

Precipitation reactions

- A precipitate is an insoluble solid that forms when solutions of soluble ionic compounds are mixed.

- The precipitate is an ionic compound that has a low solubility in the solvent.

A knowledge of the solubilities of ionic compounds in water allows chemists to predict the solutions that will form precipitates on mixing. Many sulfide compounds are insoluble in water. There are many ores in nature that contain insoluble sulfide minerals.



Worked example. The reaction of copper chloride solution with sodium sulfide solution

Observation: Copper chloride solution (CuCl_2) is clear green. Sodium sulfide (Na_2S) solution is colourless. When the solutions are mixed, a black solid forms and falls as a sediment to the bottom of the container.



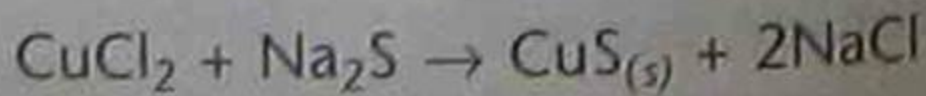
Explanation: The copper chloride solution contains copper ions (Cu^{2+}) and chloride ions (Cl^-). The sodium sulfide solution contains sodium ions (Na^+) and sulfide ions (S^{2-}). On mixing, the copper ions and the sulfide ions attract each other so strongly that they form an insoluble, black ionic solid called copper sulfide. The remaining ions do not precipitate because sodium chloride is very soluble in water.



Word equation

copper chloride + sodium sulfide \rightarrow
copper sulfide + sodium chloride

Balanced symbolic equation



Note that the subscript (s) is used to denote the solid precipitate that forms.

Figure 2.14 shows a particle diagram of the precipitation reaction.

Acids on metals and carbonates

There are a number of common laboratory acids that you should be familiar with. Their names and chemical formulae are listed in



