Topic 5: **Answers**
Salts

SYLLABUS RELEVANCE & TEXTBOOK CHAPTERS		
O-LEVEL PURE (5072)	✓	Chapter 12.1/2
O-LEVEL SCIENCE (5116)	✓	Chapter 11.1/2
N-LEVEL SCIENCE (5155)	✓	Chapter 10

Lesson Package & Accompanying Slides Designed by Alex Lee (2009)
Last Modified by Alex Lee (2011)

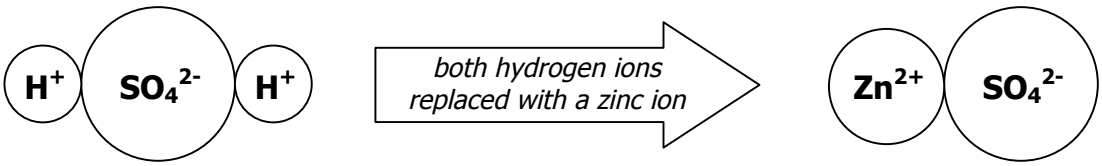
1. What Is A Salt?

When we think of the term 'salt', it is often associated with the small white crystals found in a salt shaker on any restaurant table. This is merely one particular type of salt, sodium chloride, or more commonly known as 'table salt' or 'sea salt'.

In chemistry, the term 'salt' refers to many, many more things than just sodium chloride:

A **salt** is an ionic compound which is formed when a metallic ion or an ammonium ion replaces one or more hydrogen ions of an acid.

Let us, for example, take a look at a salt **zinc sulfate**:



sulfuric acid

formula: H_2SO_4

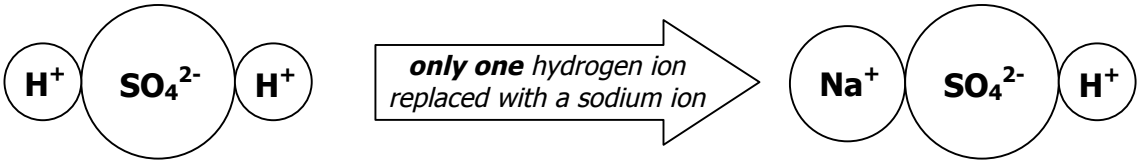
zinc sulfate (salt)

formula: $ZnSO_4$

However, in the case of dibasic and tribasic acids, it is possible that not all the hydrogen ions in an acid is completely replaced with a metallic ion. In this situation, we have both metallic ions present as well as hydrogen ions present.

This substance, containing both metallic cations and hydrogen cations, is known as an **acid salt**.

To illustrate, let us take a look at an acid salt **sodium hydrogen sulfate**:



sulfuric acid

formula: H_2SO_4

sodium hydrogen sulfate (acid salt)

formula: $NaHSO_4$

2. **Hydrated & Anhydrous Salts**

At room temperature, most salts can exist in three forms, provided they are soluble:

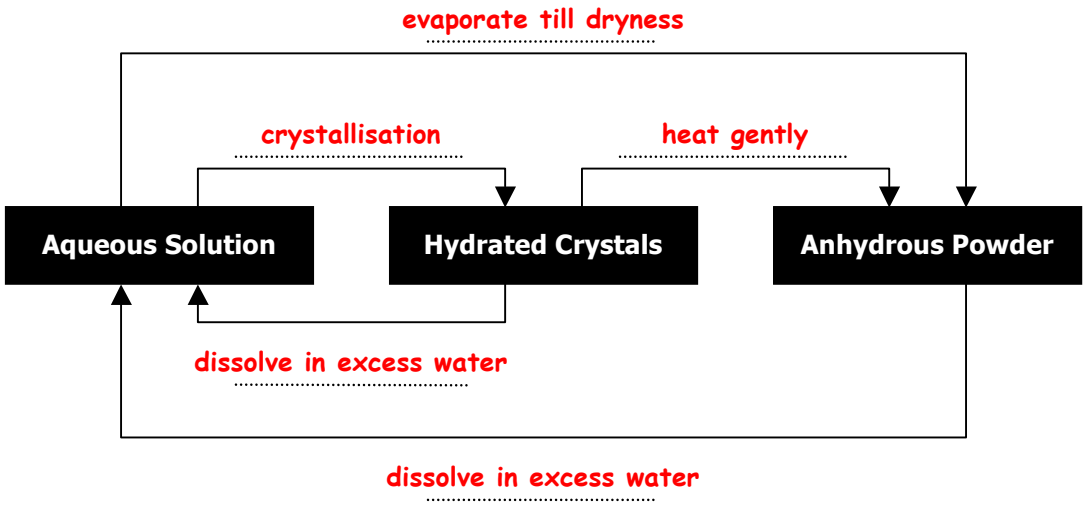
Aqueous State	**Solid Crystals** ('Hydrated' Salt)	**Solid Powder** ('Anhydrous' Salt)
Example: $CuSO_4$ (aq)	*Example:* $CuSO_4.5H_2O$ (s)	*Example:* $CuSO_4$ (s)

You would notice that the crystals contain water molecules in their formulae (and of course, structure). These 'trapped' water molecules are known as **water of crystallization**. The ratio of water molecules to salt varies from compound to compound, as you will see below. (Thankfully, there is no need to memorize this.)

Four examples of hydrated salts are given in the table below. For each of the salts, write down the corresponding chemical formula for its aqueous form and its anhydrous form.

Formula of Aqueous Salt	Formulae of Crystals	Formula of Anhydrous Salt
$CoCl_2$ (aq)	$CoCl_2.6H_2O$ (s)	$CoCl_2$ (s)
$MgSO_4$ (aq)	$MgSO_4.7H_2O$ (s)	$MgSO_4$ (s)
Na_2CO_3 (aq)	$Na_2CO_3.10H_2O$ (s)	Na_2CO_3 (s)
$ZnSO_4$ (aq)	$ZnSO_4.7H_2O$ (s)	$ZnSO_4$ (s)

Salts can be converted between an aqueous form, a crystalline from and an anhydrous form relatively easily through some physical changes in a laboratory. Complete the diagram below to illustrate the methods that may be used to perform the corresponding conversions.



