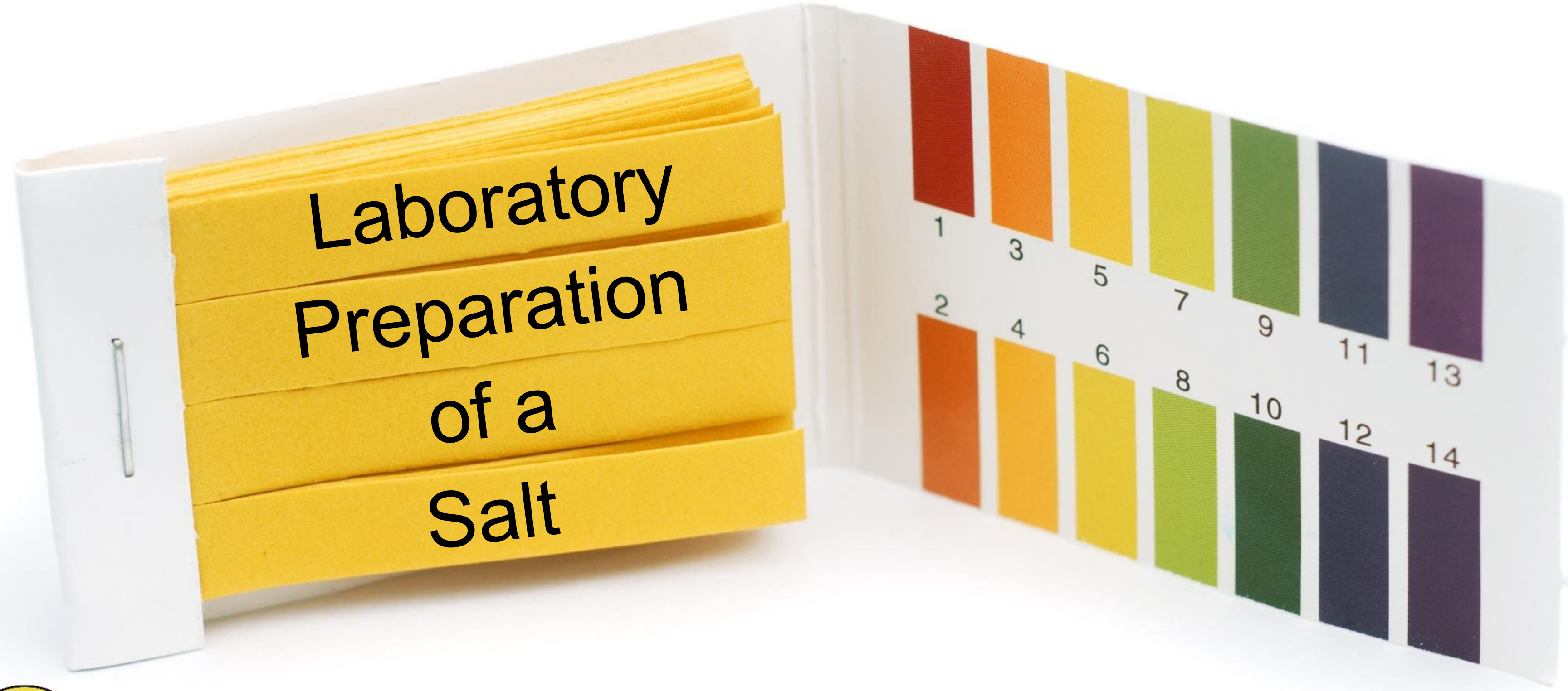
# Acids, Bases and Salts



## Laboratory Preparation of a Salt

# Acids, Bases and Salts

## Main Menu (*click to link*)

**1.** Importance of Salt Preparation – Uses of Salts

**2.** General Overview of Salt Preparation

**3.** Solubility Rules

**4.** Salt Preparation – Overview of the Different Methods

**5.** Overview of Ionic Precipitation

**6.** Overview of Titration

**7.** Overview of Excess Insoluble Base / Metal Carbonate

**8.** Solubility Curves

**9.** Problems Using Insoluble Reagents for Insoluble Salts

**10.** Using Acid + Metal Reactions to Prepare Salts

**11.** Reagents that are Unsuitable for Salt Preparation

**12.** Revision Questions (20 MCQ)

# Acids, Bases and Salts

What do I need to know and understand about the laboratory preparation of salts?

# Acids, Bases and Salts

## Salts

**(a)** Describe the techniques used in the preparation, separation and purification of salts (methods for preparation should include precipitation and titration together with reactions of acids with metals, insoluble bases and insoluble carbonates).

**(b)** Describe the general rules of solubility for common salts to include nitrates, chlorides (including silver and lead), sulfates (including barium, calcium and lead), carbonates, hydroxides, Group 1 cations and ammonium salts.

**(c)** Suggest a method of preparing a given salt from suitable starting materials, given appropriate information.

# Acids, Bases and Salts

**1.** Why is salt preparation important? *What are salts used for*?

Main Menu

# Acids, Bases and Salts

## Salt Preparation – Uses of Salts

- Ammonium phosphate – $(NH_4)_3PO_4$ – is a fertiliser used to provide plants with the elements nitrogen and phosphorus, essential for the plants' healthy growth.

- Barium sulfate – $BaSO_4$ – is an insoluble salt used to provide "barium meals" for patients. Once ingested, barium sulfate allows the patient's digestive system to be imaged using x-rays.

- Calcium ethanoate – $Ca(CH_3COO)_2$ – is used to coagulate soy milk to produce tofu.

# Acids, Bases and Salts

## Salt Preparation – Uses of Salts

- Iron(II) sulfate – $FeSO_4$ – is used to treat anaemia, a lack of haemoglobin in the blood. This reduces the blood's ability to carry oxygen, which can result in fatigue.

- Monosodium glutamate (MSG) – $NaC_5H_8NO_4$ – is the sodium salt of glutamic acid. It is used as a flavour enhancer in the food industry, and is especially used to enhance the taste of savoury foods.

- Sodium fluoride – $NaF$ – and tin(II) fluoride – $SnF_2$ – are used to provide the fluoride ions in toothpaste. The fluoride ions prevent cavities and tooth decay.

# Acids, Bases and Salts

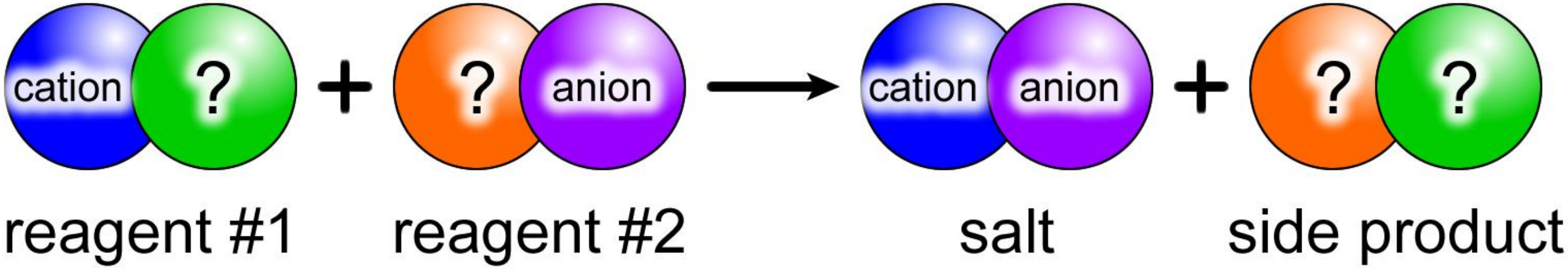
**2.** What is the *big idea* behind salt preparation?

Main Menu

# Acids, Bases and Salts

## Salt Preparation – Overview

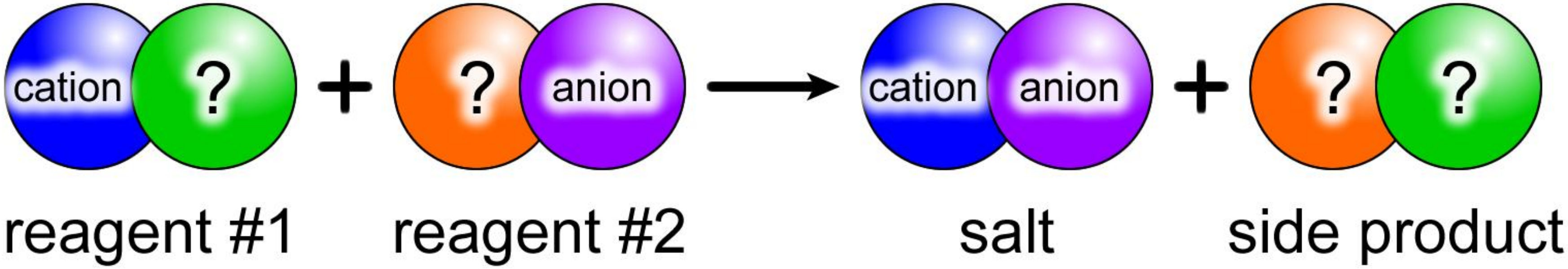
- A salt is an *ionic compound* composed of a *positive cation* (usually a metal) and a *negative anion*. Salts are often formed by replacing the hydrogen ion(s) of an acid with a metal ion(s).
- A salt is prepared in the laboratory by reacting together *two reagents*. One reagent contains the *desired cation (+)*, while the other reagent contains the *desired anion (–)*.



# Acids, Bases and Salts

## Salt Preparation – Overview

- Examples of possible reactions that can be used to prepare salts include:
  - acid + metal → salt + hydrogen
  - acid + alkali / base → salt + water
  - acid + carbonate → salt + water + carbon dioxide
  - salt **A** + salt **B** → salt **C** + salt **D**



# Acids, Bases and Salts

**3.** What are the general *solubility rules* for common salts?

# Acids, Bases and Salts

## Solubility Rules

- All ammonium salts are ________ in water.
- All potassium salts* are ________ in water.
- All sodium salts* are ________ in water.
- All carbonates are ________ in water, except ______________________
- All chlorides* are ________ in water, except _____________________
- All ethanoates ($CH_3COO^-$) are ________ in water.
- All hydroxides are ________ in water, except _____________________
- All nitrates are ________ in water.
- All sulfates are ________ in water, except ______________________
- All phosphates are ________ in water, except _____________________

# Acids, Bases and Salts

## Solubility Rules

- All ammonium salts are soluble in water.
- All potassium salts* are soluble in water.
- All sodium salts* are soluble in water.
- All carbonates are insoluble in water, except $Na_2CO_3$, $K_2CO_3$, $(NH_4)_2CO_3$
- All chlorides* are soluble in water, except $AgCl$, $PbCl_2$
- All ethanoates ($CH_3COO^-$) are soluble in water.
- All hydroxides are insoluble in water, except $NaOH$, $KOH$, $NH_4OH$
- All nitrates are soluble in water.
- All sulfates are soluble in water, except $BaSO_4$, $CaSO_4$, $PbSO_4$
- All phosphates are insoluble in water, except $Na_3PO_4$, $K_3PO_4$, $(NH_4)_3PO_4$

*Assume that the salts of all Group 1 metals are soluble in water.

*Assume that bromides and iodides follow the same rule.

# Acids, Bases and Salts

**4.** What are the different ways of preparing a salt in the laboratory?

# Acids, Bases and Salts

## Salt Preparation – Overview

# Acids, Bases and Salts

## Salt Preparation – Overview

Start here

# Acids, Bases and Salts

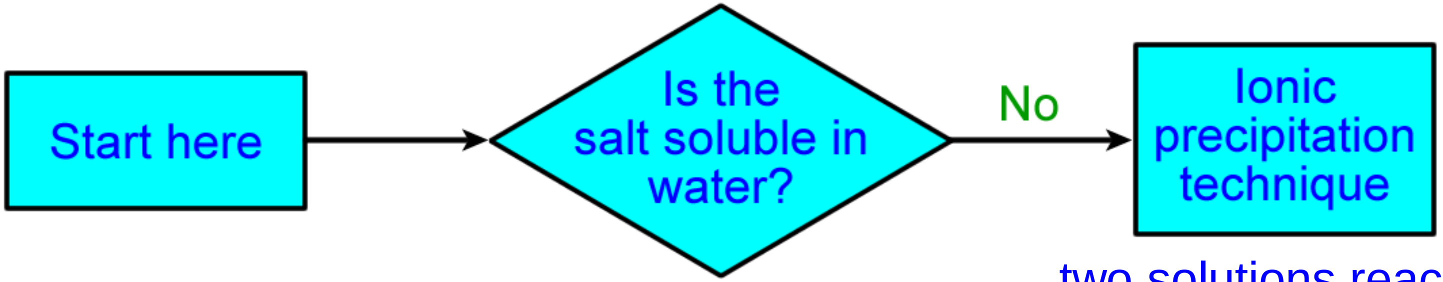
## Salt Preparation – Overview

Start here

Is the salt soluble in water?

# Acids, Bases and Salts

## Salt Preparation – Overview



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Is the salt soluble in water?

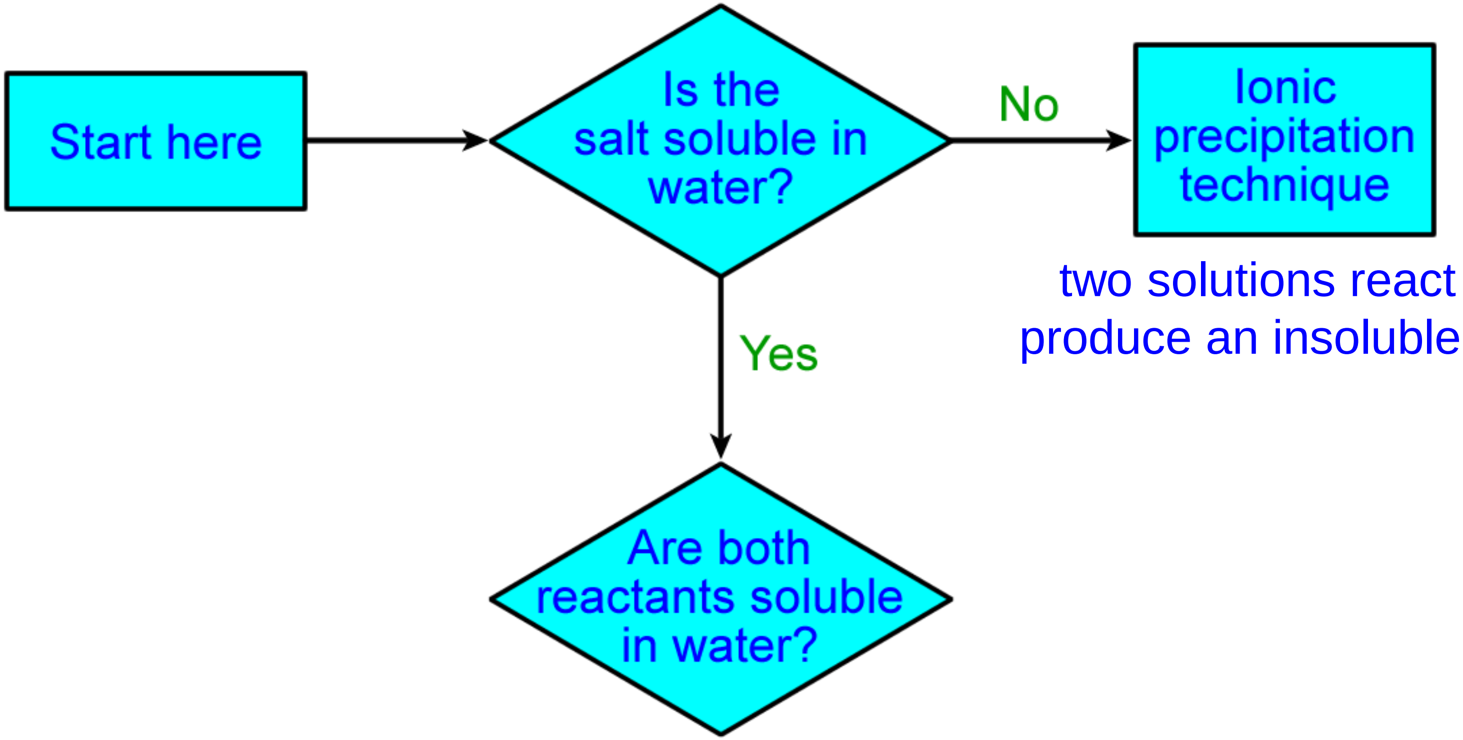
No

Ionic precipitation technique

two solutions react to produce an insoluble salt

# Acids, Bases and Salts

## Salt Preparation – Overview



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Is the salt soluble in water?

No

Ionic precipitation technique

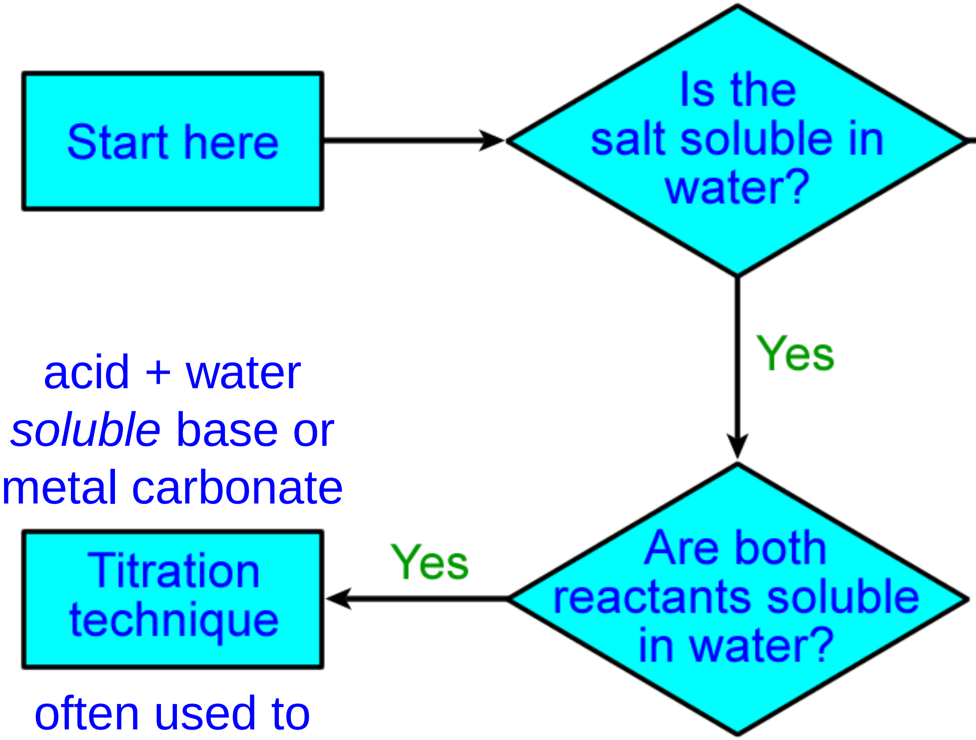
two solutions react to produce an insoluble salt

Yes

Are both reactants soluble in water?

# Acids, Bases and Salts

## Salt Preparation – Overview



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Is the salt soluble in water?

No

Ionic precipitation technique

two solutions react to produce an insoluble salt

Yes

Are both reactants soluble in water?