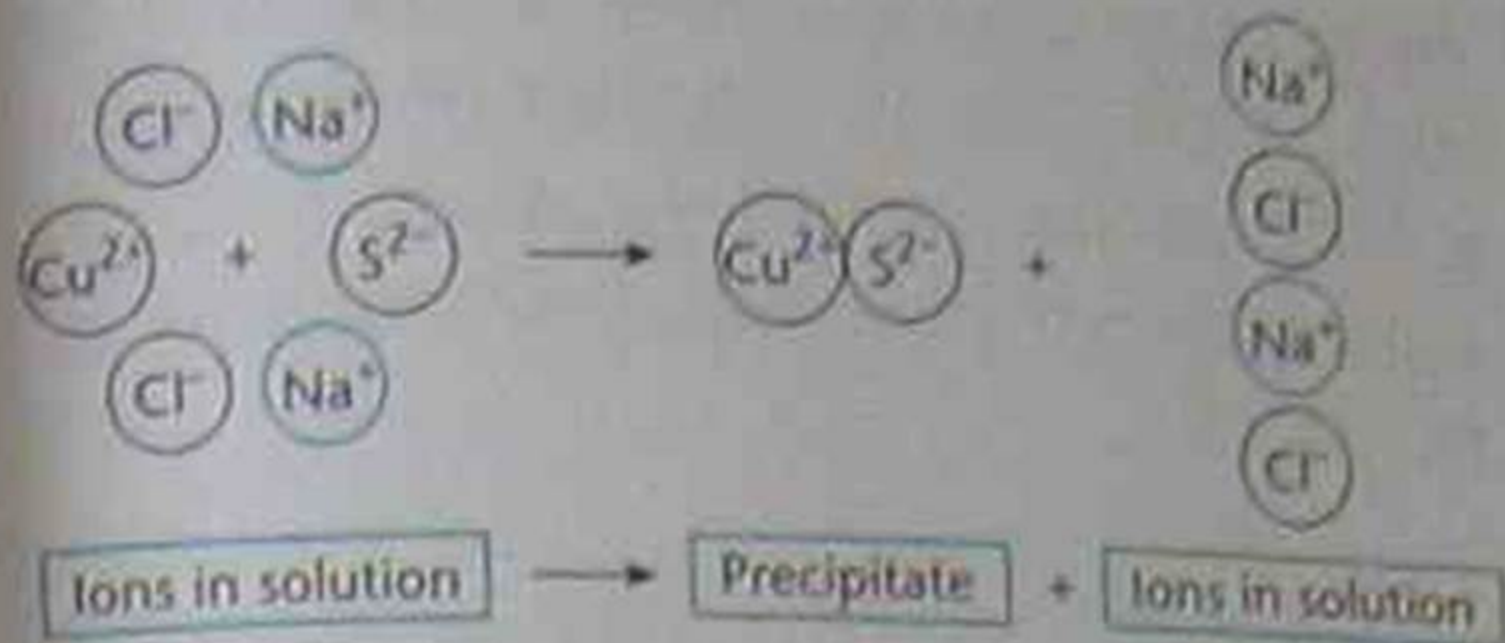


Figure 2.14 Particle diagram—precipitation

Table 2.9. They are normally used as dilute solutions for safety reasons.



Table 2.9 Common strong laboratory acids

Acid	Formula	Ions present
Hydrochloric acid	HCl	H^+ , Cl^-
Sulfuric acid	H_2SO_4	H^+ , SO_4^{2-}
Nitric acid	HNO_3	H^+ , NO_3^-

- These solutions are acidic due to the presence of **hydrogen ions (H^+)**.
- Sulfuric acid contains the sulfate anion (SO_4^{2-}). This is a polyatomic ion with a 2⁻ charge.



- Nitric acid contains the nitrate anion (NO_3^-). This is a polyatomic ion with a 1^- charge.
- There are many other acids in nature. Vinegar contains acetic acid. Citrus fruits contain citric acid. Milk contains lactic acid. All these acids are much weaker than the laboratory acids.



Acids reacting with metals

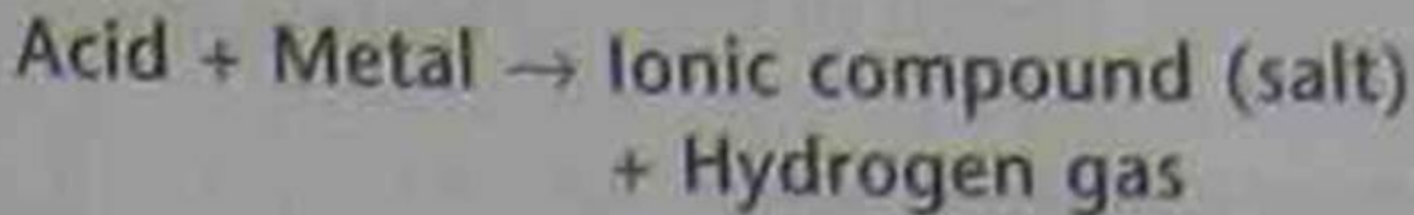
The reactions of dilute acids with a variety of different metals can be investigated in the school laboratory. Small, fresh samples of metals are placed in 2 mL samples of dilute hydrochloric or sulfuric acid. The rate of reaction depends on the:

- concentration of the acid—if the acid is too dilute the reaction is very slow;
- type of metal—some metals (eg. magnesium) react faster than other metals (eg. tin);



- surface area of the metal—powdered metals react faster than large lumps;
- temperature—warm acid solutions attack metals faster than cold solutions.

For acids such as dilute hydrochloric acid and dilute sulfuric acid the general equation for their reaction with reactive metals is:



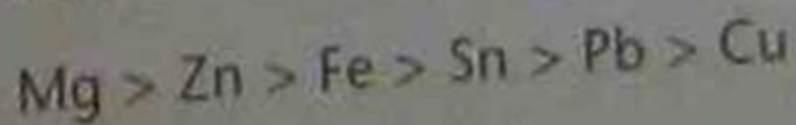
- The ionic compound formed is usually called a salt. The word 'salt' refers to any ionic compound produced by the reaction of an acid (and not just cooking salt or table salt).
- Nitric acid behaves differently to the other acids. Its reactions do not produce hydrogen gas. Nitrogen monoxide or nitrogen dioxide is produced instead.
- The hydrogen gas can be collected and identified using the 'pop' test. (A small sample of hydrogen in the presence of air and a spark/flame will explode.)