You would notice that there is no means of converting an anhydrous powder into hydrated crystals directly. Instead, one will need to dissolve the powder to form an aqueous solution first.

3. **Solubility of Salts in Water**

The table below shows the general solubility rules for common salts.

	SOLUBLE	INSOLUBLE
NITRATES, NO_3^-	All **soluble**	-
HALIDES (CHLORIDES, Cl^- & IODIDES, I^-)	All **soluble**, except	**Lead(II) and Silver** *i.e. AgCl $PbCl_2$ AgI PbI_2*
SULFATES, SO_4^{2-}	All **soluble**, except	**Calcium, Barium, Lead(II)** *i.e. $CaSO_4$ $BaSO_4$ $PbSO_4$*
BASES (HYDROXIDES, OH^- & OXIDES, O^{2-})	**Group I (Sodium, Potassium), Ammonium, Barium, Calcium** *i.e. NaOH KOH NH_4OH *$Ca(OH)_2$ *$Ba(OH)_2$*	All **insoluble**, except
CARBONATES, CO_3^{2-}	**Group I (Sodium, Potassium), Ammonium** *i.e. Na_2CO_3 K_2CO_3 $(NH_4)_2CO_3$*	All **insoluble**, except

** only slightly soluble.*

In the list of salts below, place a tick (✓) next to those which are soluble in water, and a cross (✗) next to those which are insoluble in water.

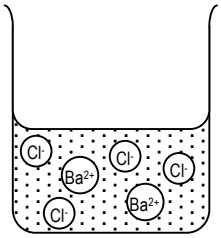
aluminium oxide ✗	copper(II) carbonate ✗	nickel(II) nitrate ✓
ammonium carbonate ✓	iron(III) chloride ✓	potassium iodide ✓
barium chloride ✓	iron(III) oxide ✗	silver chloride ✗
barium sulfate ✗	lithium chloride ✓	sodium carbonate ✓
calcium carbonate ✗	lead(II) iodide ✗	sodium nitrate ✓
calcium chloride ✓	lead(II) nitrate ✓	tin(II) sulfate ✓
cobalt(II) chloride ✓	lead(II) sulfate ✗	zinc carbonate ✗
copper(II) sulfate ✓	magnesium carbonate ✗	zinc hydroxide ✗

Based on the above table, you would notice that group I, ammonium, calcium and barium oxides are considered to be soluble or slightly solube in water. However, their aqueous **solutions are unheard of** because these oxides **react readily with water to form hydroxides**:

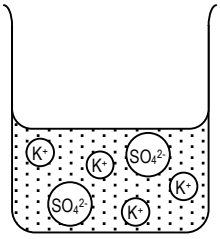
$$\mathbf{Na_2O\ (s) + H_2O\ (l) \longrightarrow 2\ NaOH\ (aq)}$$
$$\mathbf{K_2O\ (s) + H_2O\ (l) \longrightarrow 2\ KOH\ (aq)}$$
$$\mathbf{CaO\ (s) + H_2O\ (l) \longrightarrow Ca(OH)_2\ (aq)}$$

4. **Precipitation**

Barium chloride and potassium sulfate are both soluble salts. In solution, the barium ions, chloride ions, potassium ions and sulfate ions are allowed to move freely between the water molecules (and are hence able to conduct electricity).

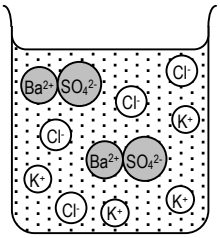


aq barium chloride, $BaCl_2$



aq potassium sulfate, K_2SO_4

When the two solutions are mixed, the barium ions (Ba^{2+}) are able to come into contact with the sulfate ions (SO_4^{2-}), forming an insoluble salt of barium sulfate ($BaSO_4$). We would observe white particles of barium sulfate suspended in the colourless solution.



precipitate of barium sulfate formed

Generally, if any mixture of ions can give rise to an insoluble salt, a precipitate will be formed. Hence it is important to know the solubility table well in order to predict any precipitation.

Write down the chemical formula of the precipitate formed in the following mixtures of salts. If there is no precipitate formed, write "none".

Solution 1	Solution 2	Precipitate Formed
potassium nitrate	copper(II) sulfate	none
magnesium sulfate	calcium nitrate	$CaSO_4$
ammonium hydroxide	zinc iodide	$Zn(OH)_2$
sodium carbonate	aluminium nitrate	$Al_2(CO_3)_3$
iron(III) chloride	sodium hydroxide	$Fe(OH)_3$
lead(II) nitrate	magnesium sulfate	$PbSO_4$
lithium carbonate	ammonium iodide	none
hydrochloric acid	silver sulfate	$AgCl$

5. **Preparation of Salts**

There are three methods of preparing a pure sample of a salt – precipitation, reaction of an acid with an insoluble reactant and titration. Each method is used to prepare a specific type of salt, and care must be taken to ensure purity and sufficient yield.

Method	Type of Salt
Precipitation	All insoluble salts.
Reaction of an Acid with an Insoluble Reactant	All soluble salts, except for Group I and Ammonium salts.
Titration	Group I and Ammonium salts.

For each of the salts below, state which method should be used in its preparation.

Desired Salt	Method of Preparation
magnesium chloride	Reaction of an Acid with an Insoluble Reactant
potassium nitrate	Titration
copper(II) carbonate	Precipitation
zinc sulfate	Reaction of an Acid with an Insoluble Reactant
ammonium sulfate	Titration
barium sulfate	Precipitation

6. **Review Questions**

Below lists eight salts. Use the corresponding alphabets next to each salt to answer the questions that follow. Each salt may be used once, more than once, or not at all.