Yes

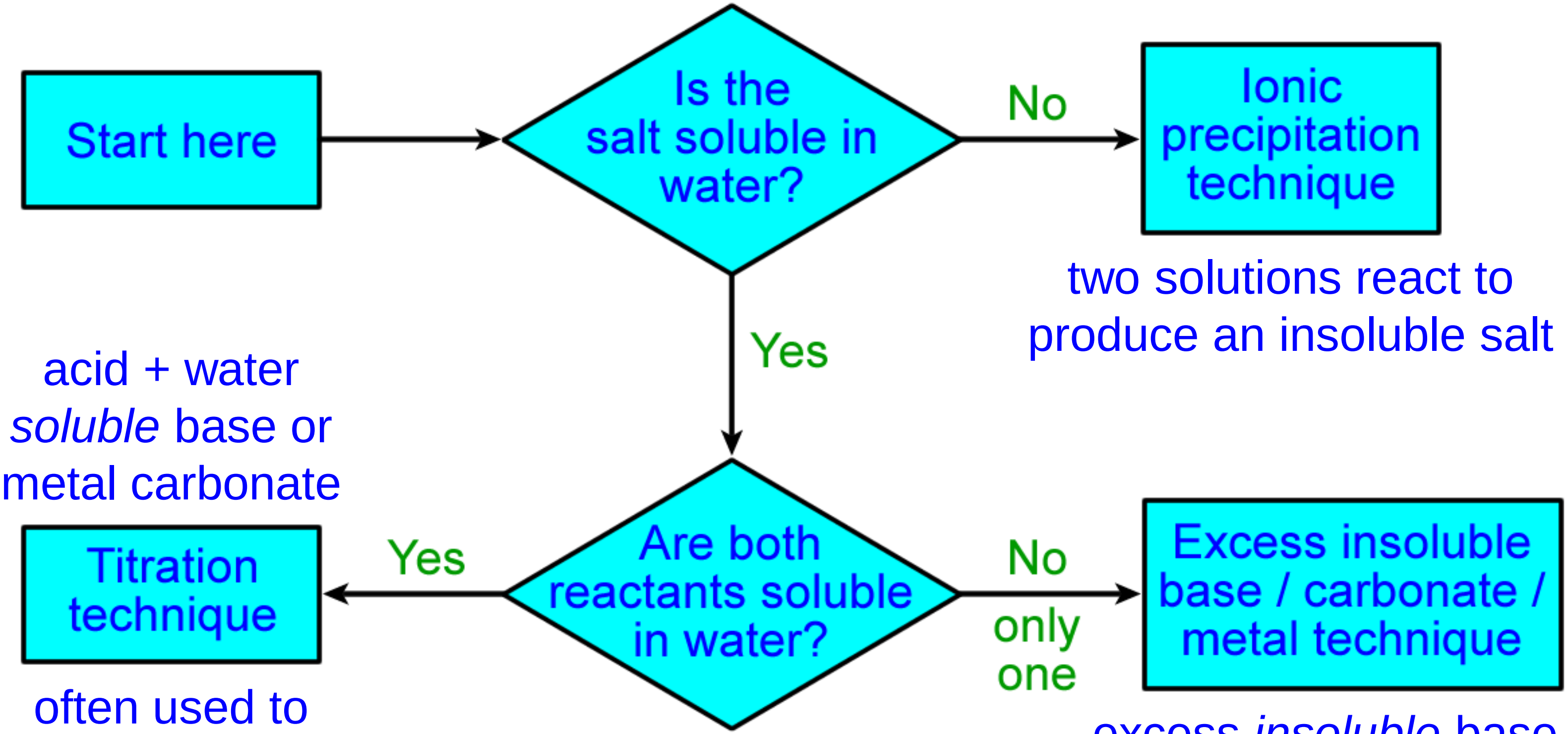
Titration technique

acid + water *soluble* base or metal carbonate

often used to prepare the salts of Group 1 metals

# Acids, Bases and Salts

## Salt Preparation – Overview



Start here

Is the salt soluble in water?

No

Ionic precipitation technique

two solutions react to produce an insoluble salt

Yes

Are both reactants soluble in water?

Yes

Titration technique

acid + water *soluble* base or metal carbonate

often used to prepare the salts of Group 1 metals

No

only one

Excess insoluble base / carbonate / metal technique

excess *insoluble* base or metal carbonate or metal is added to an acid

# Acids, Bases and Salts

## Super Summary!

To prepare the salts of Group 1 metals (and ammonium salts):

Both reagents are soluble – the desired salt is soluble

Acid & alkali or acid & carbonate ***Titration***

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

# Acids, Bases and Salts

## Super Summary!

To prepare insoluble salts:

Both reagents are soluble – the desired salt is insoluble

***Ionic precipitation***

$$Pb(NO_3)_2(aq) + 2NaCl(aq) \rightarrow PbCl_2(s) + 2NaNO_3(aq)$$

For the cation, use its nitrate (guaranteed soluble)

For the anion, use its sodium salt (guaranteed soluble)

# Acids, Bases and Salts

## Super Summary!

To prepare all other types of salts:

Soluble acid & insoluble base / carbonate / metal
– desired salt is soluble

***Excess insoluble base*** / carbonate / metal

$2HNO_3(aq) + FeCO_3(s) \rightarrow Fe(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

Use excess to ensure that all of the acid has reacted

# Acids, Bases and Salts

**5.** Overview of *ionic precipitation*.

Main Menu

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

A precipitate is formed when two *clear solutions* react together to form an *opaque solid* product.

- All solutions are *clear*.
- Solutions may be *coloured*, *e.g*. we may refer to a “blue solution of copper(II) sulfate.”
- All precipitates are *opaque*. There is no such thing as a clear precipitate!
- Precipitates may be *coloured*, *e.g*. we may refer to a “yellow precipitate of lead(II) iodide.”

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

- The ionic precipitation technique is used to prepare salts that are *insoluble in water*, for example, barium sulfate (formula, $BaSO_4$), lead(II) iodide (formula, $PbI_2$) and silver chloride (formula, $AgCl$).

- Two soluble salts are added together to form the insoluble salt. One of the soluble salts contains the desired *anion*, while the second soluble salt contains the desired *cation*.

$$(\text{cation } \mathbf{A}, \text{ anion } \mathbf{B})_{(aq)} + (\text{cation } \mathbf{C}, \text{ anion } \mathbf{D})_{(aq)} \rightarrow (\text{cation } \mathbf{A}, \text{ anion } \mathbf{D})_{(s)} + (\text{cation } \mathbf{C}, \text{ anion } \mathbf{B})_{(aq)}$$

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

- The *nitrate* of the desired *cation* should be used, as all *nitrates* are soluble in water.

- A *sodium salt* of the desired *anion* should be used, as all sodium salts are soluble in water.

$$(\text{cation } \mathbf{A}, \text{ nitrate})_{(aq)} + (\text{sodium, anion } \mathbf{D})_{(aq)} \rightarrow (\text{cation } \mathbf{A}, \text{ anion } \mathbf{D})_{(s)} + (\text{sodium, nitrate})_{(aq)}$$

$$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$$

$$Pb(NO_3)_2(aq) + 2NaI(aq) \rightarrow PbI_2(s) + 2NaNO_3(aq)$$

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

- Acids also contain aqueous solutions of anions, *e.g.* sulfuric acid contains $SO_4^{2-}(aq)$ and hydrochloric acid contains $Cl^{-}(aq)$.

- For the preparation of some insoluble salts, it may be possible to use an *acid* that contains the desired *anion*.

- For example, solid barium sulfate may be prepared by mixing aqueous barium nitrate with dilute *sulfuric acid*:

$$Ba(NO_3)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2HNO_3(aq)$$

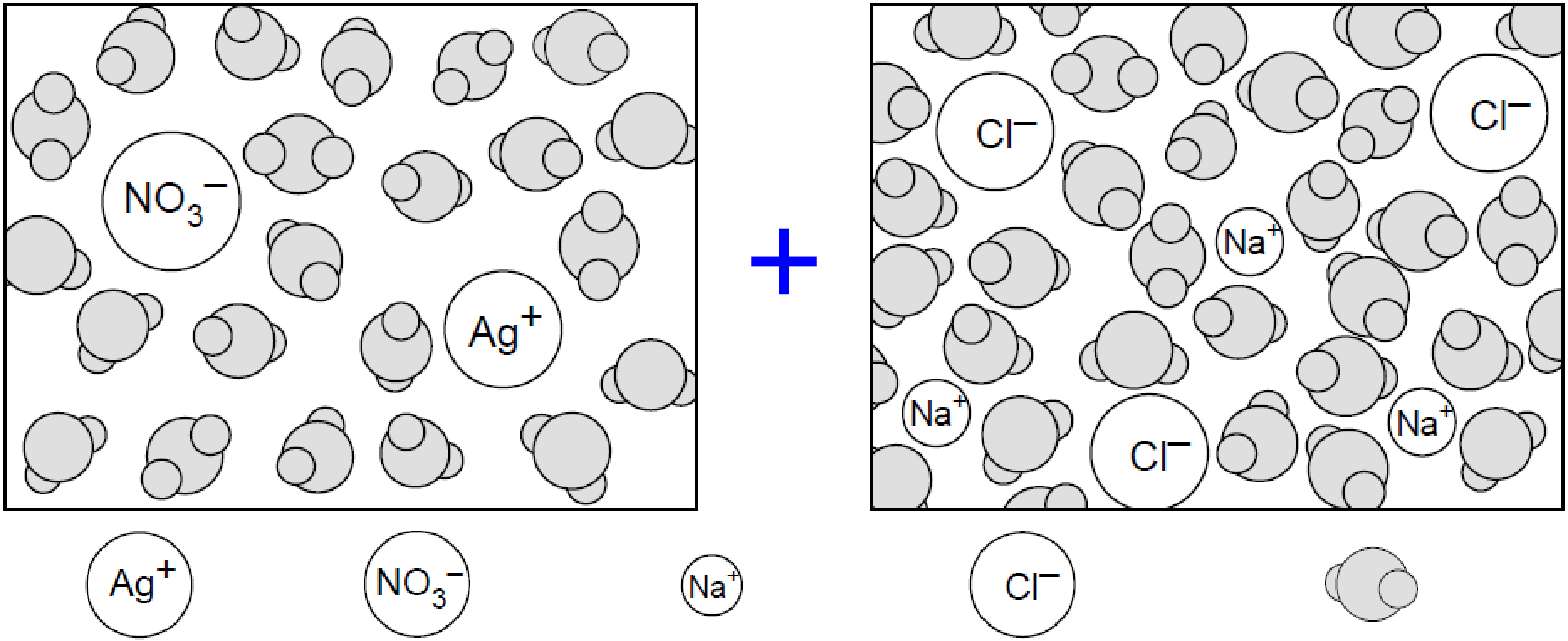
- For example, solid silver chloride may be prepared by mixing aqueous silver nitrate with dilute *hydrochloric acid*:

$$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

Aqueous Silver Nitrate + Aqueous Sodium Chloride



Silver Ion

Nitrate Ion

Sodium Ion

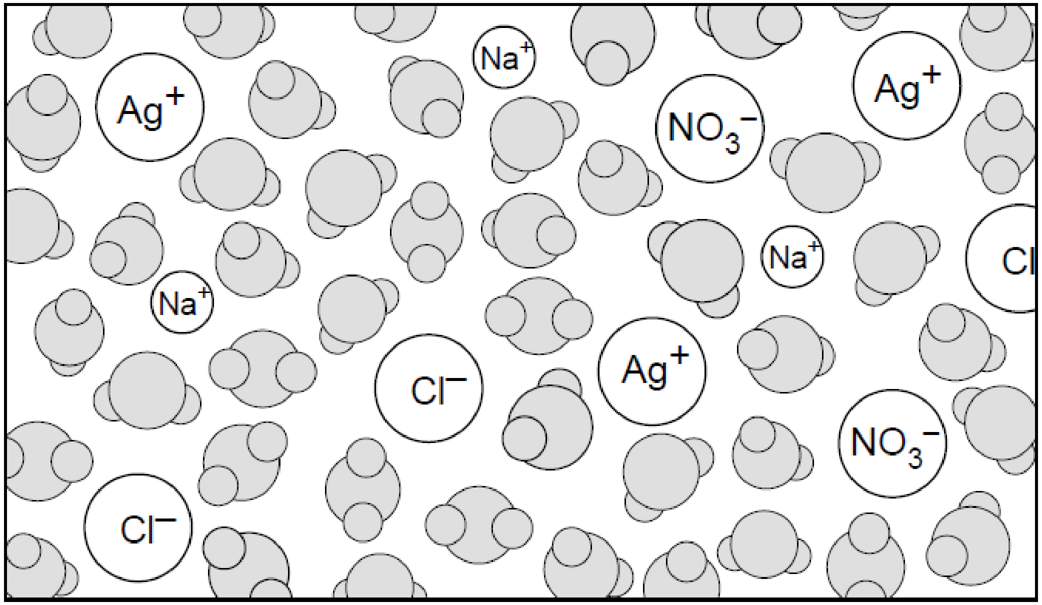
Chloride Ion

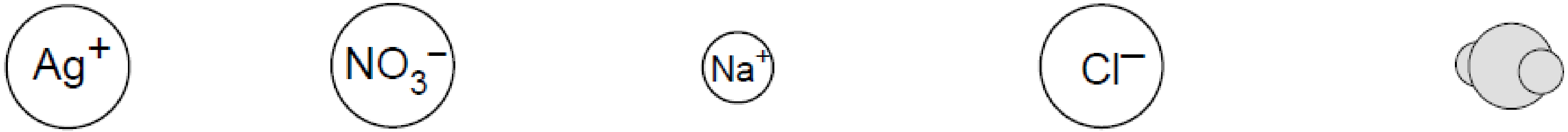
Water Molecule

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### Mixture of Aqueous Silver Nitrate and Aqueous Sodium Chloride





Silver Ion

Nitrate Ion

Sodium Ion

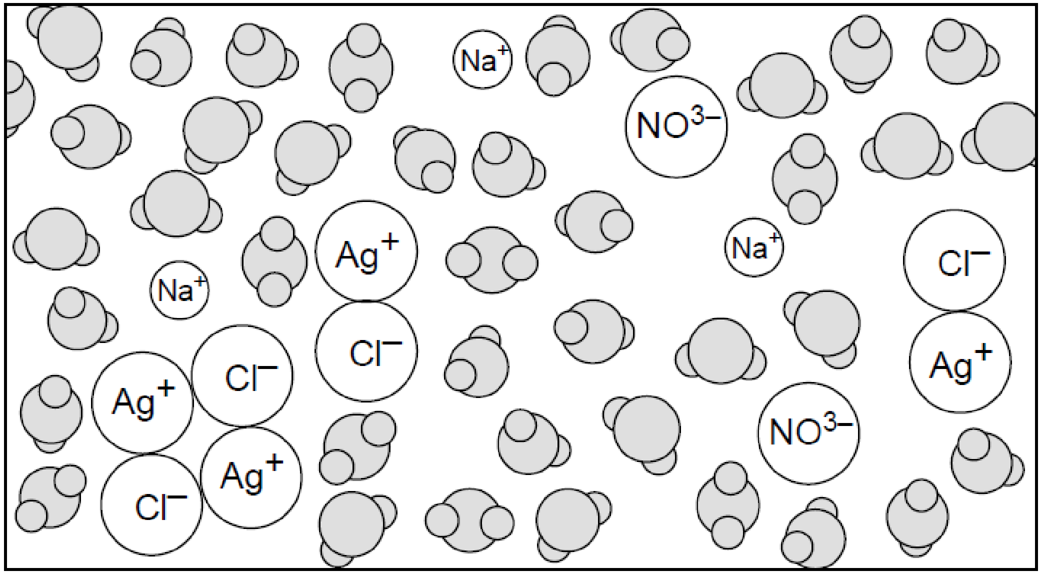
Chloride Ion

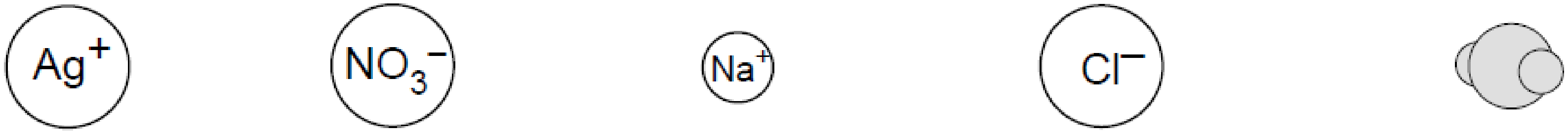
Water Molecule

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### Silver Chloride Precipitating from a Solution of Sodium Nitrate





Silver Ion

Nitrate Ion

Sodium Ion

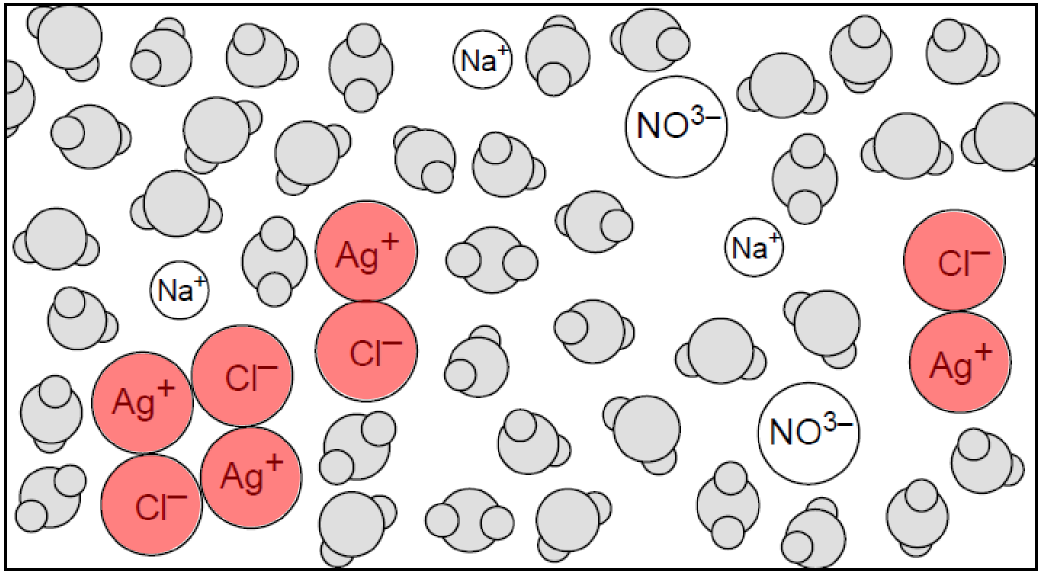
Chloride Ion

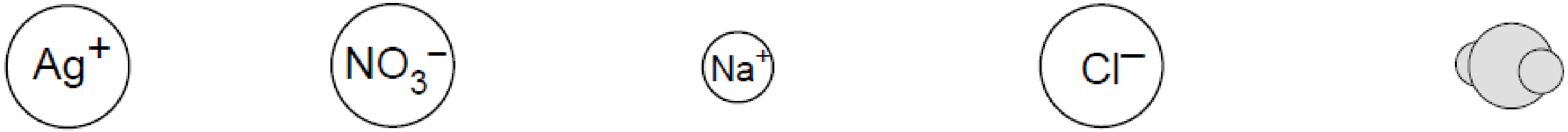
Water Molecule

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### Silver Chloride Precipitating from a Solution of Sodium Nitrate





Silver Ion
Nitrate Ion
Sodium Ion
Chloride Ion
Water Molecule

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### White Precipitate of Silver Chloride

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

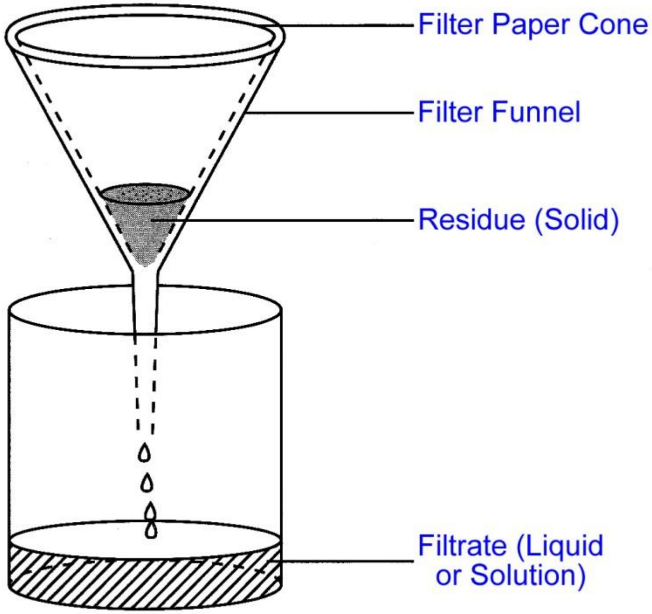
### Procedure

**1)** Add an aqueous solution of soluble salt **X** to an aqueous solution of soluble salt **Y** until no more precipitate is observed to be formed.