Investigating metal reactivity with acids

The reactivity of small samples of different metals with dilute sulfuric acid can be easily investigated in the school laboratory. Tubes containing about 2 mL of the acid are used. Clean samples of each metal (eg. magnesium, zinc, iron, tin, lead, copper) can be tested. The more reactive the metal, the more rapidly hydrogen gas is evolved.

These tests should show that the order of decreasing reactivity of the metals in the acid is:



Lead and copper are fairly unreactive metals and little or no reaction should be observed.



Worked example

Q When zinc reacts with dilute sulfuric acid, hydrogen gas is released and the

zinc dissolves to form a solution of zinc sulfate. Write a word equation and a balanced symbolic equation for this reaction.

A Refer to the general equation to complete the word equation.

Word equation

zinc + sulfuric acid \rightarrow zinc sulfate
+ hydrogen gas



Balanced symbolic equation

Step 1. Write the correct formula for each reactant and product. (Note that the correct formula of zinc sulfate is ZnSO_4 as the zinc ion has a 2^+ charge and the sulfate ion has a 2^- charge.)

Step 2. Check whether the equation is balanced; if not, insert integers in front of the formulae to balance the equation.



Acids reacting with carbonates

Carbonates are ionic compounds containing the carbonate anion (CO_3^{2-}).

Examples

- Zinc carbonate ZnCO_3
- Sodium carbonate Na_2CO_3
- Magnesium carbonate MgCO_3
- Calcium carbonate CaCO_3

Acids readily attack carbonates and dissolve them. Carbon dioxide, water and a 'salt' are formed.



Acid + Carbonate \rightarrow Salt + Water
+ Carbon dioxide

The reaction of an acid and a carbonate is a special example of a neutralisation reaction,

Worked example

Q When sulfuric acid is added to a sample of green copper carbonate, the solid



effervesces and dissolves in the acid to form a clear, blue solution of copper sulfate. Write a word equation and a balanced symbolic equation for this reaction.

A

Word equation

copper carbonate + sulfuric acid → copper sulfate + water + carbon dioxide



Balanced symbolic equation

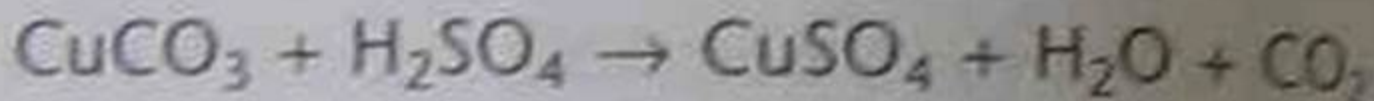
Balanced symbolic equation

Using the valency rules, the formulae for the two copper compounds can be determined.

Copper carbonate: CuCO_3 (as copper ions have a 2^+ charge and carbonate ions have a 2^- charge)

Copper sulfate: CuSO_4 (as copper ions have a 2^+ charge and sulfate ions have a 2^- charge)

Now write the equation and check that the atoms balance.



Neutralisation reactions

Neutralisation reactions involve acids and bases.

- Acids are substances that release hydrogen ions when they dissolve in water.
- Bases are substances that neutralise acids. Some common bases are compounds that contain oxide (O^{2-}), hydroxide (OH^-) or carbonate (CO_3^{2-}) ions.



- Acids also neutralise bases.
- When a base neutralises an acid, a solution of a salt is formed.
- The salt can be recovered from the solution by evaporating the water.
- Neutralisation reactions can be used to relieve indigestion. Weak bases such as sodium hydrogen carbonate or magnesium hydroxide in antacid tablets neutralise excess stomach acid.



Table 2.10 lists some common bases and their chemical formulae.

Table 2.10 Some common bases

Base	Formula
Sodium hydroxide	NaOH
Ammonium hydroxide	NH_4OH
Calcium oxide	CaO
Sodium carbonate	Na_2CO_3
Calcium carbonate	CaCO_3

The general reaction for neutralisation reactions involving oxides and hydroxide is:



Worked example

Q A student added hydrochloric acid to solid calcium oxide in a beaker. The calcium oxide dissolved to form a solution of calcium chloride. Write a word equation and a balanced symbolic equation.