A: calcium sulfate	**C**: copper(II) chloride	**E**: lead(II) iodide	**G**: sodium sulfate
B: barium chloride	**D**: iron(III) nitrate	**F**: potassium nitrate	**H**: zinc carbonate

Which of the above salts

(a) are insoluble? A, E and H

(b) can be prepared by precipitation? A, E and H

(c) can be prepared by titration? F and G

(d) when mixed, will produce a precipitate? B and G

7. **Preparation of Salts: Precipitation**

USED TO PREPARE: All insoluble salts

REACTANTS: Two aqueous solutions containing the desired cation and anion. For example, to prepare copper(II) carbonate, we could use aqueous copper(II) sulfate and aqueous sodium carbonate. Needless to say, since the reactants are aqueous, they have to be **soluble**.

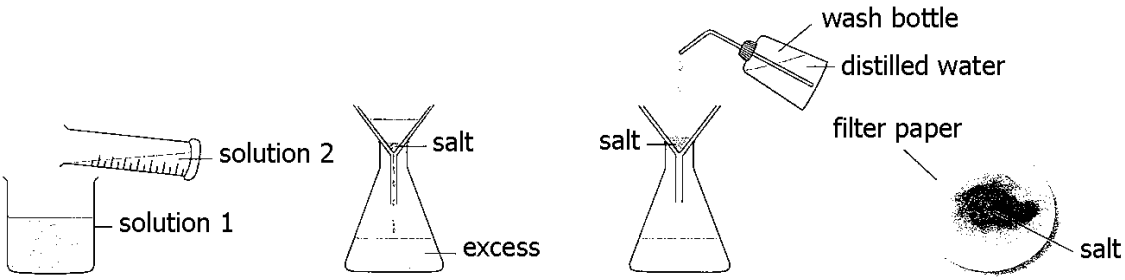
PROCEDURE:

① Mix the two solutions in a beaker. Stir with a glass rod. The precipitate of the desired salt would have been formed.

② Filter out the precipitate (i.e. the insoluble salt you want) using filter paper and a funnel.

③ Wash the **residue** by running distilled water through it.

④ Allow the salt to dry between sheets of filter paper.



Write down the **chemical formula and state symbols** of the starting reagents that could be used to prepare the following salts through the method of precipitation. If the method may not be used, write "will not precipitate".

Desired Salt	Suggested Starting Reagents
calcium sulfate	$Ca(NO_3)_2$ (aq) + K_2SO_4 (aq)/H_2SO_4 (aq)
ammonium carbonate	will not precipitate
lead(II) chloride	$Pb(NO_3)_2$ (aq) + KCl (aq)/HCl (aq)
iron(II) hydroxide	$Fe(NO_3)_2$ (aq) + KOH (aq)/NaOH (Aq)
silver iodide	$AgNO_3$ (aq) + KI (aq)
barium chloride	will not precipitate
magnesium hydroxide	$Mg(NO_3)_2$ (aq) + KOH (aq)/NaOH (Aq)
copper(II) carbonate	$Cu(NO_3)_2$ (aq) + K_2CO_3 (aq)/Na_2CO_3 (aq)

You would realise that choosing two aqueous solutions is simple if we remember that all nitrate salts and Group I salts are soluble!

8. **Preparation of Salts: Reaction of Acid With An Insoluble Reactant**

USED TO PREPARE: All soluble salts, except Group I and Ammonium Salts

REACTANTS:

A dilute acid containing the desired anion. For example, to prepare magnesium *chloride*, we would start with *hydrochloric acid*.

An insoluble base, carbonate or metal of the desired cation. For example, to prepare *magnesium* chloride, we can start with either magnesium hydroxide, magnesium oxide, magnesium carbonate or simply magnesium metal.

(However, copper metal and silver metal are too unreactive and not suitable for reaction with acids. We should only use insoluble bases or insoluble carbonates when preparing soluble copper or silver salts.)

PROCEDURE:

① Warm a sample of the acid in a beaker. Add an excess of the insoluble reactant to a beaker of the selected acid.

② Stir with a glass rod to ensure complete reaction.

③ Filter out the excess reactant, using filter paper and a filter funnel, and collect the **filtrate** (i.e. the solution of the desired salt).

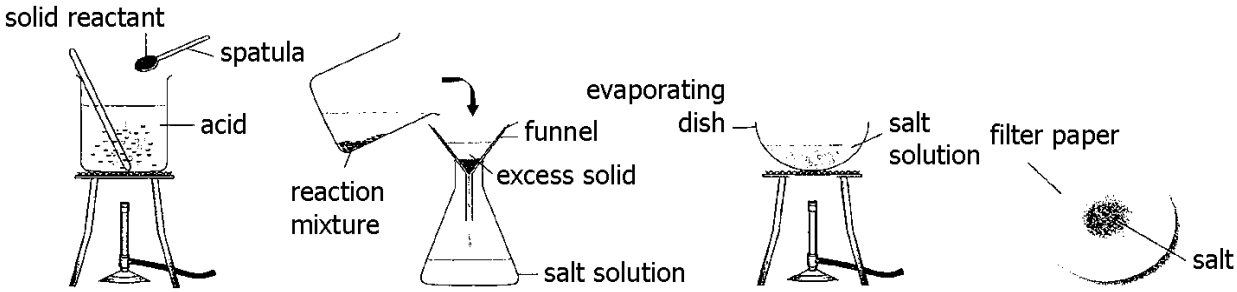
Up till this point, an aqueous solution of the desired salt has been obtained. However, to obtain a solid sample of the salt, you will need to continue with the following crystallisation steps:

④ Heat the filtrate in an evaporating dish till saturation is reached. (To test that saturation has been reached, dip a glass rod into the solution. If crystals form on the glass rod shortly after being removed from the solution, saturation has been reached.)

⑤ Allow the solution to cool. Crystals should be formed in the solution. Extract the solid crystals from the rest of the solution by either **filtration** or **decantation**.

⑥ Allow the salt to dry between sheets of filter paper.