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### Procedure



**2)** Separate the insoluble salt from the soluble salt by *filtration*. The insoluble salt will be the *residue* while the soluble salt will be the *filtrate*.

# Acids, Bases and Salts

## Preparation of an Insoluble Salt – *Ionic Precipitation*

### Procedure

**3)** Wash the insoluble salt (residue) with a small volume of cold distilled water. This will remove any excess salt solution that will contaminate the final product.

**4)** Dry the insoluble salt (residue) by pressing it between several layers of filter paper.

# Acids, Bases and Salts

**6.** Overview of *titration*.

Main Menu

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

- Titration is used to prepare a *soluble salt* from an *acid* and an *alkali*, or a *soluble metal carbonate*.
- Titration can be used to prepare *ammonium salts*, such as ammonium sulfate (formula, $(NH_4)_2SO_4$), and the salts of *Group 1 metals*, such as potassium chloride (formula, $\mathrm{KC}l$) and sodium nitrate (formula, $NaNO_3$).

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

- The *acid* will provide the desired anion. For example, *hydrochloric acid* (formula, $\mathrm{HC}l$) will provide the *chloride ion*, *nitric acid* (formula, $HNO_3$) will provide the *nitrate ion* and *sulfuric acid* (formula, $H_2SO_4$) will provide the *sulfate ion*.

- The *alkali* or *soluble metal carbonate* will provide the desired *cation*. For example, *aqueous ammonia* (formula, $NH_3$(aq)) will provide the *ammonium ion*, *potassium hydroxide* (formula, KOH) will provide the *potassium ion* and *sodium carbonate* (formula, $Na_2CO_3$) will provide the *sodium ion*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

- acid + alkali → salt + water

- aqueous ammonia + sulfuric acid → ammonium sulfate + water

$$2NH_4OH(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + 2H_2O(l)$$

- potassium hydroxide + hydrochloric acid → potassium chloride + water

$$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$$

soluble metal

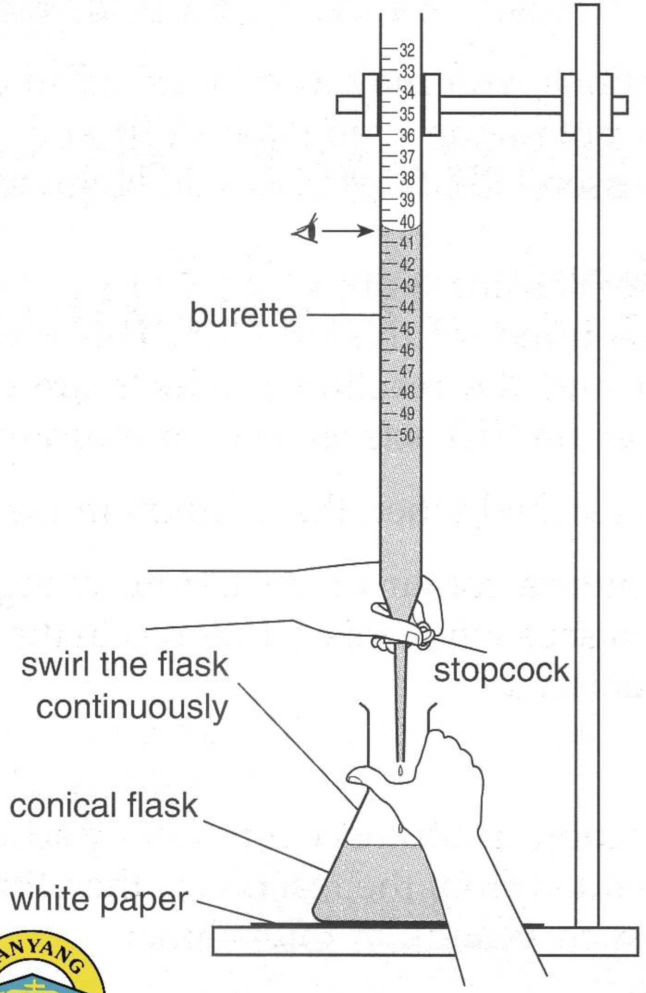
- acid + carbonate → salt + water + carbon dioxide

- sodium carbonate + nitric acid → sodium nitrate + water + carbon dioxide

$$Na_2CO_3(aq) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$$

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

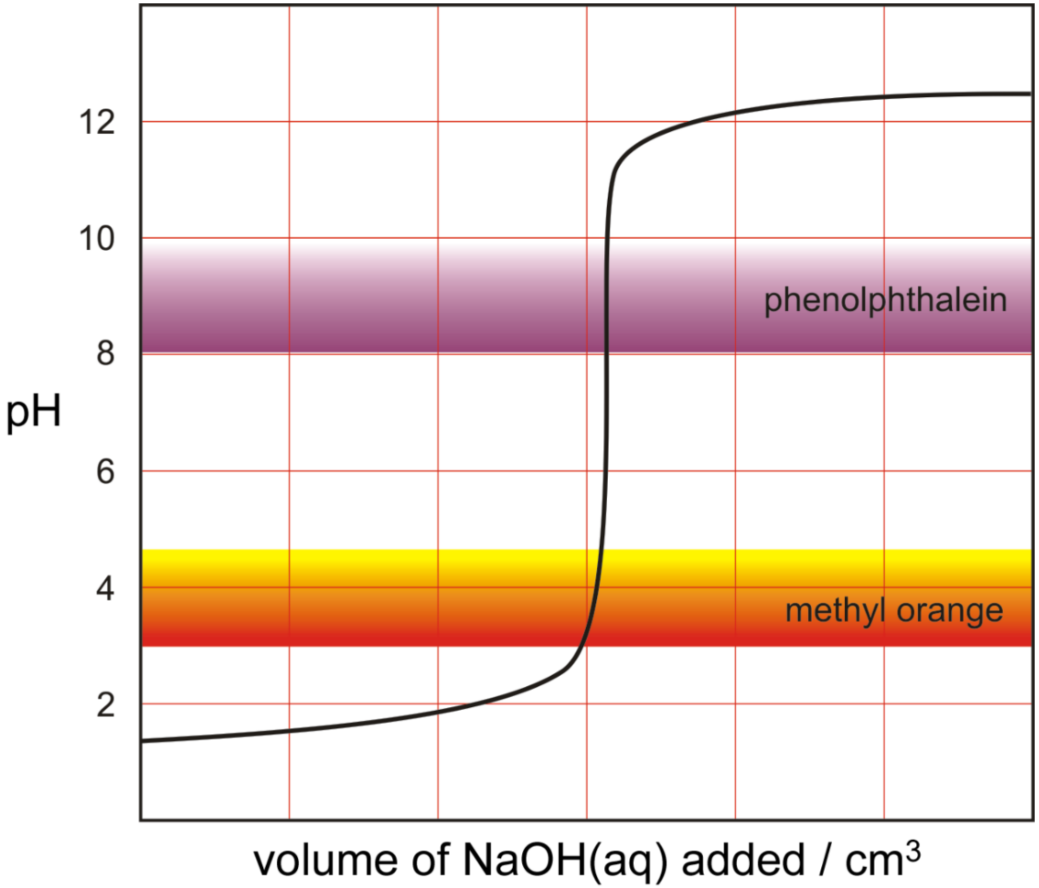


### Procedure

**1)** Titrate the acid against the alkali, using a suitable indicator that will change colour at the end-point of the reaction (the point at which the acid and alkali have exactly neutralised each other). Repeat the titration until two results within ± 0.10 $cm^3$ are obtained.

# Acids, Bases and Salts

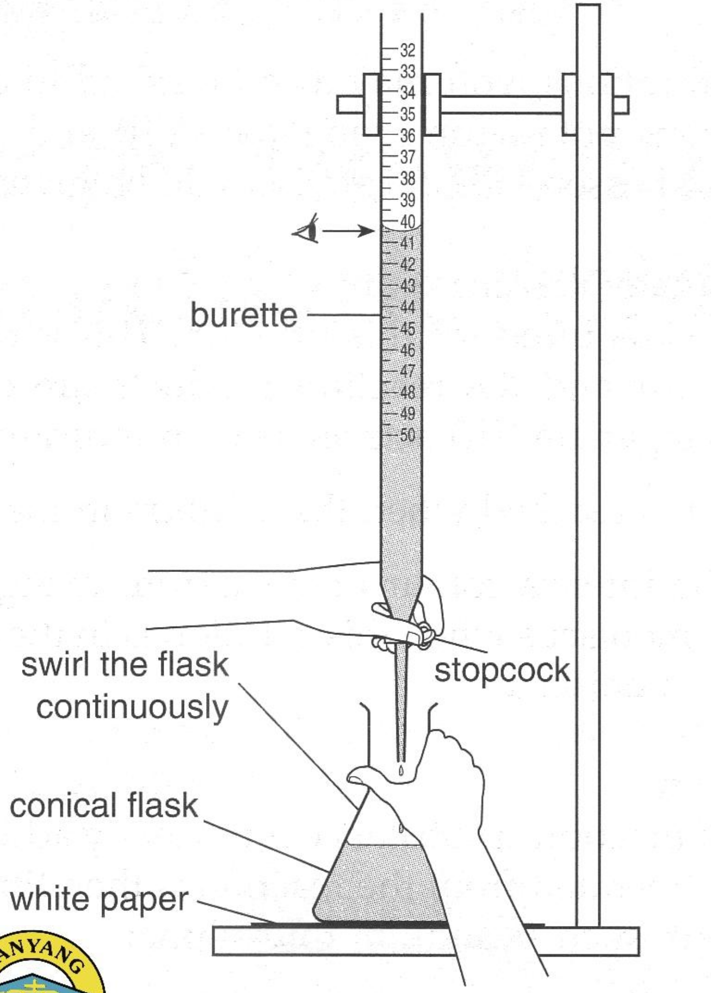
## Preparation of a Soluble Salt – *Titration*



- Both methyl orange and phenolphthalein are suitable indicators for strong acid – strong alkali titrations.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*



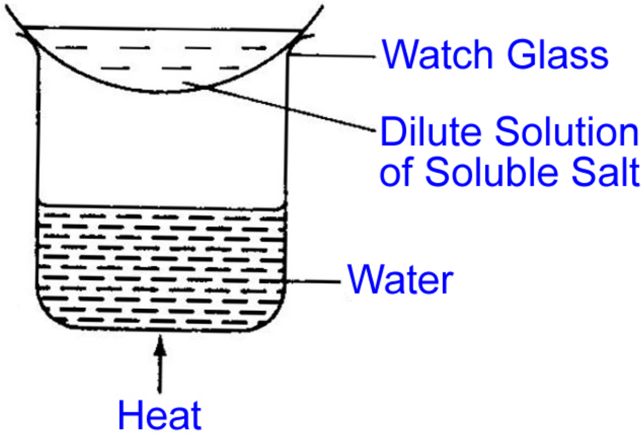
## Procedure

**2)** Repeat the titration once more *without* the indicator, adding together exactly the same volumes of acid and alkali that were determined by the previous titration experiment. This needs to be done so that the indicator does not contaminate the final product.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

### Procedure

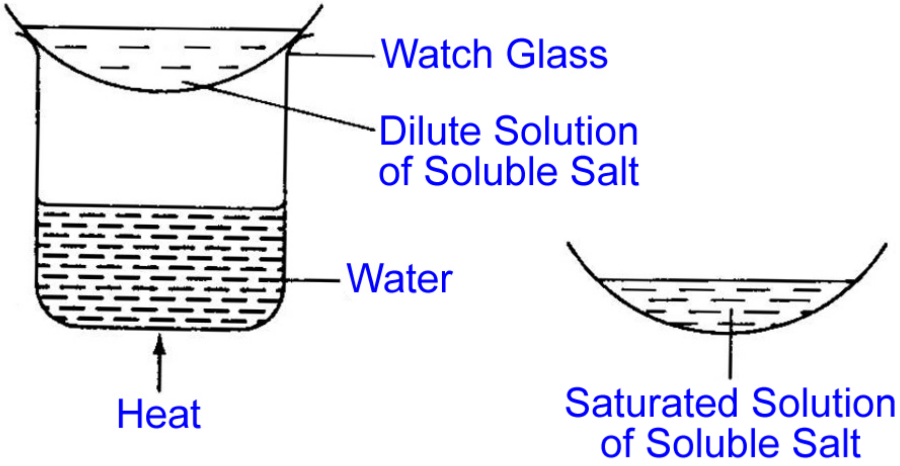


**3)** Pour the resulting salt solution into an evaporating basin, and heat over a Bunsen burner until the solution is *saturated*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

### Procedure

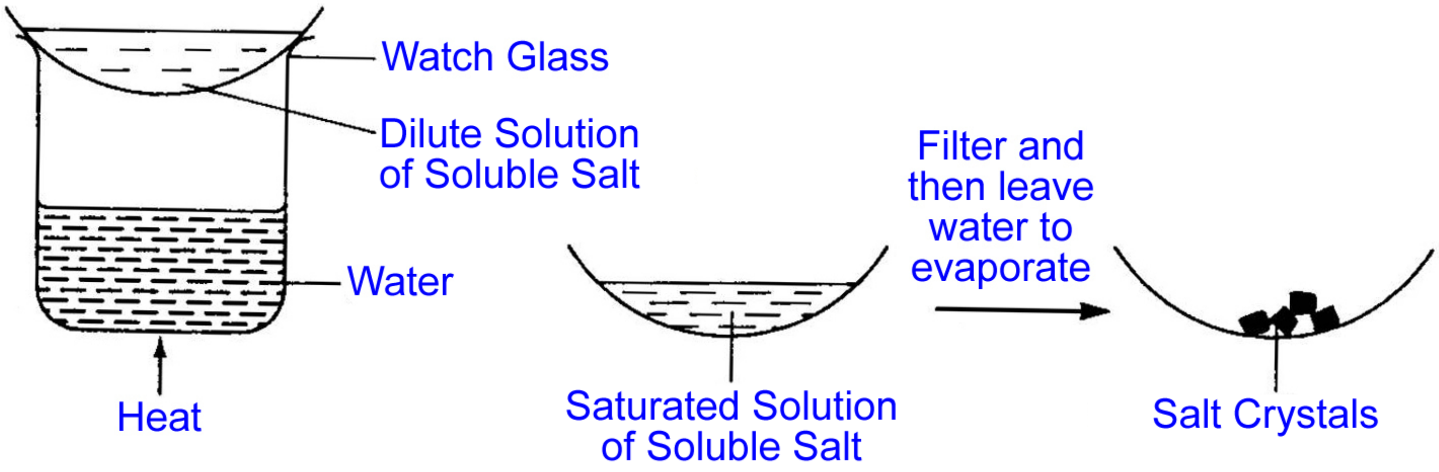


**Test for a Saturated Solution:** When a glass rod is dipped into a hot saturated solution and then removed, crystals will form on the end of the glass rod as the drop of saturated solution cools.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

### Procedure

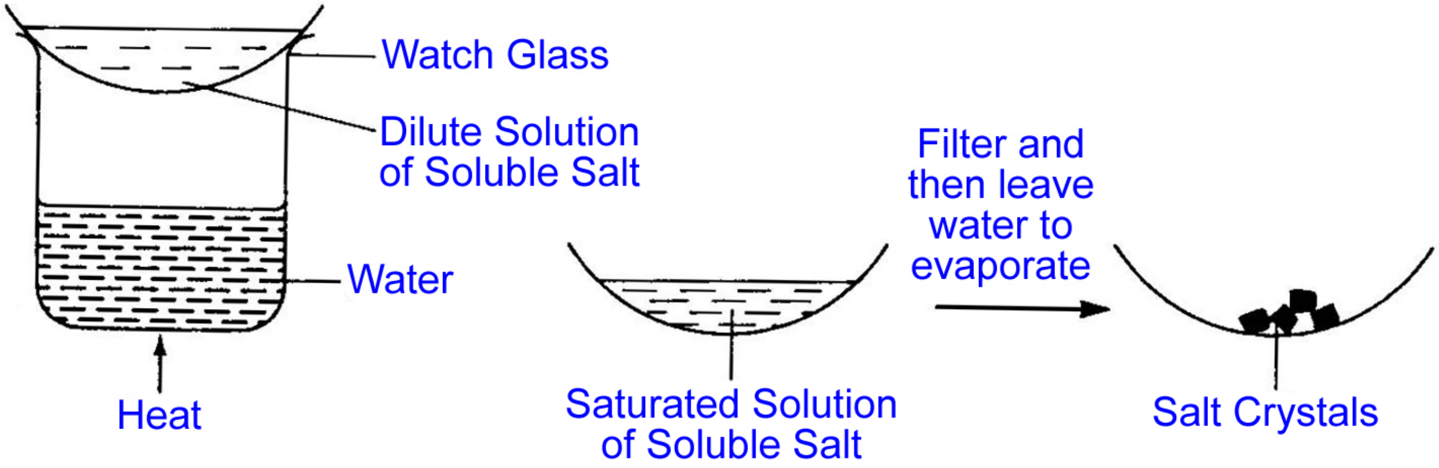


**4)** Leave the hot saturated salt solution to cool to room temperature. As the hot saturated salt solution cools, the desired salt will begin to *crystallise*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

### Procedure

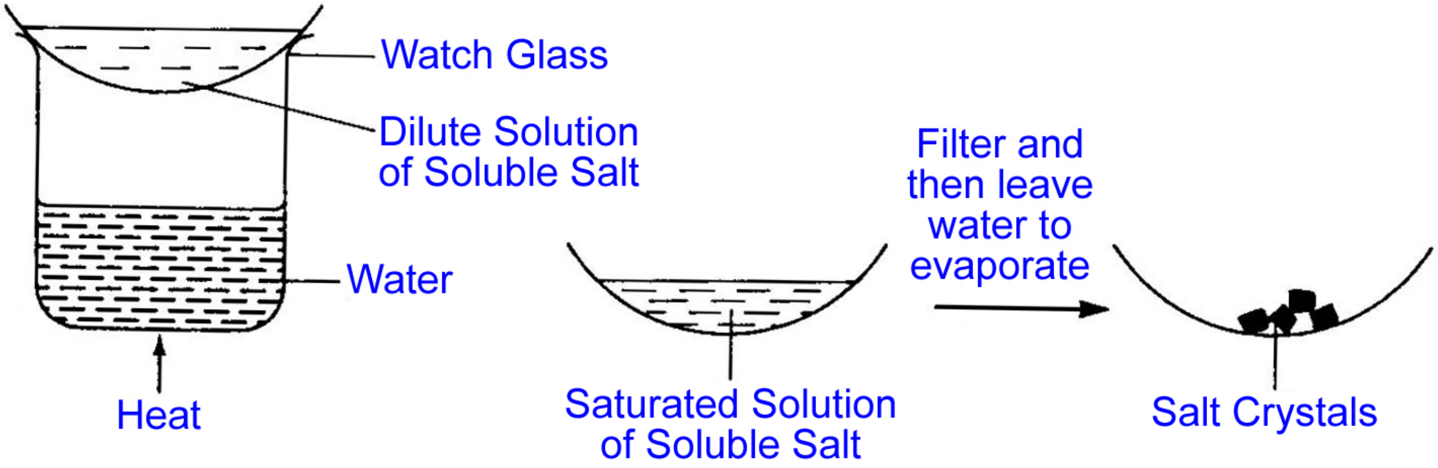


**5)** Once most of the salt has crystallised, but some solution still remains, filter the mixture and wash the crystals (residue) with a little ice-cold distilled water. This is done to remove any water soluble impurities.
Dry the crystals between layers of filter paper.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Titration*

### Procedure



**Note:** The salt is *not* heated to dryness over a non-luminous Bunsen burner flame because the salt may be *thermally unstable* and *decompose* at high temperatures, *e.g.* hydrated salts such as $Na_2CO_3 \cdot 10H_2O$.