A

Word equation

calcium oxide + hydrochloric acid →
calcium chloride + water



Balanced symbolic equation

Balanced symbolic equation

Calcium ions have a charge of 2^{+} .

Oxide ions have a charge of 2^{-} .

Chloride ions have a charge of 1^{-} .

Thus the formula of calcium oxide = CaO .

Calcium chloride = CaCl_2



Note: To balance this equation the number 2 has been inserted in front of the HCl .

Figure 2.15 shows a particle diagram of the neutralisation reaction.

The role of indicators

- Indicators are substances that change colour in the presence of an acid or base.

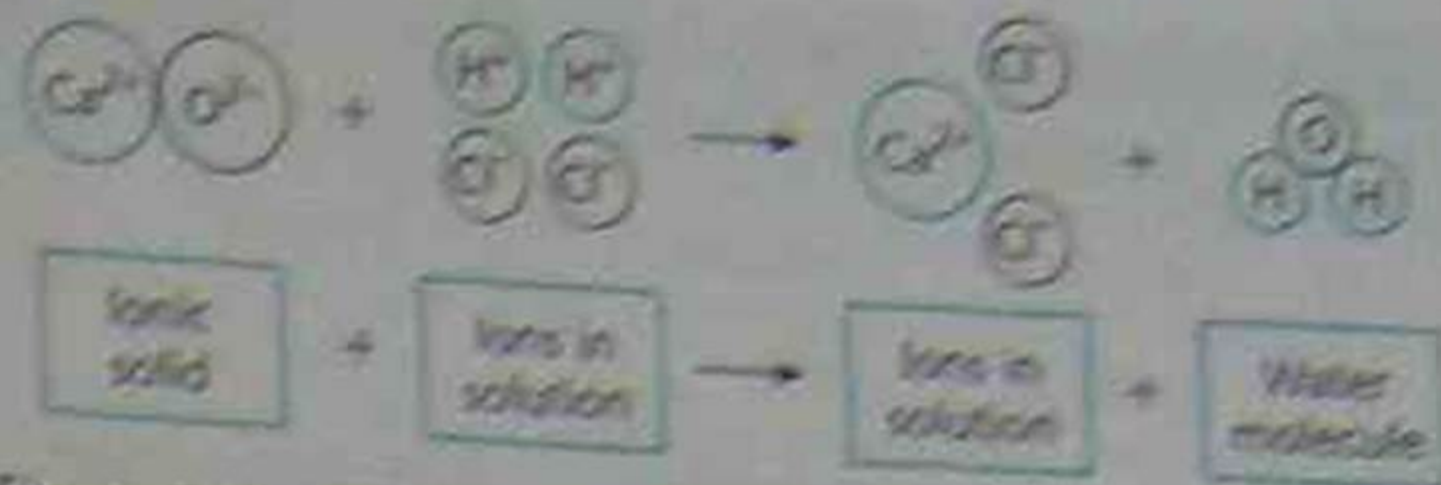


Figure 2.15 Particle model of the neutralization reaction

- Indicators can be easily prepared from plant material such as flower petals. The petals can be soaked in water to dissolve the dye. The dye extract changes colour if acids or bases are added. These types of indicators are not stable for long-term use.

use.

- Indicators can be used to determine whether a solution is acidic, neutral or basic. This is useful in the laboratory as well as domestically. Indicators are used to detect whether the water in a swimming pool is too acidic or basic.
- Indicators can be used in neutralisation reactions to determine the point where exact neutralisation occurs. This is important, especially when the reacting solutions are colourless.

Table 2.11 shows examples of some common indicators used in the school laboratory.



Table 2.11 Common indicators

Indicator	Colour in acidic solution	Colour in water (neutral)	Colour in basic solution
Litmus	red	purple	blue
Methyl orange	red	orange	yellow
Bromothymol blue	yellow	green	blue
Phenolphthalein	colourless	colourless	crimson

Worked example

Q Use the results of the following indicator experiments to classify the following solutions as acidic, basic or neutral.



Solution	Methyl orange	Phenolphthalein	Bromothymol blue
X	orange	colourless	green
Y	yellow	pink	blue
Z	orange-red	colourless	yellow-green

A Match the colours to the table of indicator colours.