*An easier process of **evaporation to dryness** may also be performed in place of crystallisation. However, this method is not suitable for salts that may get thermally decomposed in the process.*



Write down the **chemical formula and state symbols** of the starting reagents that could be used to prepare the following salts through the method of reacting an acid with an insoluble reactant.

Desired Salt	Suggested Starting Reagents
magnesium chloride	$HCl\ (aq)$ + $MgO\ (s)/MgCO_3\ (s)/Mg\ (s)$
copper(II) sulfate	$H_2SO_4\ (aq)$ + $CuO\ (s)/CuCO_3\ (s)$
zinc nitrate	$HNO_3\ (aq)$ + $ZnO\ (s)/ZnCO_3\ (s)/Zn\ (s)$
iron(II) chloride	$HCl\ (aq)$ + $FeO\ (s)/FeCO_3\ (s)/Fe\ (s)$
barium nitrate	$HNO_3\ (aq)$ + $BaO\ (s)/BaCO_3\ (s)/Ba\ (s)$
aluminium sulfate	$H_2SO_4\ (aq)$ + $Al_2O_3\ (s)/Al_2(CO_3)_3\ (s)/Al\ (s)$
calcium chloride	$HCl\ (aq)$ + $CaO\ (s)/CaCO_3\ (s)/Ca\ (s)$
silver nitrate	$HNO_3\ (aq)$ + $Ag_2O\ (s)/Ag_2CO_3\ (s)$

(a) Briefly explain why an *excess* of the insoluble reactant is needed in this preparation method.

This is to ensure that all of the acid has completely reacted, as any excess acid will contaminate the aqueous salt formed. Excess of the insoluble reactant, on the other hand, can easily be removed through filtration.

(b) A student mistakenly tries to prepare calcium sulfate, an insoluble salt, by this method. He adds an excess of solid calcium carbonate to a beaker of dilute sulfuric acid. His experiment, as expected, failed. Explain why this happened.

When calcium carbonate reacts with dilute sulfuric acid, calcium sulfate, an insoluble salt, is formed. This salt forms an insoluble layer over the calcium carbonate reactant, preventing the calcium carbonate from any further reaction.

(c) Suggest why group I salts may not be prepared through this method by reacting an acid with an excess of a group I base or carbonate.

Group I bases and carbonates are all soluble, and hence any excess reactant will not be able to be recovered through filtration.

(d) Suggest why group I salts may not be prepared through this method by reacting an acid with an excess of a group I metal.

Group I metals are very reactive and hence react violently with acids, causing the experiment to be too dangerous to perform.

9. **Preparation of Salts: Titration**

USED TO PREPARE: Group I and Ammonium Salts

REACTANTS:

A dilute acid containing the desired anion. For example, to prepare sodium *chloride*, we would start with *hydrochloric acid*.

An aqueous alkali or carbonate of the desired cation. For example, to prepare *sodium* chloride, we can start with either aqueous sodium hydroxide or aqueous sodium carbonate.

PROCEDURE:

① Using a pipette, measure out a fixed volume of acid. Transfer this solution into a conical flask.

② Add a few drops of indicator, e.g. phenolphthalein.

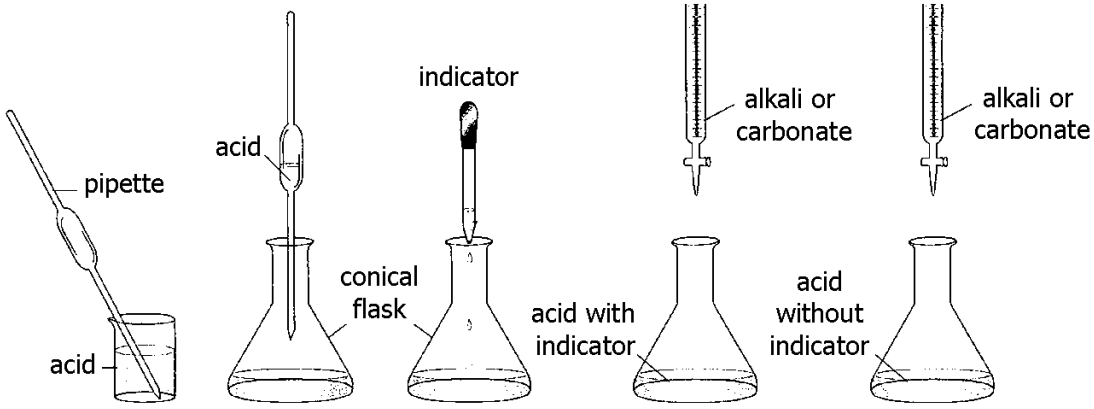
③ Using a burette, add the alkali or carbonate drop-by-drop until the indicator just changes colour. There should be no excess of either reactant.

④ Note down the volume of alkali or carbonate required for complete neutralisation.

⑤ **Repeat** the titration, this time without indicator. Stop the burette when the reading reaches the same level as earlier noted.

Up till this point, an aqueous solution of the desired salt has been obtained. To obtain a solid sample of the salt, you will need to perform crystallisation (as described in Page 7) or evaporation till dryness.

The acid and alkali or carbonate can be used interchangeably – i.e. the acid can be placed in the burette while the alkali or carbonate can be measured out using the pipette instead.