# Acids, Bases and Salts

**7.** Overview of acid with *excess insoluble base* / *metal carbonate*.

Main Menu

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

- This technique is used to prepare a *soluble salt* from an *acid* an either an *insoluble base* or an *insoluble metal carbonate*.
- Examples of salts that can be prepared this way include copper(II) sulfate (formula, $CuSO_4$), iron(III) chloride (formula, $FeCl_3$) and barium nitrate (formula, $Ba(NO_3)_2$).

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

- The *acid* will provide the desired *anion*. For example, *hydrochloric acid* (formula, $HCl$) will provide the *chloride ion*, *nitric acid* (formula, $HNO_3$) will provide the *nitrate ion* and *sulfuric acid* (formula, $H_2SO_4$) will provide the *sulfate ion*.

- The *insoluble base* or *insoluble metal carbonate* will provide the desired *cation*. For example, *copper(II) oxide* (formula, $CuO$) will provide the *copper(II) ion*, *iron(III) oxide* (formula, $Fe_2O_3$) will provide the *iron(III) ion* and *barium carbonate* (formula, $BaCO_3$) will provide the *barium ion*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

- acid + base → salt + water

- copper(II) oxide + sulfuric acid → copper(II) sulfate + water

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

- iron(III) oxide + nitric acid → iron(III) nitrate + water

$Fe_2O_3(s) + 6HC\mathit{l}(aq) \rightarrow 2FeC\mathit{l}_3(aq) + 3H_2O(l)$

insoluble metal

- acid + carbonate → salt + water + carbon dioxide

- barium carbonate + nitric acid → barium nitrate + water + carbon dioxide

$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

**1)** Pour the desired acid into a beaker. Place the beaker of acid on a tripod and gauze over a Bunsen burner.

**2)** Add the desired insoluble base or insoluble metal carbonate to the acid while gently warming the acid over the Bunsen burner. Stir the mixture continuously. **Note:** Warming and stirring the reagents increases the rate of reaction between the insoluble base / metal carbonate and the acid.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

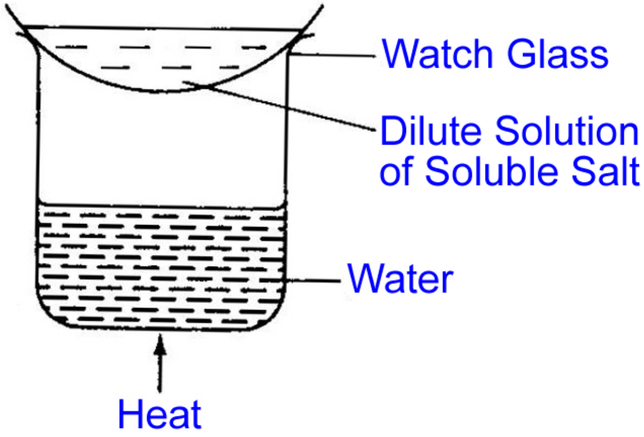
**3)** Continue to add the insoluble base or insoluble metal carbonate to the acid until an *excess* of the insoluble base or insoluble metal carbonate is observed in the bottom of the beaker. This ensures that all of the acid has reacted so the acid will not contaminate the soluble salt.

**4)** Allow the mixture to cool down and then separate the excess insoluble base or insoluble metal carbonate from the salt solution by *filtration*. The solution of the desired salt will be the *filtrate*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

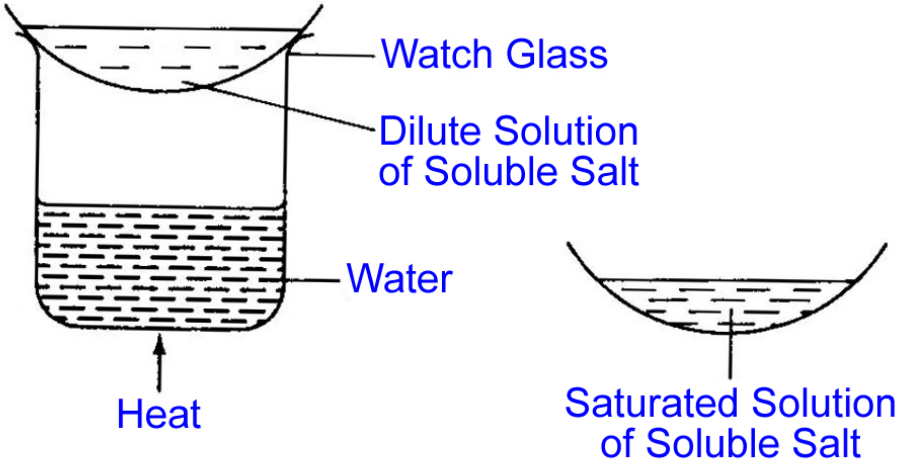


**5)** Pour the resulting salt solution into an evaporating basin, and heat over a Bunsen burner until the solution is *saturated*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

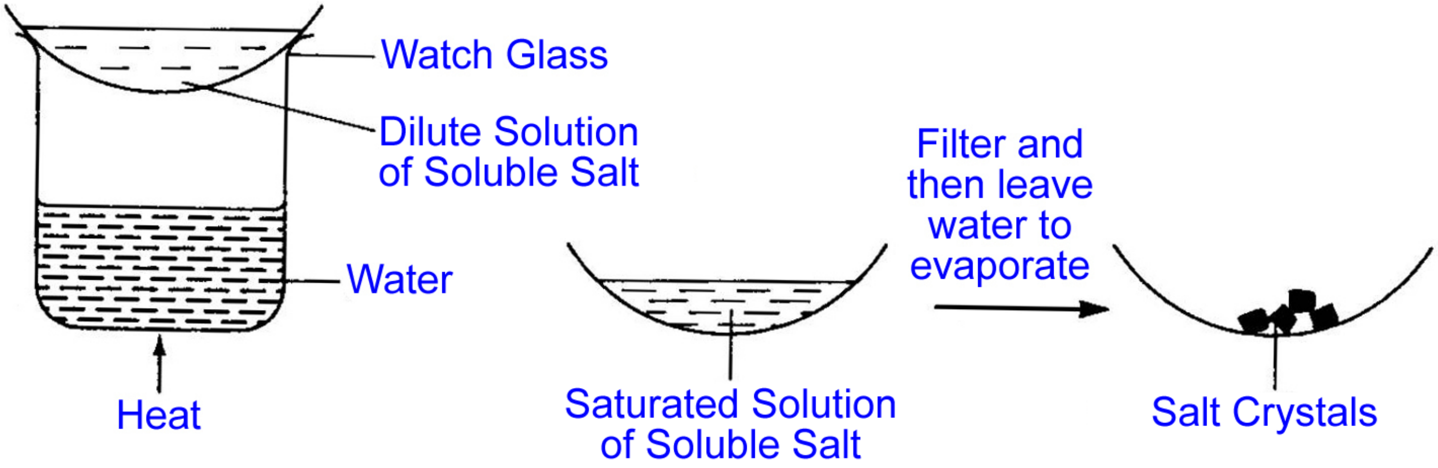


**Test for a Saturated Solution:** When a glass rod is dipped into a hot saturated solution and then removed, crystals will form on the end of the glass rod as the drop of saturated solution cools.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

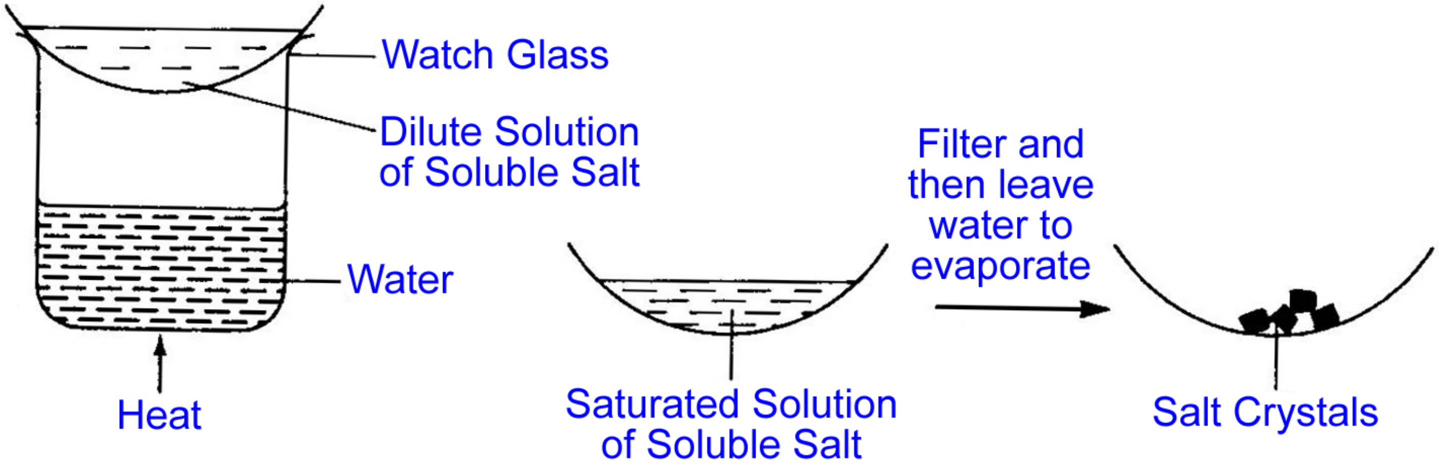


**6)** Leave the hot saturated salt solution to cool to room temperature. As the hot saturated salt solution cools, the desired salt will begin to *crystallise*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

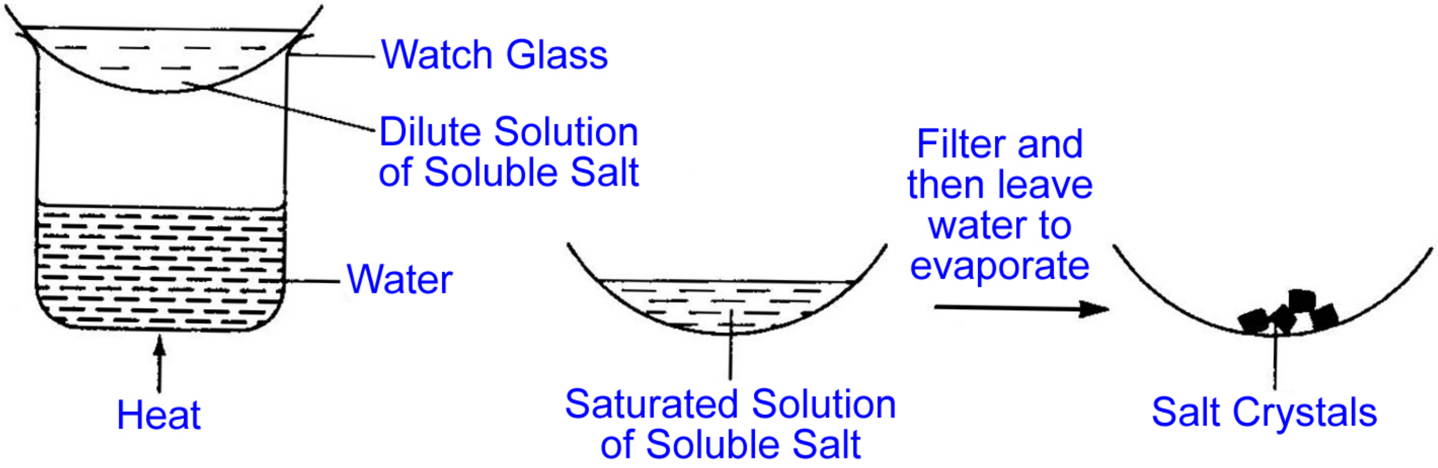


**7)** Once most of the salt has crystallised, but some solution still remains, filter the mixture and wash the crystals (residue) with a little ice-cold distilled water. This is done to remove any water soluble impurities.
Dry the crystals between layers of filter paper.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure

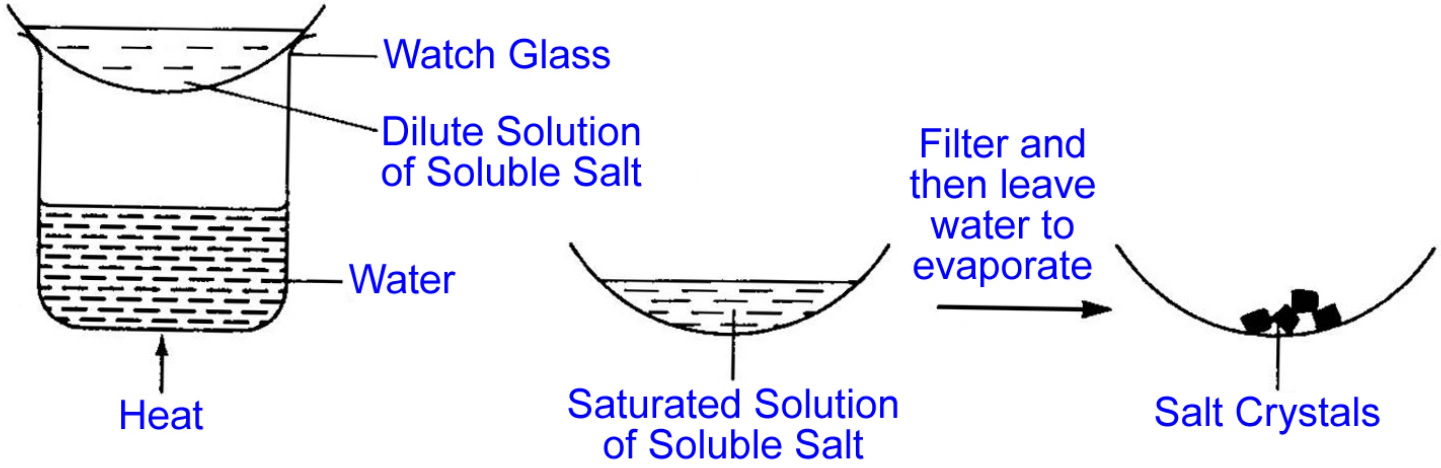


**Note:** The salt is *not* heated to dryness over a non-luminous Bunsen burner flame because the salt may be *thermally unstable* and *decompose* at high temperatures, *e.g.* hydrated salts such as $CuSO_4{\cdot}5H_2O$.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – *Excess Insoluble Base*

### Procedure



- Examples of thermal decomposition

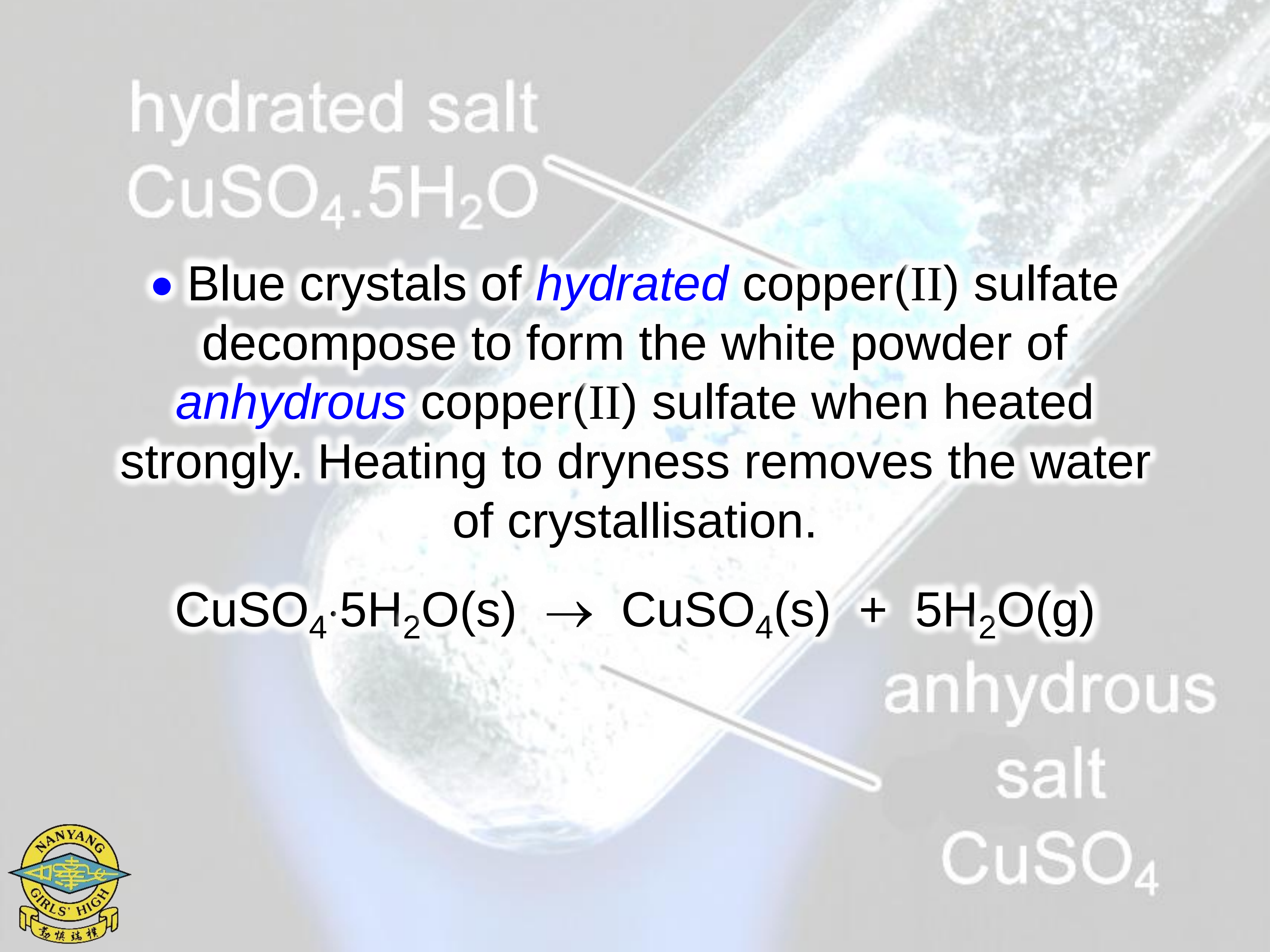
blue crystals white powder

$$CuSO_4{\cdot}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$$

green powder black black

$$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$$


hydrated salt
$CuSO_4.5H_2O$
anhydrous
[redacted] salt
$CuSO_4$



- Blue crystals of *hydrated* copper(II) sulfate decompose to form the white powder of *anhydrous* copper(II) sulfate when heated strongly. Heating to dryness removes the water of crystallisation.

$$CuSO_4{\cdot}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$$

# Acids, Bases and Salts

**8.** What are *solubility curves*, and why are they useful?

Main Menu

# Acids, Bases and Salts

## Preparation of a Soluble Salt

### Solubility Curve

- In the preparation of soluble salts, the solid salt is obtained by evaporating away most of the water and allowing the hot solution to cool. As the solution cools, it becomes *saturated*, meaning that it has the maximum amount of solute (*i.e.* salt) dissolved in the solvent.