- X is a neutral solution.
- Y is a slightly basic solution (the phenolphthalein is pink rather than crimson).
- Z is a slightly acidic solution (the bromothymol blue is yellow-green rather than yellow; the methyl orange is orange-red rather than red).



Universal indicator and pH

The acidity or basicity of a solution can be conveniently represented by the **pH scale**.

- pH is a measure of the acidity or basicity of a solution.
- Neutral solutions have a pH of 7.
- Acidic solutions have a pH less than 7. The lower the pH the more acidic is the solution.
- Strongly acidic solutions have pH around 0 to 2.
- Basic solutions have a pH greater than 7. The higher the pH the more basic is the solution.
- Strongly basic solutions have pH around 12–14.



The pH of a solution can also be correlated with the colour of indicators.

Universal indicator is a useful mixed indicator that shows a large range of colours over the pH scale.

Table 2.12 shows the correlation of the colour of Universal indicator and the pH scale.



Table 2.12 pH and the colour of Universal indicator*

pH range	0-4	4-5	5-6	7-8	8-9	9-10	10-14
Universal indicator colour	red	orange	yellow	green	blue-green	blue-violet	violet

*Note: The exact colours and ranges may vary in some different brands of Universal indicator. Always use the supplied colour card.

Worked example

Q A student dissolved some baking soda (sodium hydrogen carbonate) in water and tested the solution with Universal indicator and phenolphthalein. The Universal indicator turned green-blue and the phenolphthalein was very faintly pink.

- a Determine the pH of the baking soda solution.
- b State whether the solution is acidic, basic or neutral.
- c Predict the colour that bromothymol blue would turn in this solution.

- A**
- a the pH is between 8 and 9. This is consistent with the Universal indicator colour chart.
 - b The solution is slightly basic. This is consistent with the phenolphthalein being faintly pink.
 - c The bromothymol blue should also be green-blue.



Table 2.13 shows some common acidic and basic substances. Universal indicator or other indicators can be used to show that these substances are acidic or basic.

Table 2.13 Common household acidic and basic substances (in decreasing order of strength)

Common acidic substances	Common basic substances
Car battery acid	Caustic soda (drain cleaner)
Vinegar (acetic acid)	Ammonia solution (window cleaner)
Lemon juice	Laundry detergents
Soft drinks	Baking soda



Decomposition reactions

Decomposition reactions involve the **breakdown** of a compound into its elements or into simpler compounds.

Decomposition can be achieved in a number of ways. These include:

- **thermal decomposition**

Heating the substance with a Bunsen flame is a simple method used in a lab. Not all substances will decompose under these conditions.



these conditions.

- **electrical decomposition**

Electrolysis is the process of decomposing a substance in solution using an electrical current. Metallic electrodes connected to a DC voltage source is a common method used. Water can be decomposed into hydrogen gas and oxygen gas by this method.

water \rightarrow hydrogen gas + oxygen gas



- **photochemical decomposition**

Some substances are sensitive to decomposition by visible or ultraviolet light. For example, silver bromide in photographic film is decomposed into silver and bromine by light.

silver bromide \rightarrow silver + bromine

Thermal decomposition examples

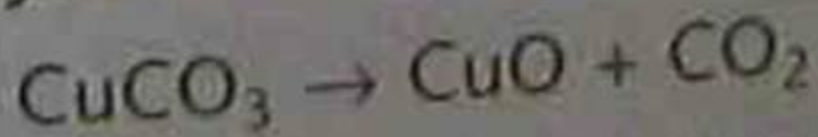
In the school laboratory the decomposition of some ionic carbonates by heat can be tested. Blue-green copper carbonate can be heated in a test tube. The solid turns black, and colourless carbon dioxide is evolved. The black solid is copper oxide.



Word equation

copper carbonate \rightarrow copper oxide + carbon dioxide

Balanced symbolic equation



Sodium carbonate and potassium carbonate are thermally stable. Carbonates of

unreactive metals decompose to produce the metal. Silver carbonate decomposes to form silver metal, oxygen and carbon dioxide.