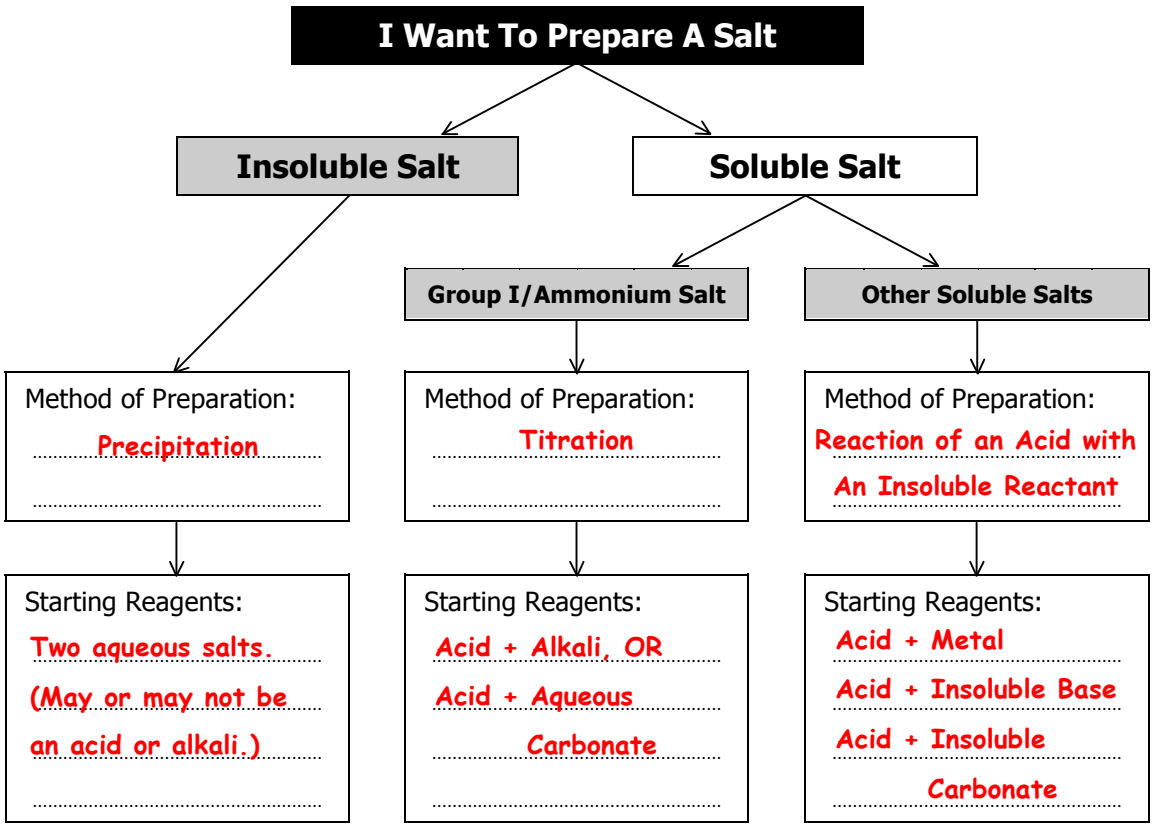


Explain why, in the preparation of sodium chloride, sodium hydroxide or sodium carbonate must be used instead of other sodium salts, e.g. sodium nitrate.

In reacting a base or carbonate with an acid, the only byproduct is water (and carbon dioxide for carbonates). If sodium nitrate was used, there would be a byproduct with nitrate ions (i.e. nitric acid), which would contaminate the salt formed.

10. **Preparation of Salts: A Summary**

Complete the flow chart below which summarizes the various methods of salt preparation.



For each of the salts listed below, suggest (i) the method in which it should be prepared, and (ii) the starting reagents which should be used in its preparation.

(a) ammonium nitrate

(i) preparation method: titration

(ii) starting reagents: aqueous ammonium hydroxide/carbonate + dilute HNO_3

(b) calcium chloride

(i) preparation method: reaction of an acid with an insoluble reactant

(ii) starting reagents: calcium carbonate/metal + dilute HCl

(c) lead(II) chloride

(i) preparation method: precipitation

(ii) starting reagents: aqueous lead(II) nitrate + any aqueous chloride/dilute HCl

Self-Designed Summary

Supplementary Questions

1. For each of the compounds listed below, write down (i) its chemical formulae, (ii) whether it is soluble in water, (iii) the method in which it should be prepared, and (iv) suggest the starting reagents. (Note that for the starting reagents, there may be multiple possibilities.) One example has been done for you.

salt	formula	solubility	method	starting reagents
iron(III) chloride	$FeCl_3$	Soluble	acid & insoluble reactant	HCl (aq) + Fe_2O_3 (s)
potassium sulfate				
potassium nitrate				
silver carbonate				
lead(II) chloride				
calcium sulfate				
magnesium nitrate				
ammonium sulfate				
ammonium carbonate				
silver iodide				
zinc nitrate				

2. Which of the following bases is an alkali?
   A BaO **B** Fe_2O_3 **C** Na_2O **D** ZnO

3. Which of the following statements regarding the solubility of salts is **not** true?
   A All calcium salts are insoluble.
   B All sodium salts are soluble.
   C Most carbonates are insoluble.
   D Most chlorides are soluble.

4. How can barium sulfate best be prepared from barium oxide?
   A by adding dilute sulfuric acid
   B by adding sodium sulfate solution
   C by adding dilute nitric acid, followed by dilute sulfuric acid
   D by heating with sulfur until there is no further reaction

5. How can calcium sulfate best be prepared from calcium carbonate?
   A by adding dilute hydrochloric acid, followed by aqueous sodium sulfate
   B by adding dilute sulfuric acid, followed by nitric acid
   C by boiling with aqueous sodium sulfate
   D by heating under strong heat until decomposition, then adding dilute sulfuric acid

6. Which one of the following is the best pair of reagents to use for preparing copper(II) sulfate?
   A copper(II) carbonate and aqueous ammonium sulfate
   B copper(II) chloride and dilute sulfuric acid
   C copper(II) nitrate and aqueous sodium sulfate
   D copper(II) oxide and dilute sulfuric acid

7. Which of the following pairs of substances, when mixed, will produce a precipitate?
   A barium chloride and nitric acid
   B hydrochloric acid and copper(II) nitrate
   C potassium hydroxide and magnesium sulfate
   D sodium nitrate and iron(III) chloride

8. Which of the following pairs of substances, when mixed, will **not** produce a precipitate?
   A copper(II) sulfate and potassium hydroxide
   B lead(II) nitrate and lithium iodide
   C magnesium chloride and barium nitrate
   D sodium sulfate and calcium chloride