- *Solubility* is the maximum amount of salt (mass in grams) that dissolves in a solvent (usually 100 $cm^3$) at a given temperature. *Solubility decreases* as *temperature decreases*. Therefore, as the solution continues to cool, there is a decrease in the amount of salt that can remain dissolved – all of the extra salt *crystallises*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt

### Solubility Curve

- It is important to leave some water after evaporation for two reasons:

**1.** Any impurities will be left in the remaining solution after cooling, and will not contaminate the crystals.

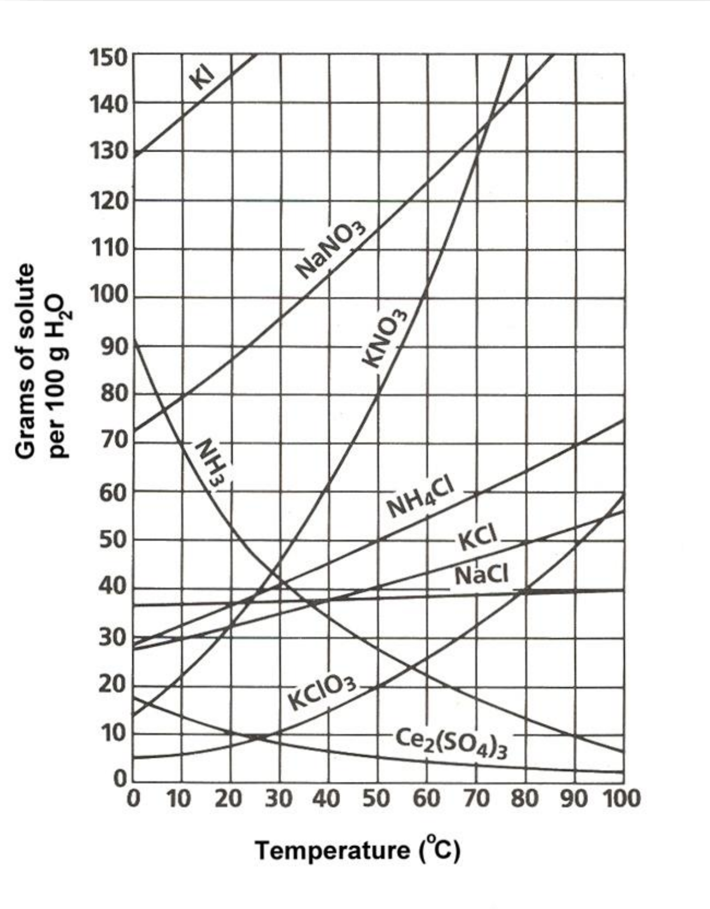
**2.** Many salts require water to be present in order to form crystals – known as *water of crystallisation* – *e.g.* hydrated copper(II) sulfate – $CuSO_4 \cdot 5H_2O$.

# Acids, Bases and Salts

## Preparation of a Soluble Salt

### Solubility Curve

- *Solubility* is a measure of how many grams of solute dissolve in 100 $cm^3$ of solvent.



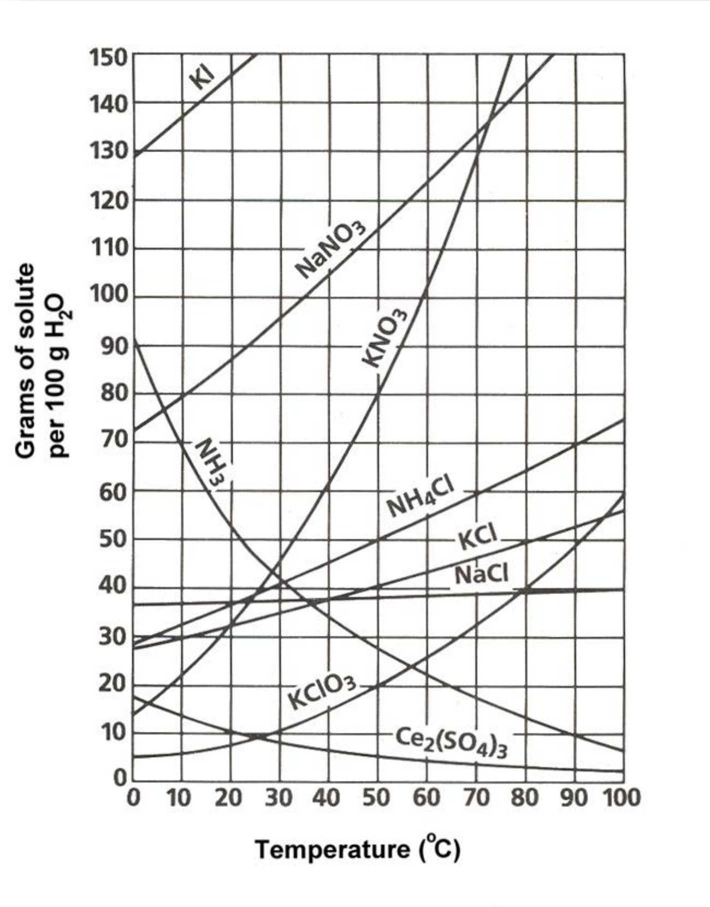
- A *solubility curve* is a graph of solubility plotted against temperature. It shows how the solubility of a chemical changes with temperature.

# Acids, Bases and Salts

## Preparation of a Soluble Salt

- The solubility of some salts, *e.g.* KNO$_3$, decrease a lot on cooling, so large amounts of these salts crystallise on cooling a *hot saturated solution*.

### Solubility Curve



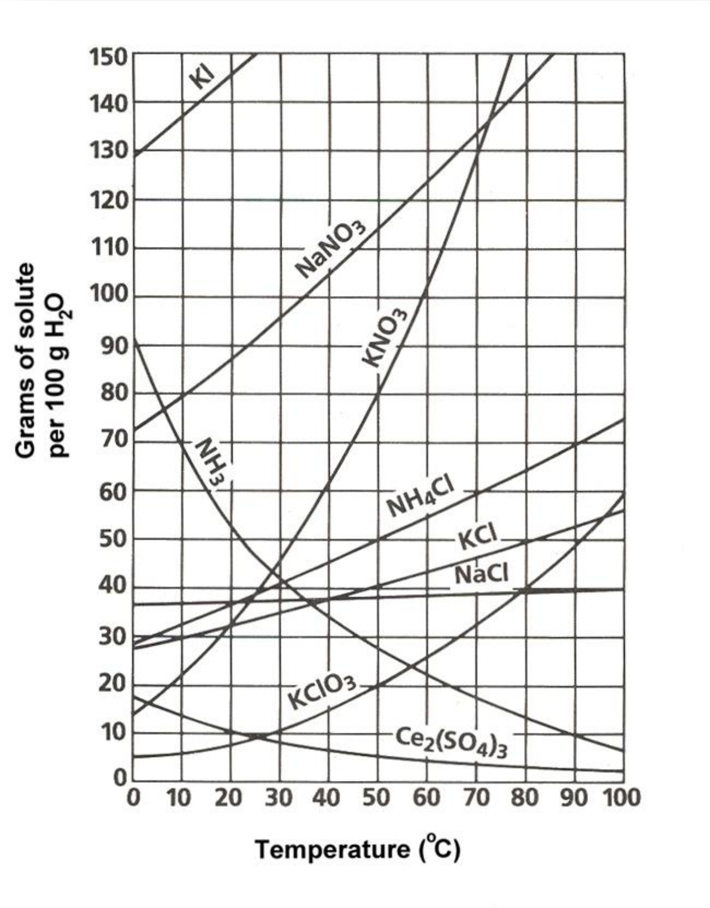
- The crystals of many salts can be obtained by cooling a hot saturated solution of the salt, a process called *crystallisation*.

# Acids, Bases and Salts

## Preparation of a Soluble Salt

- The solubility of other salts, *e.g.* NaC*l*, show very little variation on cooling, so very little solid is formed when a hot saturated solution of NaC*l* is cooled.

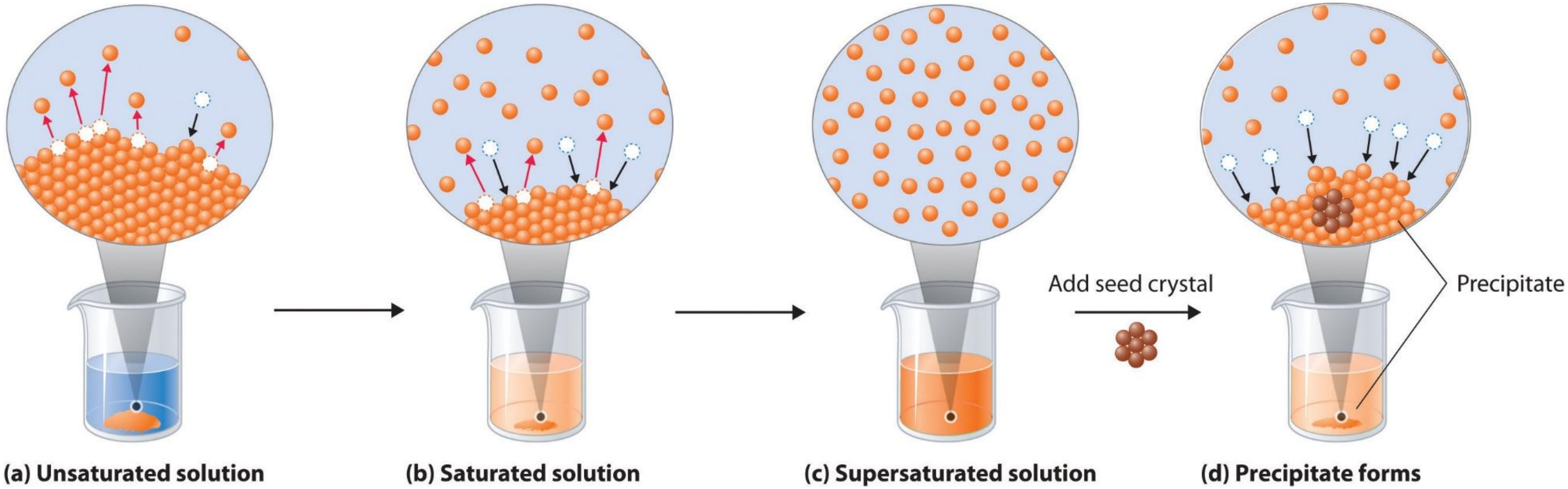
### Solubility Curve



- To obtain crystals of NaC*l* from an aqueous solution, all of the water must be heated / evaporated, a process known as *evaporation to dryness*.

# Acids, Bases and Salts

## A Note About Super Saturated Solutions



- A *saturated solution* is a solution that contains the maximum amount of solute dissolved in a solvent at a given temperature.
- A *super saturated solution* is a solution in which the solvent has more solute dissolved in it than a saturated solution, *i.e*. there is more solute dissolved in the solvent than the solvent should normally be able to hold at a given temperature.

# Acids, Bases and Salts

## A Note About Efflorescent Salts

- When some chemicals are exposed to air, they *lose water* to the atmosphere, thereby decreasing in weight. Such salts are said to be *efflorescent*. Solids that behave in this way are those that contain water of crystallization. The molecules of water of crystallization are either partially or completely lost to the atmosphere, causing the salt to lose its crystalline structure.
- For example, $Na_2SO_4 \cdot 10H_2O$ loses all its water of crystallization when exposed to air, $Na_2CO_3 \cdot 10H_2O$ loses nine of its molecules of water of crystallization and $FeSO_4 \cdot 7H_2O$ loses all its molecules of water of crystallization.

# Acids, Bases and Salts

## A Note About Deliquescent Salts

- A *deliquescent* salt is one which *absorbs water* when exposed to the air, sometimes absorbing enough water to form a solution. Examples of deliquescent salts include solid $CaCl_2$, $FeCl_3$, KOH, $MgCl_2$ and NaOH.
- Substances which absorb water from air can be used as drying agents for gases. For example, $CaCl_2$ can be used to dry most gases, except $NH_3(g)$. Concentrated $H_2SO_4$ is used to dry acidic gases such as $HCl(g)$. CaO is used to dry alkaline / basic gases such as $NH_3(g)$.

# Acids, Bases and Salts

## Crystallisation

# Acids, Bases and Salts

## Crystallisation

- The Dead Sea is a salt lake bordered by Jordan to the East and Israel and Palestine to the West.

- The shore of the Dead Sea are 429 m *below* sea level, making it the Earth’s lowest elevation on land.

- At 304 m deep, the Dead Sea is the world’s deepest hypersaline lake. With 32.4 % salinity, the Dead Sea is 9.6 times more salty than the ocean.

- The concentration of ions in g/kg of water at the surface of the Dead Sea is $\mathrm{C}l^{-} = 181.4$, $\mathrm{Br}^{-} = 4.2$, $\mathrm{SO_4}^{2-} = 0.4$, $\mathrm{HCO_3}^{-} = 0.2$, $\mathrm{Ca}^{2+} = 14.1$, $\mathrm{Na}^{+} = 32.5$, $\mathrm{K}^{+} = 6.2$ and $\mathrm{Mg}^{2+} = 35.2$.

# Acids, Bases and Salts

- For a project called *Salt Bride*, Israeli artist Sigalit Landau submerged a black dress in the Dead Sea.

- The dress was submerged in the hypersaline waters of the Dead Sea for two months.

# Acids, Bases and Salts

- Over two months, various salts, *e.g.* $\mathrm{NaC}l$ and $\mathrm{MgC}l_2$ crystallised over the surface of the dress.

Crystallisation

- The formation of salt crystals changed the appearance of the dress from dull black to sparling white.

# Acids, Bases and Salts

**9.** Why can’t I prepare an *insoluble salt* by the excess insoluble base method?

# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base

- The insoluble salt will precipitate over the surface of the insoluble base or metal carbonate, for example:

- barium carbonate + sulfuric acid → barium sulfate + water + carbon dioxide

$BaCO_3(s) + H_2SO_4(aq) \rightarrow BaSO_4(s) + H_2O(l) + CO_2(g)$

- The insoluble salt will then form a solid layer (barrier) between the acid and the insoluble base or metal carbonate.

# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base

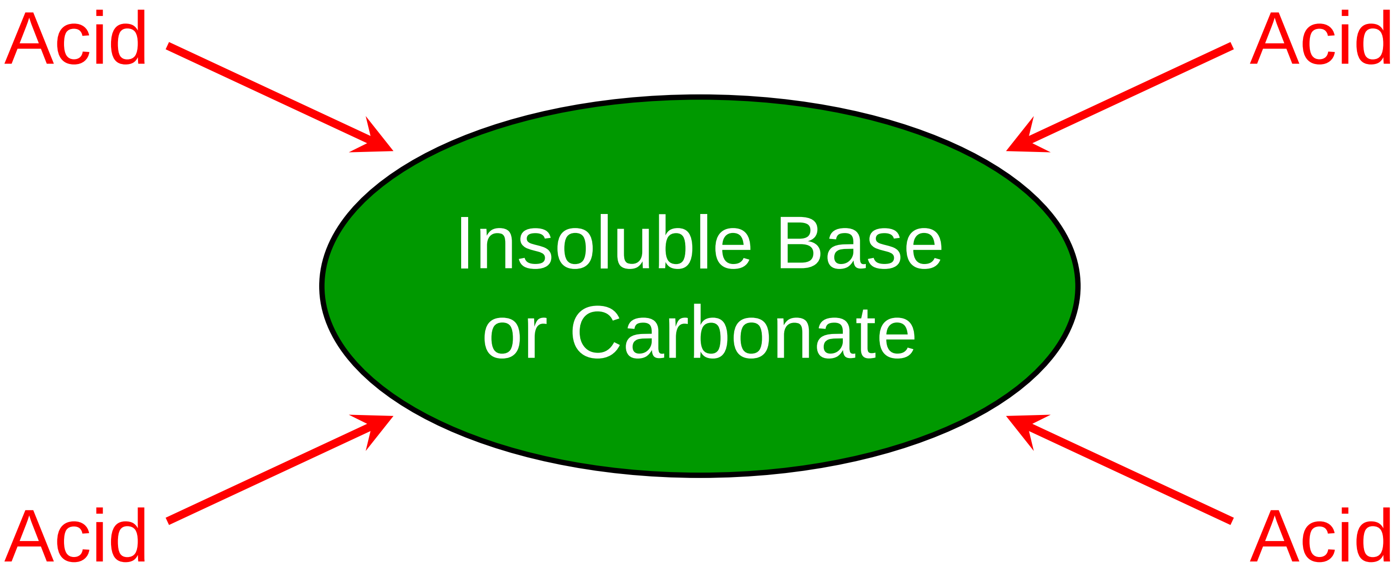
# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base

Insoluble Base
or Carbonate

# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base



Acid

Acid

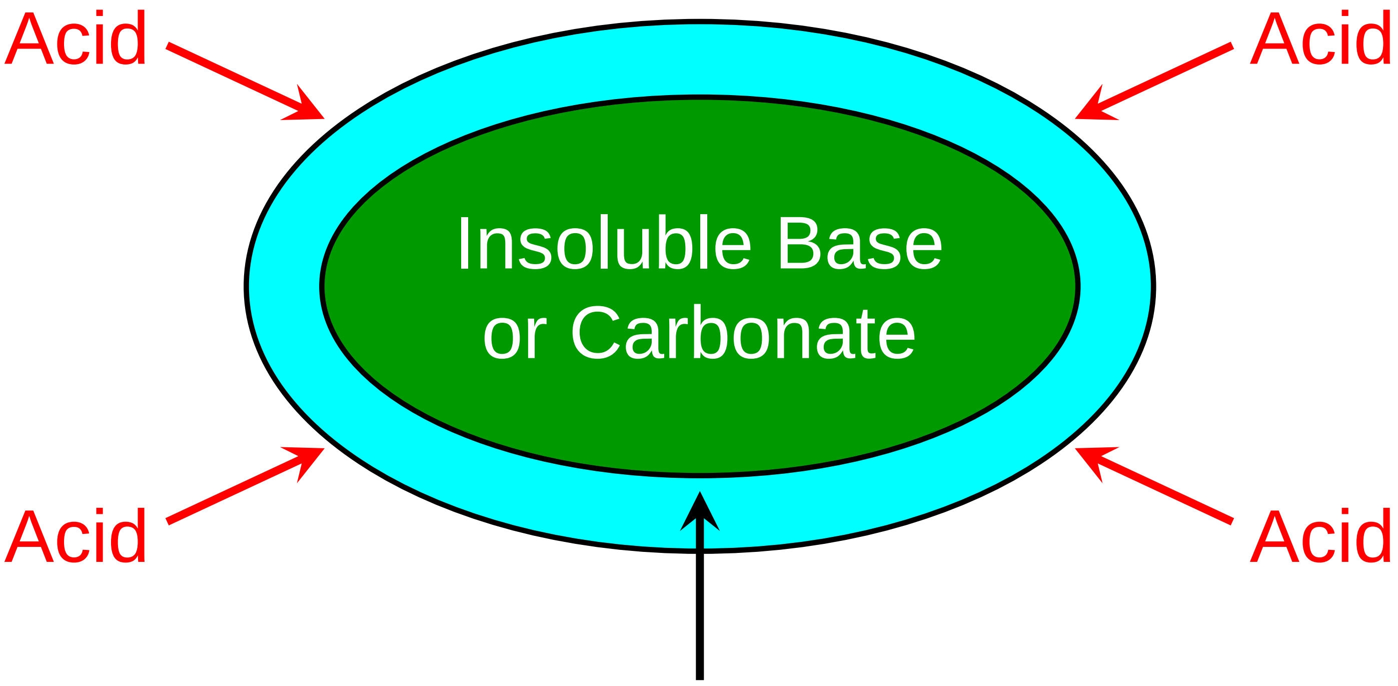
Insoluble Base or Carbonate

Acid

Acid

# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base



- Layer of Insoluble Salt

# Acids, Bases and Salts

## Preparation of a Soluble Salt – Excess Insoluble Base

- The layer of insoluble salt will prevent the acid from reacting with the insoluble base or metal carbonate.
- When the reaction has stopped, the flask will contain a mixture of insoluble salt and unreacted insoluble base or metal carbonate.
- Because of this, *the reaction will be incomplete* – with a *low yield of product* – and the reaction product will also be impure. In addition, the mixture of insoluble salt and unreacted insoluble base or metal carbonate will be very difficult to separate.

