barium, Ba^{2+}	Apple green flame

Nitrates

- Group 1 nitrates (except lithium nitrate) decompose to give the metal nitrite and oxygen gas
- Group 2 nitrates (and lithium nitrate) decompose to give the metal oxide, the brown gas nitrogen dioxide and oxygen:
- Thermal stability increases down both groups

Carbonates

- Group 1 carbonates will not decompose on heating, except lithium carbonate:
- Group 2 carbonates all decompose (except for barium carbonate, which is stable) to form the metal oxide and carbon dioxide gas
- Thermal stability increases down both groups

Tests for gases

Gas	Description of gas	Test	Expected observation
Hydrogen, H_2	Colourless, odourless	Ignite using a lighted splint	'Squeaky pop' sound. Pale blue flame
Oxygen, O_2	Colourless, odourless	Glowing splint	Splint ignites or glows brighter
Carbon dioxide, CO_2	Colourless, odourless	Bubble through lime water	Turns cloudy white
Ammonia, NH_3	Colourless, pungent	Moist red litmus paper	Turns blue
Chlorine, Cl_2	Yellow-green, pungent	(a) Moist universal indicator paper (b) Bubble through KBr (aq)	Turns red then bleached white Solution turns yellow-orange
Nitrogen dioxide, NO_2	Brown, pungent	Moist universal indicator paper	Turns red
Sulphur dioxide, SO_2	Colourless, pungent	Moist dichromate paper	Turns from orange to green

Acknowledgements: *This Factsheet was researched and written by Kieron Heath.* ***Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU. ChemistryFactsheets*** *may be copied free of charge by teaching staff or students, provided that their school is a registered subscriber. No part of these Factsheets may be reproduced, stored in a retrieval system, or transmitted, in any other form or by any other means, without the prior permission of the publisher.* ***ISSN 1351-5136***