9. Which one of the following hydroxides will **not** give a good yield of salt with dilute sulfuric acid?
   A iron(II) hydroxide
   B lead(II) hydroxide
   C magnesium hydroxide
   D zinc hydroxide

10. Which of the following substances is the **least** satisfactory for preparing a sample of crystalline magnesium sulfate by reaction with dilute sulfuric acid?
   A aqueous magnesium nitrate
   B magnesium metal
   C solid magnesium carbonate
   D solid magnesium hydroxide

11. Which of the following substances is **least** satisfactory for preparing a sample of solid calcium sulfate by reaction with dilute sulfuric acid?
   A aqueous calcium chloride
   B aqueous calcium nitrate
   C aqueous calcium hydroxide (limewater)
   D calcium metal

12. Which of the following substances is best prepared by the titration method?
   A calcium chloride
   B copper(II) sulfate
   C lithium carbonate
   D magnesium nitrate

13. Titration method is used to prepare aqueous potassium sulfate fro potassium carbonate and dilute sulfuric acid. Which of the following conclusions can be drawn from this information?
   A Potassium carbonate is insoluble in water.
   B Potassium carbonate neutralises sulfuric acid.
   C Potassium carbonate reacts more vigorously than sodium carbonate with dilute sulfuric acid.
   D Potassium sulfate is an insoluble salt.

14. Which one of the following statements is correct for all these three acids: dilute hydrochloric acid, dilute nitric acid and dilute sulfuric acid?
   A They react with aqueous silver nitrate to give a precipitate.
   B They react with aqueous sodium carbonate to give carbon dioxide.
   C They react with copper to give hydrogen.
   D They react with zinc hydroxide to give hydrogen.

15. A sample of calcium sulfate is being prepared by reacting aqueous calcium hydroxide (limewater) with dilute sulfuric acid. What is the ionic equation for this reaction?
   A $2\ H^+ + Ca(OH)_2 \longrightarrow Ca^{2+} + 2\ H_2O$
   B $Ca(OH)_2 + H_2SO_4 \longrightarrow CaSO_4 + 2\ H_2O$
   C $Ca^{2+} + SO_4^{2-} \longrightarrow CaSO_4$
   D $H^+ + OH^- \longrightarrow H_2O$

Supplementary Questions (Answers)

Question 1

salt	formula	solubility	method	starting reagents
iron(III) chloride	$FeCl_3$	Soluble	acid & insoluble reactant	$HCl\ (aq) + Fe_2O_3\ (s)^*$
potassium sulfate	K_2SO_4	Soluble	titration	$KOH\ (aq)^* + H_2SO_4\ (aq)$
potassium nitrate	KNO_3	Soluble	titration	$KOH\ (aq)^* + HNO_3\ (aq)$
silver carbonate	Ag_2CO_3	Insoluble	precipitation	$AgNO_3\ (aq) + K_2CO_3\ (aq)^{**}$
lead(II) chloride	$PbCl_2$	Insoluble	precipitation	$Pb(NO_3)_2\ (aq) + KCl\ (aq)^{**}$
calcium sulfate	$CaSO_4$	Insoluble	precipitation	$Ca(NO_3)_2\ (aq) + K_2SO_4\ (aq)^{**}$
magnesium nitrate	$Mg(NO_3)_2$	Soluble	acid & insoluble reactant	$HNO_3\ (aq) + MgO\ (s)^\wedge$
ammonium sulfate	$(NH_4)_2SO_4$	Soluble	titration	$NH_4OH\ (aq)^* + H_2SO_4\ (aq)$
ammonium carbonate	$(NH_4)_2CO_3$	Soluble	titration	$NH_4OH\ (aq)^* + H_2CO_3\ (aq)$
silver iodide	AgI	Insoluble	precipitation	$AgNO_3\ (aq) + KI\ (aq)^{**}$
zinc nitrate	$Zn(NO_3)_2$	Soluble	acid & insoluble reactant	$HNO_3\ (aq) + ZnO\ (s)^\wedge$

** carbonates also can be used.*
*** other soluble salts can be used as well.*
^ hydroxides, carbonates and metals also can be used.

Multiple-Choice Questions

2	C	3	A	4	C	5	A	6	D
7	C	8	C	9	B	10	A	11	D
12	C	13	B	14	B	15	B		

Lecture Slides

Salts

Anglo-Chinese School (Barker Road)

CHEMISTRY
Prepared by Alex Lee

Chapter Overview

In This Chapter, We Will Learn …

1. What Is A Salt?
2. Hydrated and Anhydrous Salts
3. Solubility Table
4. Precipitation
5. Preparation of Salts

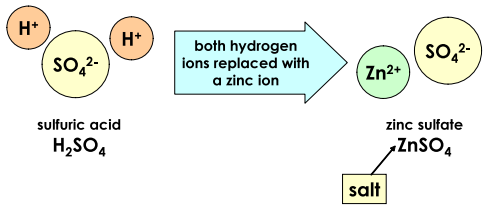
What Is A Salt?

- A **salt** is an **ionic compound** which is formed when a **metallic ion or an ammonium ion** replaces one or more **hydrogen ions in an acid**.
- The salt we use in food, generally known as **table salt**, refers only to one particular type of salt: **sodium chloride**.
- There are many other types of salts beside sodium chloride!

Images: Kate Sears http://www.realsimple.com (Salt Shaker)

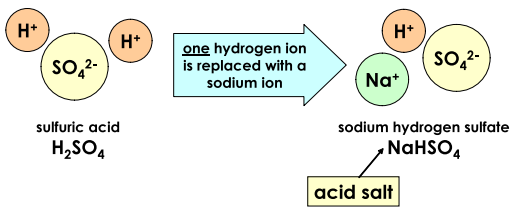
What Is A Salt?

- Zinc sulfate is a **salt** because it is formed when **zinc ions replace** the **hydrogen ions** in sulfuric acid.



What Is A Salt?