# Acids, Bases and Salts

**10.** Is it possible to prepare a salt by reacting an *acid* with a *metal*?

Main Menu

# Acids, Bases and Salts

## Preparation of a Salt – Acid and Metal

- It is possible to prepare a salt by reacting a metal with an acid. Excess metal will be added to the acid to ensure that all of the acid has reacted. The excess metal will then be removed by filtration before the salt is crystallised from solution. There are however two problems with this method…

- Problem Number One: *Not all metals react with acids*. For example, copper does not react with acids, so it is impossible to prepare copper(II) sulfate by reacting copper with sulfuric acid.

- Problem Number Two: *Metals such as sodium and potassium are very reactive*. It is very dangerous to add these metals to an acid because the reaction is very vigorous and potentially explosive because the hydrogen gas that is produced may be ignited by the energy that is released.

# Acids, Bases and Salts

## Preparation of a Salt – Acid and Metal

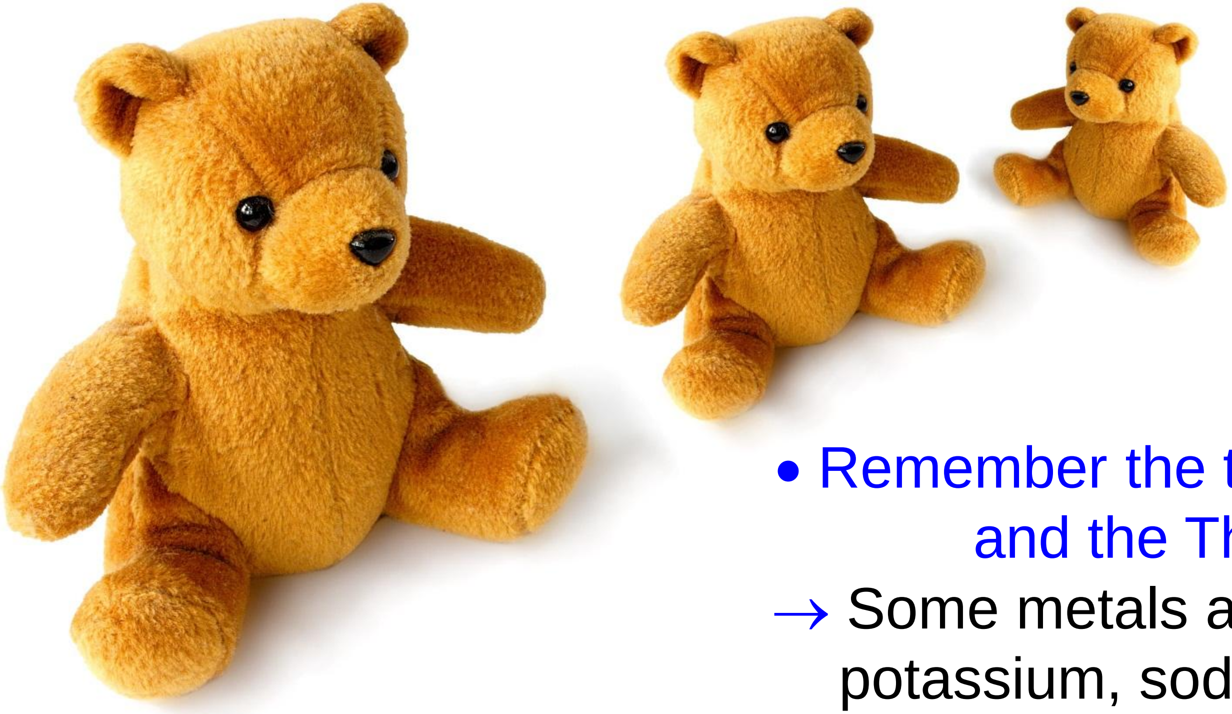
- Copper ore.

- Most, but *not all* metals react with acids.
- Metals *below hydrogen* in the reactivity series do *not* react with acids.

Potassium
Sodium
Calcium
Magnesium ✓
Aluminium
Zinc
Iron
→ Hydrogen ←
Copper ✗
Silver

# Acids, Bases and Salts

## Preparation of a Salt – Acid and Metal



- Remember the tale of Goldie Locks and the Three Bears?

→ Some metals are too reactive, *e.g.* potassium, sodium and calcium.

→ Some metals aren’t reactive enough, *e.g.* copper and silver.

→ Some metals are just right, *e.g.* magnesium, zinc and iron.

# Acids, Bases and Salts

**11.** Which reagents are unsuitable for preparing salts in the laboratory?

Main Menu

# Acids, Bases and Salts

## Reagents Unsuitable for Preparing Salts – $Ca(OH)_2(aq)$

- Calcium hydroxide is *sparingly soluble* in water, meaning its solution will be *very dilute* (the maximum solubility of calcium hydroxide is 1.73 $g/dm^3$ or 0.0233 $mol/dm^3$ at 20.0 °C).
- Even though an *aqueous solution of calcium hydroxide* could be used to prepare an insoluble calcium salt by ionic precipitation, or a soluble calcium salt by titration, the use of this reagent is *not recommended*, as the mass of salt produced would be *very small*.
- Using an aqueous solution of calcium hydroxide to prepare an insoluble calcium salt by ionic precipitation:

$$Ca(OH)_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaOH(aq)$$

- Using an aqueous solution of calcium hydroxide to prepare a soluble calcium salt by titration:

$$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$

# Acids, Bases and Salts

## Reagents Unsuitable for Preparing Salts – $Ca(OH)_2(aq)$

- Calcium hydroxide has a *very low solubility in water*. To increase the mass of insoluble calcium salt produced by ionic precipitation, a calcium compound that has a *much greater solubility* should be used as the starting material.

- A good example would be *calcium nitrate*, which has a maximum solubility of 1212 g/dm$^3$ or 7.39 mol/dm$^3$ at 20.0 °C. This would produce a much greater mass of insoluble calcium salt than an aqueous solution of calcium hydroxide.

$$Ca(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaNO_3(aq)$$

- **Note:** Calcium salts that are *soluble* in water should be made by the *excess insoluble base* / *excess insoluble carbonate* method, and *not* by titration using an aqueous solution of calcium hydroxide.

# Acids, Bases and Salts

## Reagents Unsuitable for Preparing Salts – $H_2CO_3(aq)$

- The solubility of carbon dioxide gas in water is 1.45 g/dm$^3$ or 0.0330 mol/dm$^3$. Assuming that all of the carbon dioxide gas reacts with water to form carbonic acid, the concentration of carbonic acid in aqueous solution will be *very low*.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

- Even though an *aqueous solution of carbonic acid* could be used to prepare an insoluble carbonate by ionic precipitation, or a soluble carbonate by titration, the use of this reagent is *not recommended*, as the mass of salt produced would be *very small*.

- Preparing an insoluble carbonate by ionic precipitation:

$$Cu(NO_3)_2(aq) + H_2CO_3(aq) \rightarrow CuCO_3(s) + 2HNO_3(aq)$$

- Preparing a soluble carbonate by titration:

$$2NaOH(aq) + H_2CO_3(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(l)$$

# Acids, Bases and Salts

## Reagents Unsuitable for Preparing Salts – $H_2CO_3(aq)$

- Carbonic acid has a *very low solubility in water*. To increase the mass of insoluble carbonate produced by ionic precipitation, a carbonate that has a *much greater solubility* should be used as the starting material.

- A good example would be *sodium carbonate*, which has a maximum solubility of 503 g/dm$^3$ or 4.75 mol/dm$^3$ at 30.0 °C. This would produce a much greater mass of insoluble carbonate than an aqueous solution of carbonic acid.

$$Cu(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow CuCO_3(s) + 2NaNO_3(aq)$$

- **Note:** There is little choice except to prepare *soluble carbonates*, such as $(NH_4)_2CO_3$, $K_2CO_3$ and $Na_2CO_3$, in the laboratory by *titration*. The large scale, industrial manufacture of these carbonates is more complex.

# Acids, Bases and Salts

**12.** Could I please have some *questions* to test my understanding?

Main Menu

# Acids, Bases and Salts

## Question 1:

How would you prepare a pure, dry sample of *silver nitrate*?

# Acids, Bases and Salts

## Question 1:

How would you prepare a pure, dry sample of *silver nitrate*?

## Answer:

Add excess insoluble base to an acid.

silver oxide + nitric acid → silver nitrate + water

$$Ag_2O(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l)$$

$$Ag_2O(s) + 2H^+(aq) \rightarrow 2Ag^+(aq) + H_2O(l)$$

# Acids, Bases and Salts

## Question 2:

How would you prepare a pure, dry sample of *potassium sulfate*?

# Acids, Bases and Salts

## Question 2:

How would you prepare a pure, dry sample of *potassium sulfate*?

## Answer:

Titrate acid against alkali.

potassium hydroxide + sulfuric acid → potassium sulfate + water

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

$$2OH^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l)$$

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

# Acids, Bases and Salts

## Question 3:

How would you prepare a pure, dry sample of *lead(II) chloride*?

# Acids, Bases and Salts

## Question 3:

How would you prepare a pure, dry sample of
*lead(II) chloride*?

## Answer:

Ionic precipitation reaction.

lead(II) nitrate + sodium chloride → lead(II) chloride + sodium nitrate

$$Pb(NO_3)_2(aq) + 2NaCl(aq) \rightarrow PbCl_2(s) + 2NaNO_3(aq)$$

$$Pb^{2+}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_2(s)$$

# Acids, Bases and Salts

## Question 4:

How would you prepare a pure, dry sample of *calcium carbonate*?

# Acids, Bases and Salts

## Question 4:

How would you prepare a pure, dry sample of *calcium carbonate*?

## Answer:

Ionic precipitation reaction.

calcium nitrate + sodium carbonate → calcium carbonate + sodium nitrate

$$Ca(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaNO_3(aq)$$

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

# Acids, Bases and Salts

## Question 5:

How would you prepare a pure, dry sample of *copper(II) nitrate*?

# Acids, Bases and Salts

## Question 5:

How would you prepare a pure, dry sample of *copper(II) nitrate*?

## Answer:

Add excess insoluble base to an acid.

copper(II) oxide + nitric acid → copper(II) nitrate + water

$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$

$CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$

# Acids, Bases and Salts

**MCQ Question 1.**

Which one of the following salts *cannot* be prepared by a reaction between a dilute acid and an excess of an insoluble base?

**A.** Copper(II) chloride

**B.** Magnesium nitrate

**C.** Potassium sulfate

**D.** Zinc sulfate

# Acids, Bases and Salts

**MCQ Question 1.**

Which one of the following salts *cannot* be prepared by a reaction between a dilute acid and an excess of an insoluble base?

**A.** Copper(II) chloride

**B.** Magnesium nitrate

**C.** Potassium sulfate ✓

**D.** Zinc sulfate

**A.** $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$

**B.** $MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$

**C.** $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

**D.** $ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$

**Note:** Potassium oxide is *soluble* in water. It reacts with water to form an aqueous solution of potassium hydroxide: $K_2O(s) + H_2O(l) \rightarrow 2KOH(aq)$

# Acids, Bases and Salts

**MCQ Question 2.**

Lead(II) sulfate can be prepared by the reaction of sulfuric acid with…

I Lead(II) oxide
II Lead(II) nitrate solution
III Lead(II) carbonate

**A.** I only

**B.** II only

**C.** I and II only

**D.** I, II and III

# Acids, Bases and Salts

**MCQ Question 2.**

Lead(II) sulfate can be prepared by the reaction of sulfuric acid with…

I Lead(II) oxide
II Lead(II) nitrate solution
III Lead(II) carbonate

**A.** I only
**B.** II only ✓
**C.** I and II only
**D.** I, II and III

• Lead(II) sulfate is *insoluble* in water. It should be made by ionic precipitation by adding a solution of lead(II) ions to a solution of sulfate ions:

$$Pb(NO_3)_2(aq) \ + \ H_2SO_4(aq) \ \rightarrow \ PbSO_4(s) \ + \ 2HNO_3(aq)$$

$$Pb^{2+}(aq) \ + \ SO_4^{2-}(aq) \ + \ PbSO_4(s)$$

**Note:** Lead(II) oxide and lead(II) carbonate are both *insoluble* in water. *Insoluble salts* should *not* be prepared from *insoluble starting materials*.

# Acids, Bases and Salts

**MCQ Question 3.**

Which one of the following chemicals *cannot* be prepared by ionic precipitation?

**A.** Barium sulfate

**B.** Calcium carbonate

**C.** Lead(II) chloride

**D.** Silver nitrate

# Acids, Bases and Salts

**MCQ Question 3.**

Which one of the following chemicals *cannot* be prepared by ionic precipitation?

**A.** Barium sulfate

**B.** Calcium carbonate

**C.** Lead(II) chloride

**D.** Silver nitrate ✓

- Ionic precipitation is used to prepare *insoluble* salts from *soluble* starting materials. Barium sulfate (**A**), calcium carbonate (**B**) and lead(II) chloride (**C**) are all *insoluble* in water, and *can* be prepared by ionic precipitation. Silver nitrate is *soluble* in water, and should be prepared by adding excess insoluble base or metal carbonate to an acid:

$$Ag_2O(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l)$$

$$Ag_2CO_3(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l) + CO_2(g)$$

# Acids, Bases and Salts

**MCQ Question 4.**

Which pair of compounds could be used in the preparation of calcium sulfate?

**A.** Calcium carbonate and sodium sulfate.

**B.** Calcium chloride and ammonium sulfate.

**C.** Calcium hydroxide and barium sulfate.

**D.** Calcium nitrate and lead(II) sulfate.

# Acids, Bases and Salts

**MCQ Question 4.**

Which pair of compounds could be used in the preparation of calcium sulfate?

**A.** Calcium carbonate and sodium sulfate.

**B.** Calcium chloride and ammonium sulfate. ✓

**C.** Calcium hydroxide and barium sulfate.

**D.** Calcium nitrate and lead(II) sulfate.

- Calcium sulfate is *insoluble* in water and should therefore be prepared by *ionic precipitation*, adding an aqueous solution of calcium ions to an aqueous solution of sulfate ions:

$$CaCl_2(aq) + (NH_4)_2SO_4(aq) \rightarrow CaSO_4(s) + 2NH_4Cl(aq)$$

$$Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s)$$

# Acids, Bases and Salts

**MCQ Question 5.**

Which reactants could be used safely to prepare sodium nitrate?

**A.** Aqueous sodium hydroxide and dilute nitric acid.

**B.** Aqueous sodium sulfate and aqueous potassium nitrate.

**C.** Sodium and aqueous potassium nitrate.

**D.** Sodium and dilute nitric acid.

# Acids, Bases and Salts

**MCQ Question 5.**

Which reactants could be used safely to prepare sodium nitrate?

**A.** Aqueous sodium hydroxide and dilute nitric acid. ✓

**B.** Aqueous sodium sulfate and aqueous potassium nitrate.

**C.** Sodium and aqueous potassium nitrate.

**D.** Sodium and dilute nitric acid.

- Sodium nitrate is the salt of a Group 1 metal. It is soluble in water and should be prepared by titration, reacting aqueous sodium hydroxide with dilute nitric acid:

$$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

**Note:** Although metallic sodium will react directly with dilute nitric acid (**D**) to produce sodium nitrate, the reaction is very *exothermic* (produces a lot of heat) and also produces flammable hydrogen gas. This method is therefore *unsafe*: $2Na(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2(g)$

# Acids, Bases and Salts

**MCQ Question 6.**

Which three salts are all prepared by precipitation?

**A.** Barium sulfate, calcium nitrate, lead(II) sulfate.

**B.** Barium sulfate, calcium nitrate, silver chloride.

**C.** Barium sulfate, lead(II) sulfate, silver chloride.

**D.** Calcium nitrate, lead(II) sulfate, silver chloride.

# Acids, Bases and Salts

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**B.** Barium sulfate, calcium nitrate, silver chloride.

**C.** Barium sulfate, lead(II) sulfate, silver chloride. ✓

**D.** Calcium nitrate, lead(II) sulfate, silver chloride.

- *Ionic precipitation* is used to prepare salts that are *insoluble* in water.

**A.** Barium sulfate = insoluble. Calcium nitrate = soluble. Lead(II) sulfate = insoluble.
**B.** Barium sulfate = insoluble. Calcium nitrate = soluble. Silver chloride = insoluble.
**C.** Barium sulfate = insoluble. Lead(II) sulfate = insoluble. Silver chloride = insoluble.
**D.** Calcium nitrate = soluble. Lead(II) sulfate = insoluble. Silver chloride = insoluble.

# Acids, Bases and Salts

**MCQ Question 7.**
In which one of the following reactions is the sulfate ion removed from solution?

**A.** $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

**B.** $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

**C.** $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

**D.** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$

# Acids, Bases and Salts

**MCQ Question 7.**

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**C.** $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

**D.** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$

- In option **A**, sulfate ions are removed from aqueous solution as an insoluble precipitate of barium sulfate is formed.

**A.** $BaCl_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2HCl(aq)$

**B.** $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

**C.** $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

**D.** $Na_2CO_3(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

# Acids, Bases and Salts

**MCQ Question 8.**

Which solutions, when mixed together, form an insoluble salt?

**A.** Dilute hydrochloric acid and barium nitrate.

**B.** Dilute sulfuric acid and sodium hydroxide.

**C.** Dilute hydrochloric acid and lead(II) nitrate.

**D.** Dilute sulfuric acid and zinc chloride.

# Acids, Bases and Salts

**MCQ Question 8.**

Which solutions, when mixed together, form an insoluble salt?

**A.** Dilute hydrochloric acid and barium nitrate.

**B.** Dilute sulfuric acid and sodium hydroxide.

**C.** Dilute hydrochloric acid and lead(II) nitrate. ✓

**D.** Dilute sulfuric acid and zinc chloride.

**A.** $2HCl(aq) + Ba(NO_3)_2(aq) \rightarrow$ no observed reaction

$\cancel{2H}^+(aq) + \cancel{2Cl}^-(aq) + \cancel{Ba}^{2+}(aq) + \cancel{2NO_3}^-(aq) \rightarrow \cancel{Ba}^{2+}(aq) + \cancel{2Cl}^-(aq) + \cancel{2H}^+(aq) + \cancel{2NO_3}^-(aq)$

Attempting to write an ionic equation for **A** – *everything cancels* – there is no reaction.

**B.** $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

**C.** $2HCl(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2(s) + 2HNO_3(aq)$

**D.** $H_2SO_4(aq) + ZnCl_2(aq) \rightarrow$ no observed reaction

$\cancel{2H}^+(aq) + \cancel{SO_4}^{2-}(aq) + \cancel{Zn}^{2+}(aq) + \cancel{2Cl}^-(aq) \rightarrow \cancel{Zn}^{2+}(aq) + \cancel{SO_4}^{2-}(aq) + \cancel{2H}^+(aq) + \cancel{2Cl}^-(aq)$

Attempting to write an ionic equation for **D** – *everything cancels* – there is no reaction.

# Acids, Bases and Salts

**MCQ Question 9.**

Aqueous solutions of silver nitrate and barium chloride are added together and the resulting mixture is poured through filter paper. Which one of the following correctly identifies the filtrate and residue?

| | Residue | Filtrate |
|---|---|---|
| **A.** | silver nitrate | barium chloride |
| **B.** | barium chloride | silver nitrate |
| **C.** | silver chloride | barium nitrate |
| **D.** | barium nitrate | silver chloride |

# Acids, Bases and Salts

### MCQ Question 9.

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| | Residue | Filtrate | |
|---|---|---|---|
| **A.** | silver nitrate | barium chloride | |
| **B.** | barium chloride | silver nitrate | |
| **C.** | silver chloride | barium nitrate | ✓ |
| **D.** | barium nitrate | silver chloride | |

$$2AgNO_3(aq) + BaC\mathit{l}_2(aq) \rightarrow 2AgC\mathit{l}(s) + Ba(NO_3)_2(aq)$$

- The solid precipitate of silver chloride will be collected in the filter paper as the residue, while the solution of barium nitrate will pass through the filter paper to be collected as the filtrate.

# Acids, Bases and Salts

**MCQ Question 10.**

Which one of the following reactions is *least* suitable for preparing the given salt?

| | **Reactants** | **Salt** |
|---|---|---|
| **A.** | iron + hydrochloric acid | iron(II) chloride |
| **B.** | copper(II) oxide + nitric acid | copper(II) nitrate |
| **C.** | magnesium chloride + sulfuric acid | magnesium sulfate |
| **D.** | lead(II) carbonate + nitric acid | lead(II) nitrate |

# Acids, Bases and Salts

**MCQ Question 10.**

Which one of the following reactions is *least* suitable for preparing the given salt?

| | Reactants | Salt | |
|---|---|---|---|
| **A.** | iron + hydrochloric acid | iron(II) chloride | |
| **B.** | copper(II) oxide + nitric acid | copper(II) nitrate | |
| **C.** | magnesium chloride + sulfuric acid | magnesium sulfate | ✓ |
| **D.** | lead(II) carbonate + nitric acid | lead(II) nitrate | |

**A.** $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

**B.** $CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$

**C.** $MgCl_2(aq) + H_2SO_4(aq) \rightarrow$ no observed reaction

$\cancel{Mg}^{2+}(aq) + \cancel{2Cl}^{-}(aq) + \cancel{2H}^{+}(aq) + \cancel{SO_4}^{2-}(aq) \rightarrow \cancel{Mg}^{2+}(aq) + \cancel{SO_4}^{2-}(aq) + \cancel{2H}^{+}(aq) + \cancel{2Cl}^{-}(aq)$

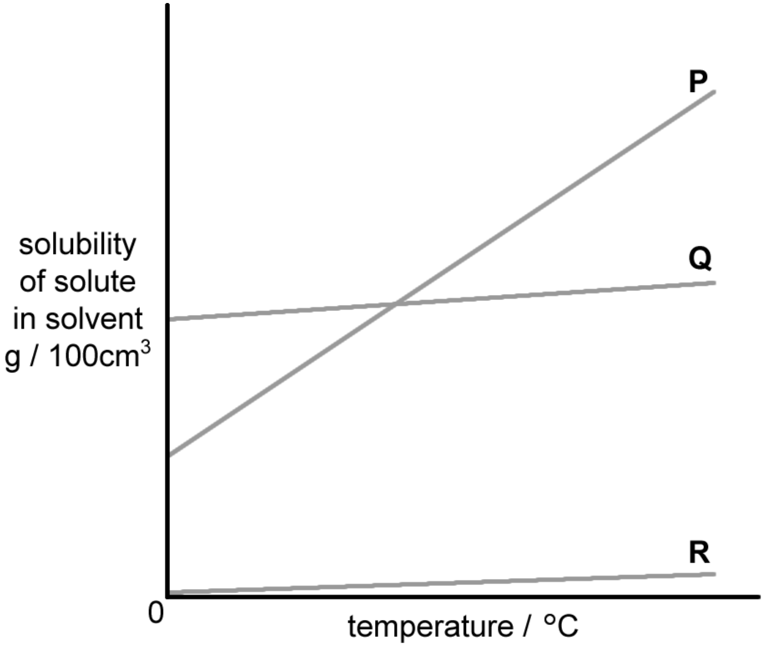
Attempting to write an ionic equation for **C** – *everything cancels* – there is no reaction.

**D.** $PbCO_3(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

# Acids, Bases and Salts

**MCQ Question 11.**

The graph on the right shows how the solubilities of three salts, **P**, **Q** and **R**, are affected by temperature. Which is the best method to recover each salt?



| | **P** | **Q** | **R** |
|---|---|---|---|
| **A.** | crystallisation | filtration | heat to dryness |
| **B.** | crystallisation | heat to dryness | filtration |
| **C.** | filtration | crystallisation | heat to dryness |
| **D.** | heat to dryness | crystallisation | filtration |

# Acids, Bases and Salts

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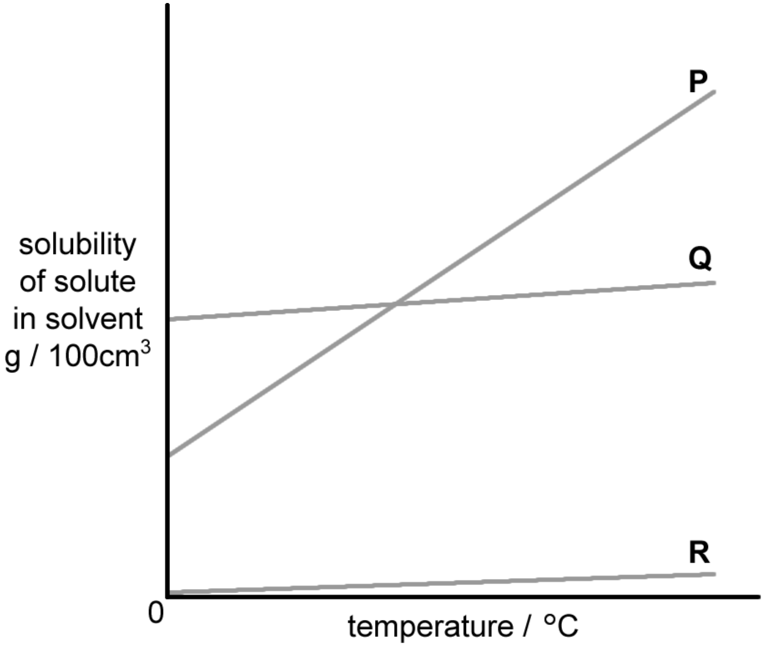
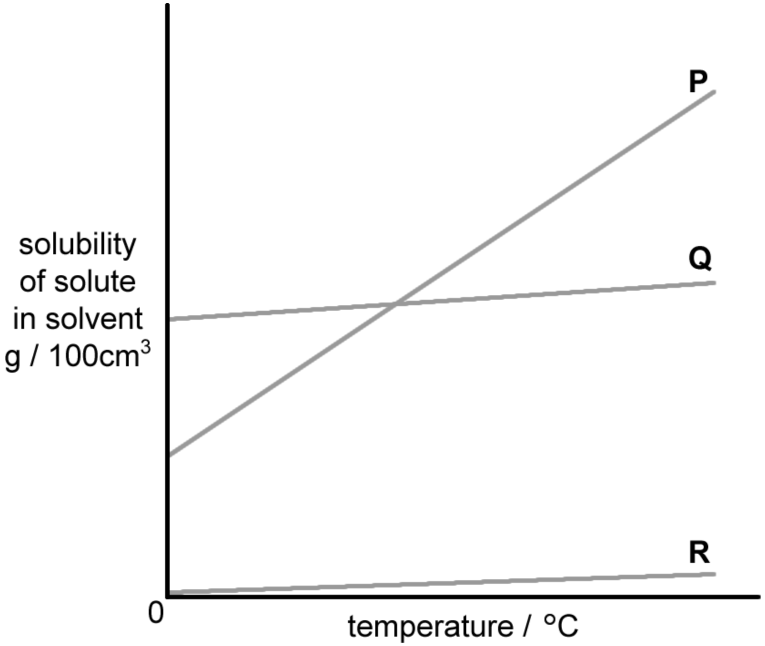


| | P | Q | R | |
|---|---|---|---|---|
| **A.** | crystallisation | filtration | heat to dryness | |
| **B.** | crystallisation | heat to dryness | filtration | ✓ |
| **C.** | filtration | crystallisation | heat to dryness | |
| **D.** | heat to dryness | crystallisation | filtration | |

# Acids, Bases and Salts

## MCQ Question 11.

The graph on the right shows how the solubilities of three salts, **P**, **Q** and **R**, are affected by temperature. Which is the best method to recover each salt?



- A significant mass of salt **P** will crystallise from a hot saturated solution of the salt as it is cooled to room temperature. Salt **P** should be recovered by *crystallisation*.
- Salt **Q** is quite soluble in water, but only a very small mass will crystallise from a hot saturated solution as it is cooled to room temperature. Salt **Q** should be recovered by *heating to dryness*, *i.e.* boiling away all of the water.
- Salt **R** is almost completely insoluble in water, and can be simply recovered by *filtration*.

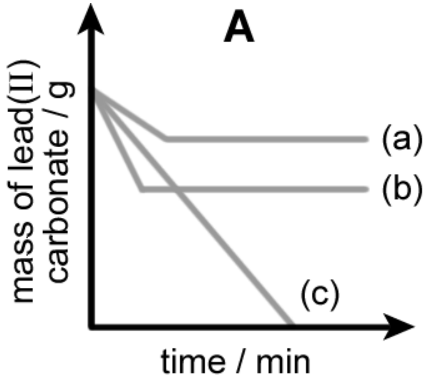
# Acids, Bases and Salts

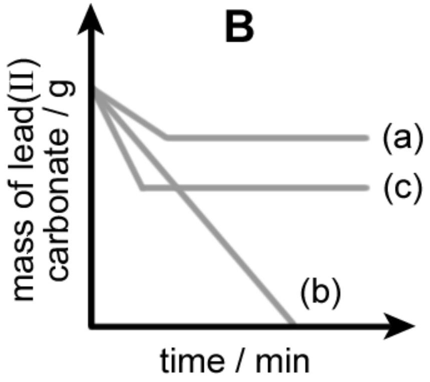
## MCQ Question 12.

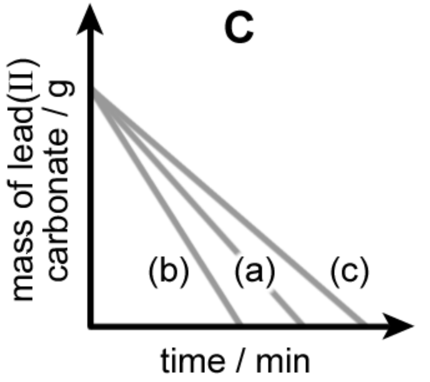
Equal masses of lead(II) carbonate were reacted with three different acids of the same concentration, all other conditions being kept constant. The acids were added in excess. The mass of lead(II) carbonate was measured at regular time intervals, and results for each experiment plotted.

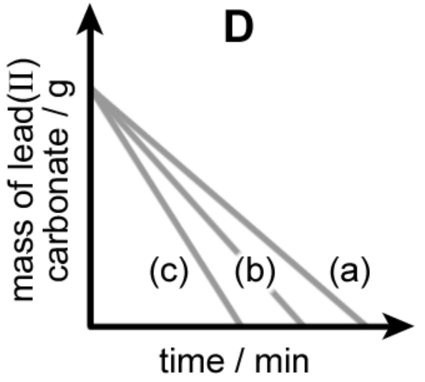
(a) = $HCl(aq)$ (b) = $H_2SO_4(aq)$ (c) = $HNO_3(aq)$

Which set of graphs represent the results of the experiments?









# Acids, Bases and Salts

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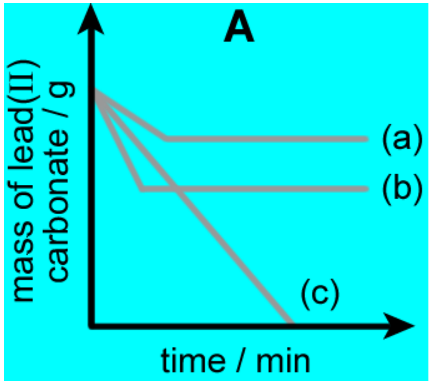

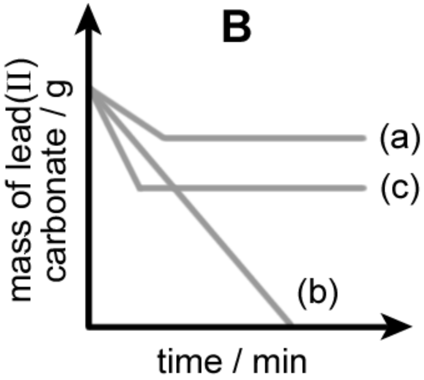

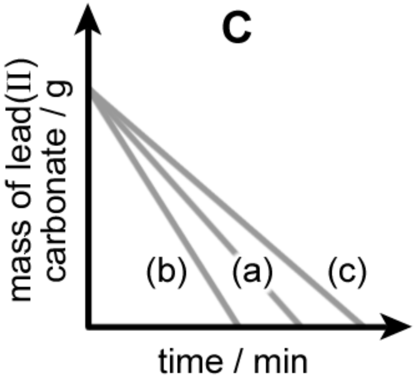

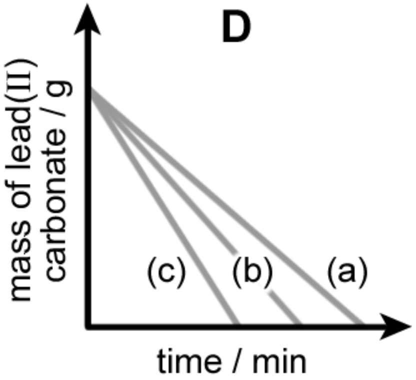

- $PbCO_3(s) + 2HC\mathit{l}(aq) \rightarrow PbC\mathit{l}_2(s) + H_2O(\mathit{l}) + CO_2(g)$
- $PbCO_3(s) + H_2SO_4(aq) \rightarrow PbSO_4(s) + H_2O(\mathit{l}) + CO_2(g)$
- $PbCO_3(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(\mathit{l}) + CO_2(g)$

# Acids, Bases and Salts

## MCQ Question 12.

Equal masses of lead(II) carbonate were reacted with three different acids of the same concentration, all other conditions being kept constant. The acids were added in excess. The mass of lead(II) carbonate was measured at regular time intervals, and results for each experiment plotted.

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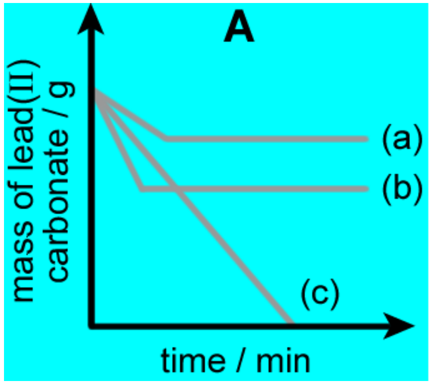
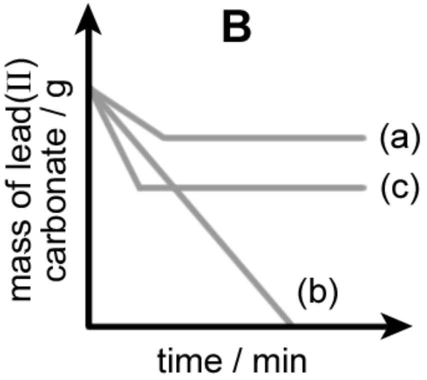
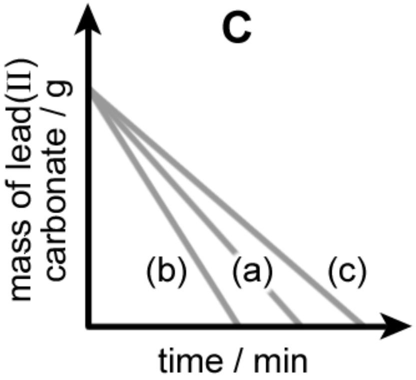
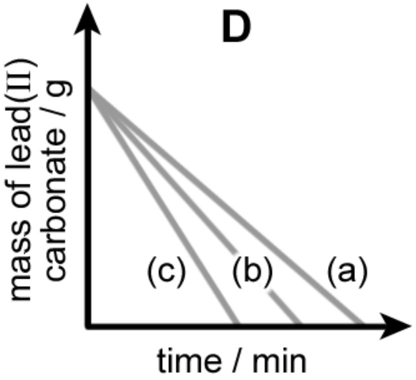








- $PbCl_2(s)$ will *precipitate* over the $PbCO_3(s)$ stopping the reaction.
- $PbSO_4(s)$ will *precipitate* over the $PbCO_3(s)$ stopping the reaction.
- $Pb(NO_3)_2(aq)$ is *soluble* in water and will *not precipitate* over the $PbCO_3(s)$, allowing the reaction to go to completion (*slides 66-72*).

# Acids, Bases and Salts

## MCQ Question 13.

Which one of the following statements about the preparation of hydrated copper(II) chloride from copper(II) hydroxide and dilute hydrochloric acid is correct?

**A.** The hydrated copper(II) chloride should be prepared by titration.

**B.** Copper(II) hydroxide should be added in excess.

**C.** The hydrated copper(II) chloride should be heated to dryness.

**D.** Either the copper(II) or hydrochloric acid can be added in excess.

# Acids, Bases and Salts

**MCQ Question 13.**

Which one of the following statements about the preparation of hydrated copper(II) chloride from copper(II) hydroxide and dilute hydrochloric acid is correct?

**A.** The hydrated copper(II) chloride should be prepared by titration.

**B.** Copper(II) hydroxide should be added in excess. ✓

**C.** The hydrated copper(II) chloride should be heated to dryness.

**D.** Either the copper(II) or hydrochloric acid can be added in excess.

- Copper(II) chloride is soluble in water and should be prepared by the excess insoluble base method. Excess copper(II) hydroxide should be added to ensure that all of the hydrochloric acid reacts.

$Cu(OH)_2(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + 2H_2O(l)$

# Acids, Bases and Salts

**MCQ Question 14.**

What is the most appropriate way to prepare magnesium carbonate in the laboratory?

**A.** Mix magnesium hydroxide with aqueous sodium hydroxide and then bubble carbon dioxide gas through the reaction mixture.

**B.** Mix magnesium sulfate with aqueous sodium hydroxide and then bubble carbon dioxide gas through the reaction mixture.

**C.** Mix together solid magnesium, calcium carbonate and water.

**D.** Dissolve solid magnesium sulfate in water and mix with aqueous sodium carbonate.

# Acids, Bases and Salts

## MCQ Question 14.

What is the most appropriate way to prepare magnesium carbonate in the laboratory?

**A.** Mix magnesium hydroxide with aqueous sodium hydroxide and then bubble carbon dioxide gas through the reaction mixture.

**B.** Mix magnesium sulfate with aqueous sodium hydroxide and then bubble carbon dioxide gas through the reaction mixture.

**C.** Mix together solid magnesium, calcium carbonate and water.

**D.** Dissolve solid magnesium sulfate in water and mix with aqueous sodium carbonate. ✓

- Magnesium carbonate is insoluble in water and should be prepared by ionic precipitation.

$$MgSO_4(aq) + Na_2CO_3(aq) \rightarrow MgCO_3(s) + Na_2SO_4(aq)$$

# Acids, Bases and Salts

## MCQ Question 15.

Which one of the following pairs of reactants can be used to prepare a pure and dry sample of silver nitrate?

**A.** $\mathrm{Ag}$ and $\mathrm{HNO_3}$

**B.** $\mathrm{AgC}l$ and $\mathrm{HNO_3}$

**C.** $\mathrm{AgOH}$ and $\mathrm{HNO_3}$

**D.** $\mathrm{Ag_2SO_4}$ and $\mathrm{HNO_3}$

# Acids, Bases and Salts

**MCQ Question 15.**

Which one of the following pairs of reactants can be used to prepare a pure and dry sample of silver nitrate?