- In the case of dibasic or tribasic acids, it is possible that **not all the hydrogen ions** get replaced.



Hydrated & Anhydrous Salts

- At room temperature, salts can exist in three forms (provided it is soluble in water):

Dissolved *"Aqueous Solution"*	Solid Crystals *"Hydrated Salt"*	Solid Powder *"Anhydrous Salt"*

Images: http://www.femalemag.com.sg (Brown Solution) http://www.gourmetsleuth.com (Brown Crystals), http://psychoactiveherbs.com/catalog (Brown Powder)

Hydrated & Anhydrous Salts

- Salts in crystal form contain water molecules trapped in its structure. These water molecules are known as **water of crystallisation**.

$CuSO_4.5H_2O$

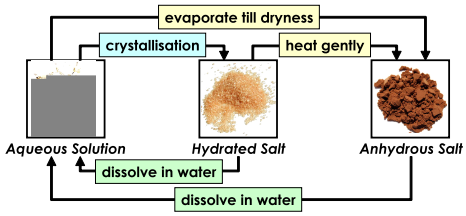
formula of copper(II) sulfate

ratio of water molecules to salt

- The ratio of water of crystallization to salt varies from compound to compound.

Various Forms of Salt

- Changing between solution, crystals and anhydrous forms is a **physical change**, easily done in a laboratory.



Images: http://www.femalemag.com.sg (Brown Solution) http://www.gourmetsleuth.com (Brown Crystals), http://psychoactiveherbs.com/catalog (Brown Powder)

Various Forms of Salt

- Obtaining an **anhydrous salt** can easily be done by **heating till dryness in an evaporating dish**.
- However, we must be careful of salts that **decompose** easily under heat.

Various Forms of Salt

- Obtaining crystals from an aqueous solution requires a slow process known as **crystallisation**:

CRYSTALLISATION STEP-BY-STEP

Step 1: Heat solution in an evaporating dish to evaporate some water until saturation is reached.

Step 2: Test for saturation by dipping a glass rod into the solution. After removal from the solution, crystals should form on the glass rod on cooling. If not, continue heating the solution.

Step 3: Transfer the contents into a beaker and allow it to cool slowly. Crystals will gradually form in the beaker.

Step 4: Remove the crystals from the rest of the solution either by decanting or filtration.

Step 5: Allow the crystals to dry on a sheet of filter paper.

The Solubility Table

MUST MEMORISE!

	SOLUBLE	INSOLUBLE
Nitrates, NO_3^-	All **soluble**	-
Halides (Chlorides, Cl^- & Iodides, I^-)	All **soluble**, except	**Lead(II), Silver**
Sulfates, SO_4^{2-}	All **soluble**, except	**Lead(II), Barium, Calcium**
Bases (Hydroxides, OH^- & Oxides, O^{2-})	**Group 1, Ammonium, Barium*, Calcium***	All **insoluble**, except
Carbonates, CO_3^{2-}	**Group 1, Ammonium**	All **insoluble**, except

The Solubility Table

Memory Tip!

Nitrates, Halides (i.e. **Chlorides** & **Iodides**), and **Sulfates** are generally soluble, except:

"Lead Salts Can Be Lethal."

Lead(II) Silver — Insoluble Halides

Calcium Barium Lead(II) — Insoluble Sulfates

The Solubility Table

Memory Tip!

Bases (i.e. **Oxides** & **Hydroxides**) and **Carbonates** are generally insoluble, except:

"1 A B C"

Group 1 Ions (sodium, potassium, lithium) | Ammonium | Barium* | Calcium*

Soluble Carbonates

Soluble Bases — Slightly Soluble Bases

The Solubility Table

Anion \ Cation	K^+/ Na^+/ Li^+/ NH_4^+	Ca^{2+}/ Ba^{2+}	Pb^{2+}	Ag^+	Others e.g. Mg^{2+}
NO_3^-	✓	✓	✓	✓	✓
Cl^- / I^-	✓	✓	✗	✗	✓
SO_4^{2-}	✓	✗	✗	✓	✓
OH^- / O^{2-}	✓	✓*	✗	✗	✗
CO_3^{2-}	✓	✗	✗	✗	✗

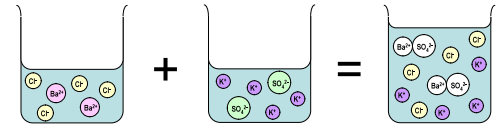
Oxides & Hydroxides

- Although **Group I and Ammonium Oxides** are soluble in water, it is **incorrect to represent them as aqueous solutions**.
- This is because, when dissolved in water, the oxides readily turn into **hydroxides**.

$$Na_2O\ (s) + H_2O\ (l) \longrightarrow 2\ NaOH\ (aq)$$
$$K_2O\ (s) + H_2O\ (l) \longrightarrow 2\ KOH\ (aq)$$
$$CaO\ (s) + H_2O\ (l) \longrightarrow Ca(OH)_2\ (aq)$$

Precipitation

- In aqueous solution, ions are allowed to move freely.
- When two aqueous salts are mixed, sometimes an insoluble salt, known as a **precipitate**, can be formed.



aq barium chloride, $BaCl_2$ + aq potassium sulfate, K_2SO_4 = precipitate of $BaSO_4$ formed

Precipitation

- To predict if a precipitate would be formed, first list all the cations and anions present.
- For example, in a mixture of calcium chloride and magnesium sulfate:

Calcium, Ca^{2+} — *Chloride, Cl^-*

Magnesium, Mg^{2+} — *Sulfate, SO_4^{2-}*

- Then we identify if any insoluble salt can be formed.

*A precipitate of **calcium sulfate** formed.*

Precipitation

- Mixture of silver nitrate and potassium iodide.

Silver, Ag^+ — *Nitrate, NO_3^-*

Potassium, K^+ — *Iodide, I^-*

Precipitate of silver iodide (AgI) formed.

- Mixture of sodium hydroxide and zinc chloride.