**A.** Ag and $HNO_3$

**B.** $\mathrm{AgC}l$ and $HNO_3$

**C.** AgOH and $HNO_3$ ✓

**D.** $Ag_2SO_4$ and $HNO_3$

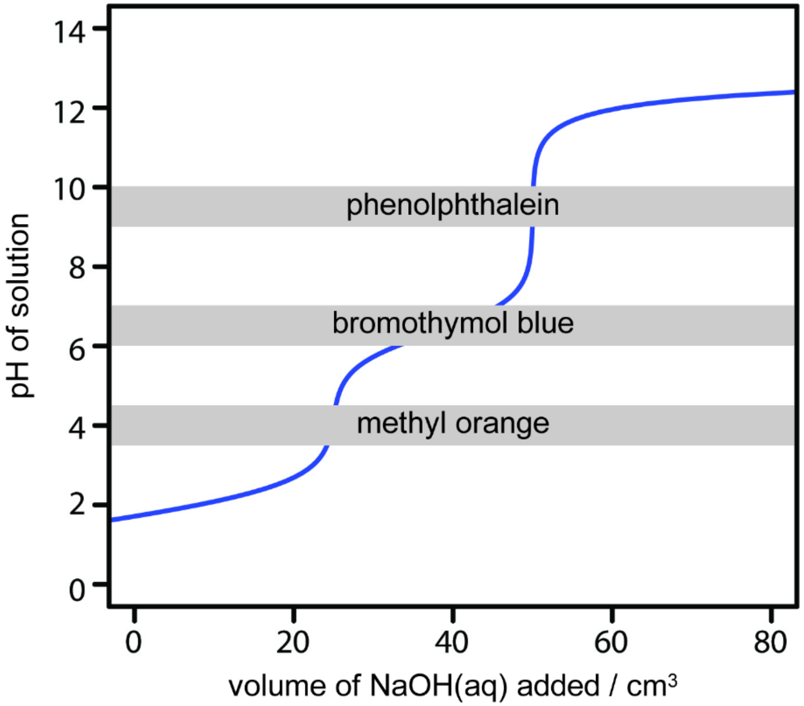
- Silver nitrate is soluble in water and should be prepared by the excess insoluble base method. From the options available, only silver hydroxide (an insoluble base) will react with nitric acid to produce silver nitrate.

$$AgOH(s) + HNO_3(aq) \rightarrow AgNO_3(aq) + H_2O(l)$$

# Acids, Bases and Salts

## MCQ Question 16.

A student wants to prepare a pure and dry sample of hydrated sodium hydrogen sulfate by titration. A graph showing how the pH of the solution changes when aqueous sodium hydroxide is added to dilute sulfuric acid is given on the right. How should the student prepare the salt?



**A.** Titrate until methyl orange changes colour, then heat to dryness.
**B.** Titrate until methyl orange changes colour, then crystallise.
**C.** Titrate until bromothymol blue changes colour, then heat to dryness.
**D.** Titrate until phenolphthalein changes colour, then crystallise.

# Acids, Bases and Salts

## MCQ Question 16.

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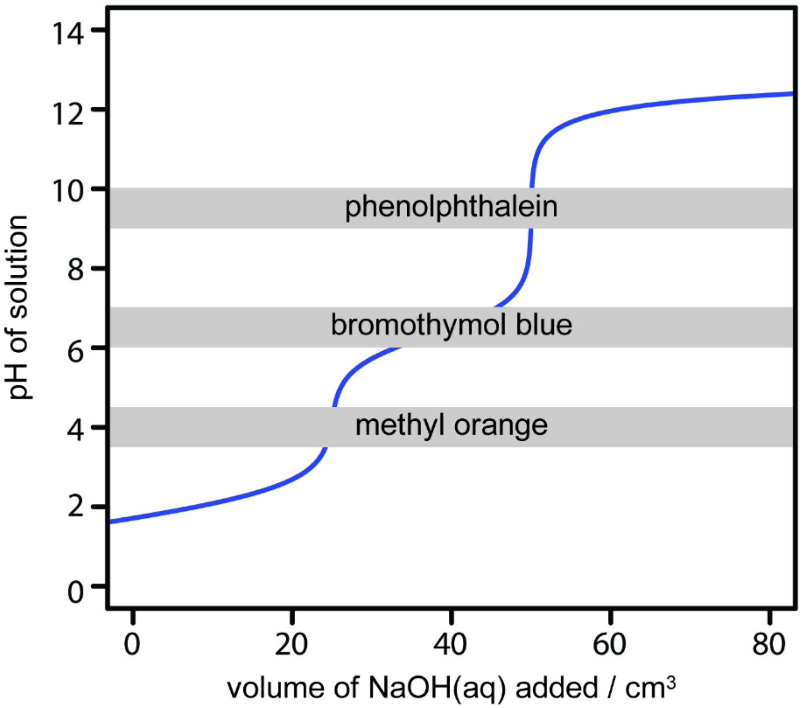

**A.** Titrate until methyl orange changes colour, then heat to dryness.

**B.** Titrate until methyl orange changes colour, then crystallise. ✓

**C.** Titrate until bromothymol blue changes colour, then heat to dryness.

**D.** Titrate until phenolphthalein changes colour, then crystallise.

# Acids, Bases and Salts

## MCQ Question 16.

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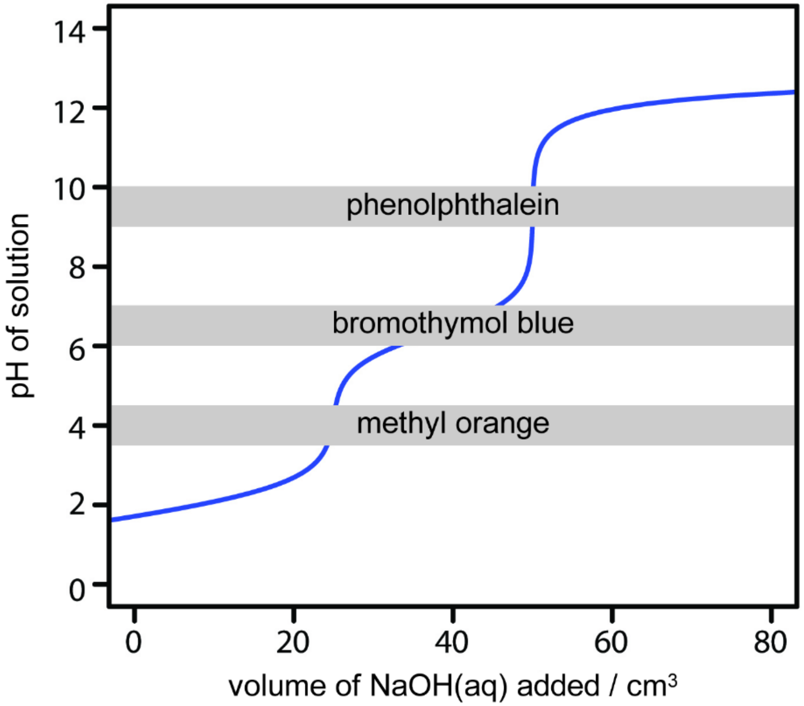

- Methyl orange will change colour to indicate the end-point for:

$NaOH(aq) + H_2SO_4(aq) \rightarrow NaHSO_4(aq) + H_2O(l)$

- Phenolphthalein will change colour to indicate the end-point for:

$NaOH(aq) + NaHSO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$

- Bromothymol blue does not indicate the end-point of any stage of the reaction.
- *Methyl orange* indicates the end-point for the formation of sodium hydrogen sulfate. It should be *crystallised* because it must be *hydrated*.

# Acids, Bases and Salts

**MCQ Question 17.**

Which one of the following is the **best** method for preparing calcium sulfate?

**A.** Add calcium carbonate to dilute nitric acid, then add the resulting mixture to aqueous sodium sulfate.

**B.** Add solid calcium nitrate to solid potassium sulfate.

**C.** Add calcium carbonate to dilute sulfuric acid.

**D.** Add aqueous calcium hydroxide to dilute sulfuric acid.

# Acids, Bases and Salts

## MCQ Question 17.

Which one of the following is the **best** method for preparing calcium sulfate?

**A.** Add calcium carbonate to dilute nitric acid, then add the resulting mixture to aqueous sodium sulfate. ✓

**B.** Add solid calcium nitrate to solid potassium sulfate.

**C.** Add calcium carbonate to dilute sulfuric acid.

**D.** Add aqueous calcium hydroxide to dilute sulfuric acid.

- Calcium sulfate is an insoluble salt, prepared by ionic precipitation.

**A.** This is the *best* method available. Calcium carbonate will react with nitric acid to form an aqueous solution of calcium nitrate.

$$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

When the solution of calcium nitrate is added to aqueous sodium sulfate, a precipitate of calcium sulfate will be formed.

$$Ca(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaNO_3(aq)$$

# Acids, Bases and Salts

## MCQ Question 17.

Which one of the following is the **best** method for preparing calcium sulfate?

**A.** Add calcium carbonate to dilute nitric acid, then add the resulting mixture to aqueous sodium sulfate. ✓

**B.** Add solid calcium nitrate to solid potassium sulfate.

**C.** Add calcium carbonate to dilute sulfuric acid.

**D.** Add aqueous calcium hydroxide to dilute sulfuric acid.

**B.** There will be no observed reaction when *solid* calcium nitrate is added to *solid* potassium sulfate – the salts *should be aqueous*.

**C.** Calcium carbonate will react with sulfuric acid to form a *small amount* of calcium sulfate, but the reaction will soon *stop* once a layer of calcium sulfate precipitates over the surface of the calcium carbonate, preventing the reactants from coming into contact.

$$CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_2O(\mathit{l}) + CO_2(g)$$

# Acids, Bases and Salts

## MCQ Question 17.

Which one of the following is the **best** method for preparing calcium sulfate?

**A.** Add calcium carbonate to dilute nitric acid, then add the resulting mixture to aqueous sodium sulfate. ✓

**B.** Add solid calcium nitrate to solid potassium sulfate.

**C.** Add calcium carbonate to dilute sulfuric acid.

**D.** Add aqueous calcium hydroxide to dilute sulfuric acid.

**D.** Aqueous calcium hydroxide will react with dilute sulfuric acid to form a *small* amount of calcium sulfate.

$$Ca(OH)_2(aq) + H_2SO_4(aq) \rightarrow CaSO_4(s) + 2H_2O(l)$$

Calcium hydroxide is only *slightly soluble* in water (the solution is known as limewater). Because the concentration of calcium hydroxide is *low*, the amount of calcium sulfate produced will also be *low*.

# Acids, Bases and Salts

**MCQ Question 18.**

Which salt could be obtained as the insoluble product of a reaction between a dilute acid and an aqueous salt?

**A.** Barium sulfate

**B.** Copper(II) sulfate

**C.** Magnesium sulfate

**D.** Silver nitrate

# Acids, Bases and Salts

**MCQ Question 18.**

Which salt could be obtained as the insoluble product of a reaction between a dilute acid and an aqueous salt?

**A.** Barium sulfate ✓

**B.** Copper(II) sulfate

**C.** Magnesium sulfate

**D.** Silver nitrate

- Only option **A**, barium sulfate, is *insoluble* in water. Copper(II) sulfate, magnesium sulfate and silver nitrate are all *soluble* in water.

$$Ba(NO_3)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2HNO_3(aq)$$

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

# Acids, Bases and Salts

**MCQ Question 19.**

Sodium nitrate can be prepared by reacting aqueous sodium hydroxide with dilute nitric acid. What is the ionic equation for this reaction?

**A.** $H^+ + OH^- \rightarrow H_2O$

**B.** $Na^+ + NO_3^- \rightarrow NaNO_3$

**C.** $Na^+ + HNO_3 \rightarrow NaNO_3 + H^+$

**D.** $NaOH + H^+ \rightarrow Na^+ + H_2O$

# Acids, Bases and Salts

**MCQ Question 19.**
Sodium nitrate can be prepared by reacting aqueous sodium hydroxide with dilute nitric acid. What is the ionic equation for this reaction?

**A.** $H^+ + OH^- \rightarrow H_2O$ ✓

**B.** $Na^+ + NO_3^- \rightarrow NaNO_3$

**C.** $Na^+ + HNO_3 \rightarrow NaNO_3 + H^+$

**D.** $NaOH + H^+ \rightarrow Na^+ + H_2O$

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

$$H^+(aq) + \cancel{NO_3}^-(aq) + \cancel{Na}^+(aq) + OH^-(aq) \rightarrow \cancel{Na}^+(aq) + \cancel{NO_3}^-(aq) + H_2O(l)$$

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

# Acids, Bases and Salts

## MCQ Question 20.

An aqueous solution of a sulfate is made from a solid hydroxide of a metal **M** by the reaction:

$$\mathbf{M}(OH)_2(s) + H_2SO_4(aq) \rightarrow \mathbf{M}SO_4(aq) + 2H_2O(l)$$

For which hydroxide would the method **not** work?

**A.** Barium hydroxide

**B.** Copper(II) hydroxide

**C.** Iron(II) hydroxide

**D.** Magnesium hydroxide

# Acids, Bases and Salts

**MCQ Question 20.**

An aqueous solution of a sulfate is made from a solid hydroxide of a metal **M** by the reaction:

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For which hydroxide would the method **not** work?

**A.** Barium hydroxide ✓

**B.** Copper(II) hydroxide

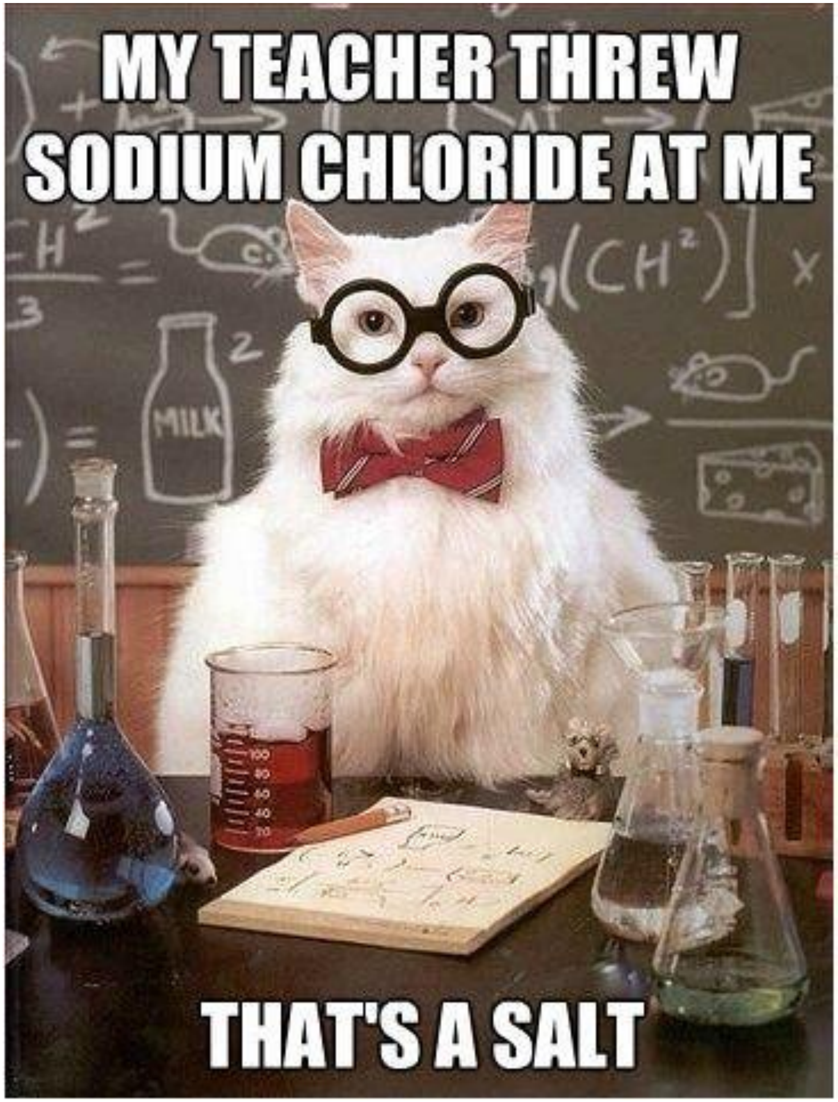
**C.** Iron(II) hydroxide

**D.** Magnesium hydroxide

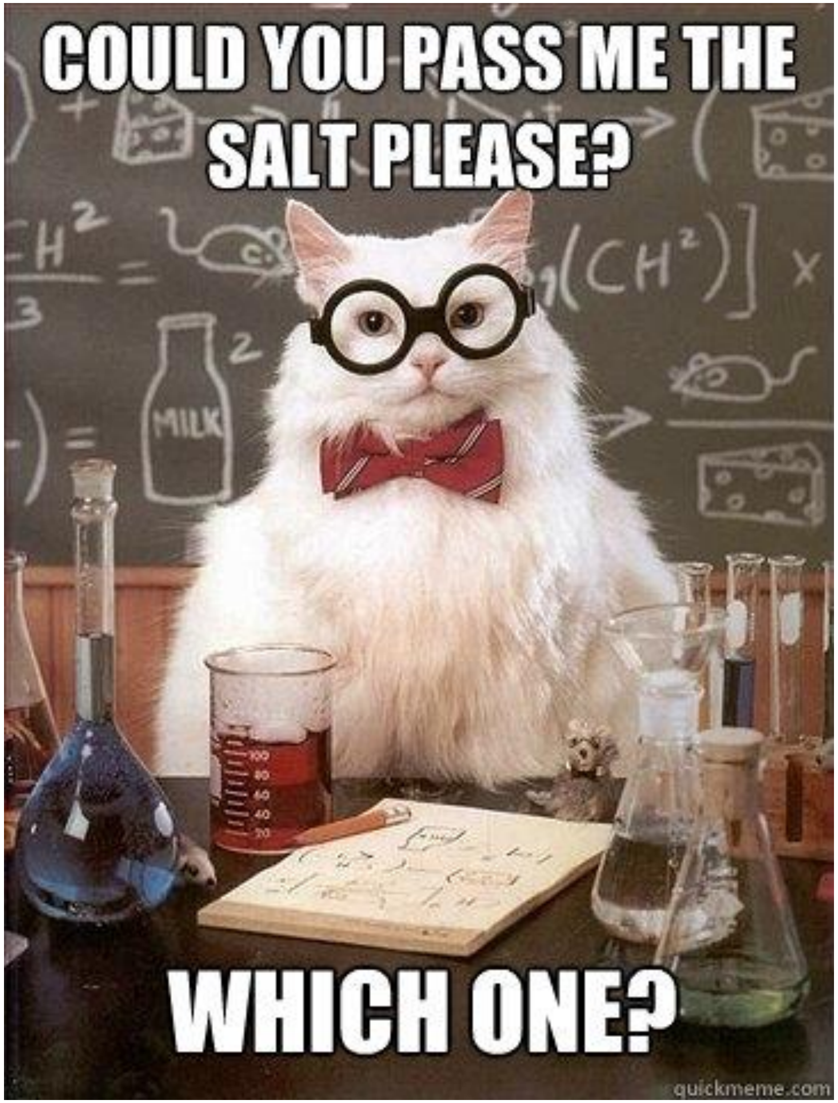
- Option **A** will *not* work. $Ba(OH)_2$ is *soluble* in water (46.8 g/dm$^3$ or 0.273 mol/dm$^3$ at 25 °C) and $BaSO_4$ is *insoluble* in water. The hydroxides of the other metals are all *insoluble* in water, and their sulfates are all *soluble* in water.

$$Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$$

# Acids, Bases and Salts



# Acids, Bases and Salts



# Acids, Bases and Salts

Presentation on
Salt Preparation
by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

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