Sodium, Na^+ — *Hydroxide, OH^-*

Zinc, Zn^{2+} — *Chloride, Cl^-*

Precipitate of zinc hydroxide ($Zn(OH)_2$) formed.

Preparation of Salts

- In many industrial applications, we often need to prepare a pure sample of a particular salt.

Method	Type of Salt
Precipitation	All insoluble salts
Reaction of an Acid with an Insoluble Reactant	All soluble salts, *except for Group I and ammonium salts*
Titration	Group I and ammonium salts

Preparation of Salts

PRECIPITATION

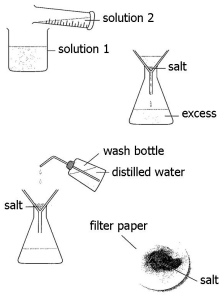
- Used to prepare **all insoluble salts**.

- Reactants:
  Two aqueous solutions, containing the desired cation and anion of the salt to be prepared.

Preparation of Salts

PRECIPITATION

① **Mix the two solutions** in a beaker. **Stir** with a glass rod. The precipitate of the salt would have been formed.
② **Filter** out the precipitate using a funnel and filter paper.
③ **Wash** the residue by running **distilled water** through it.
④ Allow the salt to **dry between sheets of filter paper**.



Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

- Used to prepare **all soluble salts, *except* Group I salts and ammonium salts.**

- Reactants:
  A dilute acid, containing the anion, and
  An insoluble base, carbonate or metal* of the cation of the salt to be prepared.

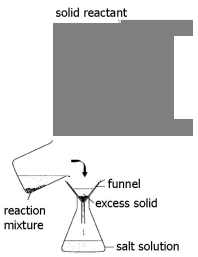
** except copper metal and silver metal*

Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

① Warm a sample of the **acid** in a beaker. Add an **excess** of the insoluble reactant.
② **Stir** with a glass rod to ensure complete reaction.
③ **Filter** out the excess reactant, using filter paper and a filter funnel, and collect the filtrate.

(Aqueous solution obtained.)

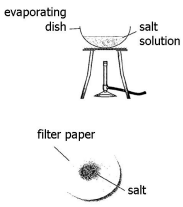


Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

To obtain crystals:

④ **Heat** the filtrate in an **evaporating dish** till **saturation** is reached.
⑤ Allow the solution to **cool**. Extract the solid crystals from the rest of the solution by **filtration**.
⑥ Allow the salt to **dry between sheets of filter paper**.



Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

Alternatively, to obtain powder:

④ **Heat** the filtrate in an **evaporating dish till dryness**.

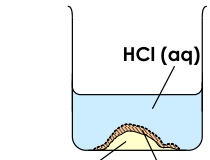
However, some salts **may thermally decompose** through this process so this is not advised unless you are assured of its thermal stability.

Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

- **Why is this method only suitable for soluble salts?**

*If this method were to be used to prepare an insoluble salt, the **insoluble salt produced** will form a **'protective layer'** over the insoluble reactant, **preventing any further reaction** and hence a low yield.*



Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

- **Why must an excess of insoluble reactant be added?**

*This is to ensure that all of the acid has completely reacted, to **prevent any excess acid** which will contaminate the aqueous salt formed.*

Excess of the insoluble reactant, on the other hand, can easily be removed through filtration.

Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

- **Suggest why Group I salts may not be prepared through this method by reacting an acid with an excess of a <u>Group I base or carbonate</u>.**

Group I bases and carbonates are all soluble in water, and hence any excess reactant will not be able to be removed through filtration.

Preparation of Salts

REACTION OF AN ACID WITH AN INSOLUBLE REACTANT

- **Suggest why Group I salts may not be prepared through this method by reacting an acid with an excess of a <u>Group I metal</u>.**

Group I metals are very reactive and hence react violently with acids, causing the experiment to be too dangerous to perform.

Preparation of Salts

TITRATION

- Used to prepare **Group I salts and ammonium salts**.

- <u>Reactants</u>:

  A dilute acid, containing the anion, and

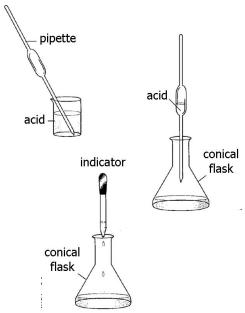
  An aqueous alkali or aqueous carbonate containing the cation of the salt to be prepared.

Preparation of Salts

TITRATION

① Using a **pipette**, measure out a **fixed volume of acid**. Transfer this solution into a conical flask.

② Add a few drops of **indicator**, e.g. phenolphthalein.



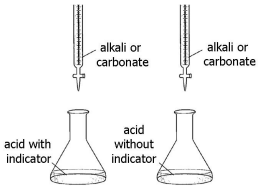
Preparation of Salts

TITRATION

③ Using a **burette**, add the alkali or carbonate drop-by-drop until the indicator just changes colour.

④ **Note down** the volume of alkali or carbonate required for complete neutralisation.

⑤ **Repeat** the titration, this time **without indicator**. Stop the burette when the reading reaches the same level as earlier noted.



Preparation of Salts

TITRATION

- To obtain a solid sample, perform crystallisation or evaporation to dryness.
- Acid and alkali or carbonate can be interchanged in this method, i.e. placing the alkali or carbonate in the conical flask and the acid in the burette.

Preparation of Salts

TITRATION

- **Suggest why the titration needs to be repeated a second time without using an indicator.**

  During the first titration, the salt sample produced has been contaminated by the indicator added.

  Repeating the titration without indicator will produce a pure sample of the salt, without contamination.

Preparation of Salts

TITRATION

- **Explain why an alkali or carbonate (e.g. sodium hydroxide) must be used in titration, instead of any other metal salt (e.g. sodium nitrate).**

  In reacting a base or carbonate with an acid, the only byproduct is water (and carbon dioxide for carbonates). If sodium nitrate is used, there will be a byproduct with nitrate ions (i.e. nitric acid), which would contaminate the salt formed.

Preparation of Salts: Summary