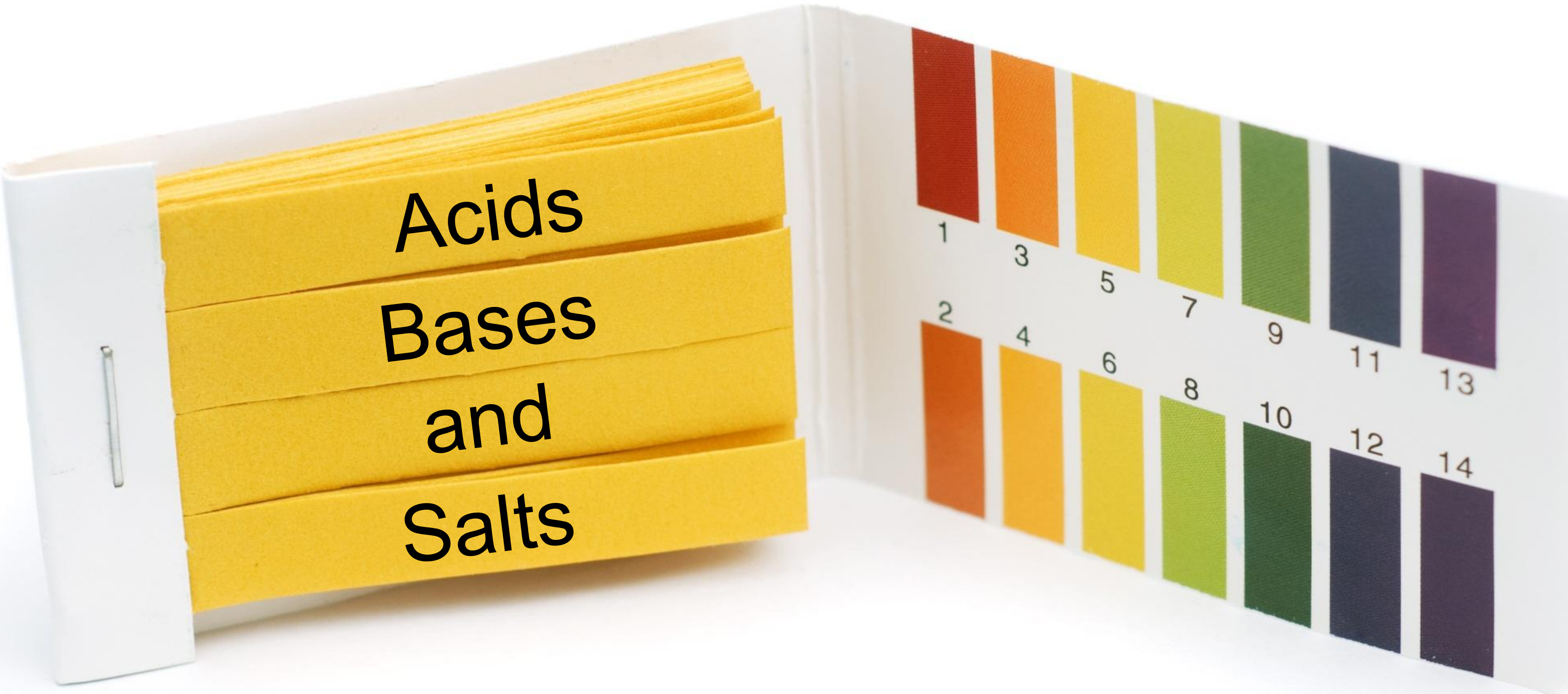
Acids, Bases and Salts



Acids, Bases and Salts

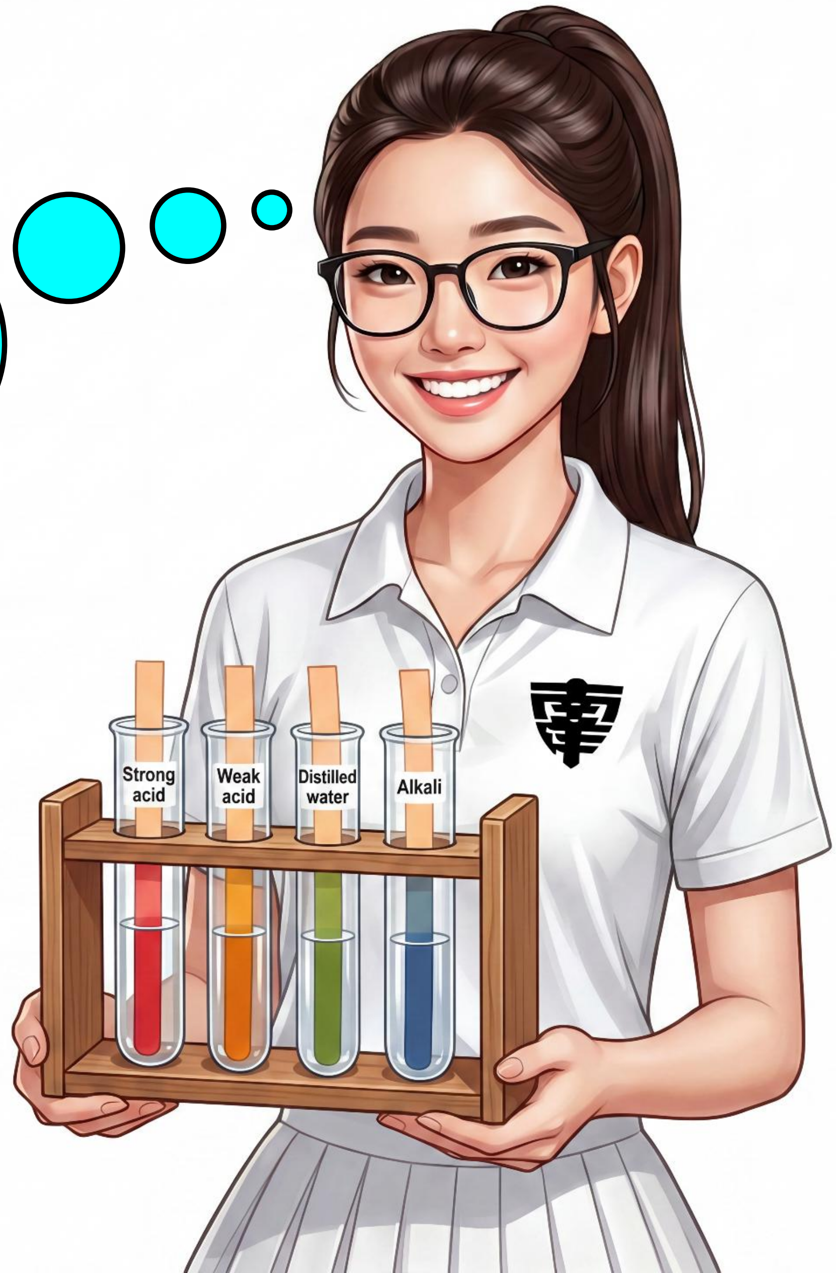
Main Menu (*click to link*)

Acids, Bases and Salts

Main Menu (*click to link*)

Acids, Bases and Salts

What do I need to know and understand about acids, bases and salts?



Acids, Bases and Salts

Acids and bases

(a) Describe the meanings of the terms acid and alkali in terms of the ions they produce in aqueous solution and their effects on Universal Indicator.

(b) Describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator and the pH scale.

(c) Describe qualitatively the difference between strong and weak acids in terms of the extent of ionisation.

(d) Describe the characteristic properties of acids as in reactions with metals, bases and carbonates.

(e) State the uses of sulfuric acid in the manufacture of detergents and fertilisers; and as a battery acid.

(f) Describe the reaction between hydrogen ions and hydroxide ions to produce water,

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

as neutralisation.

(g) Describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide.

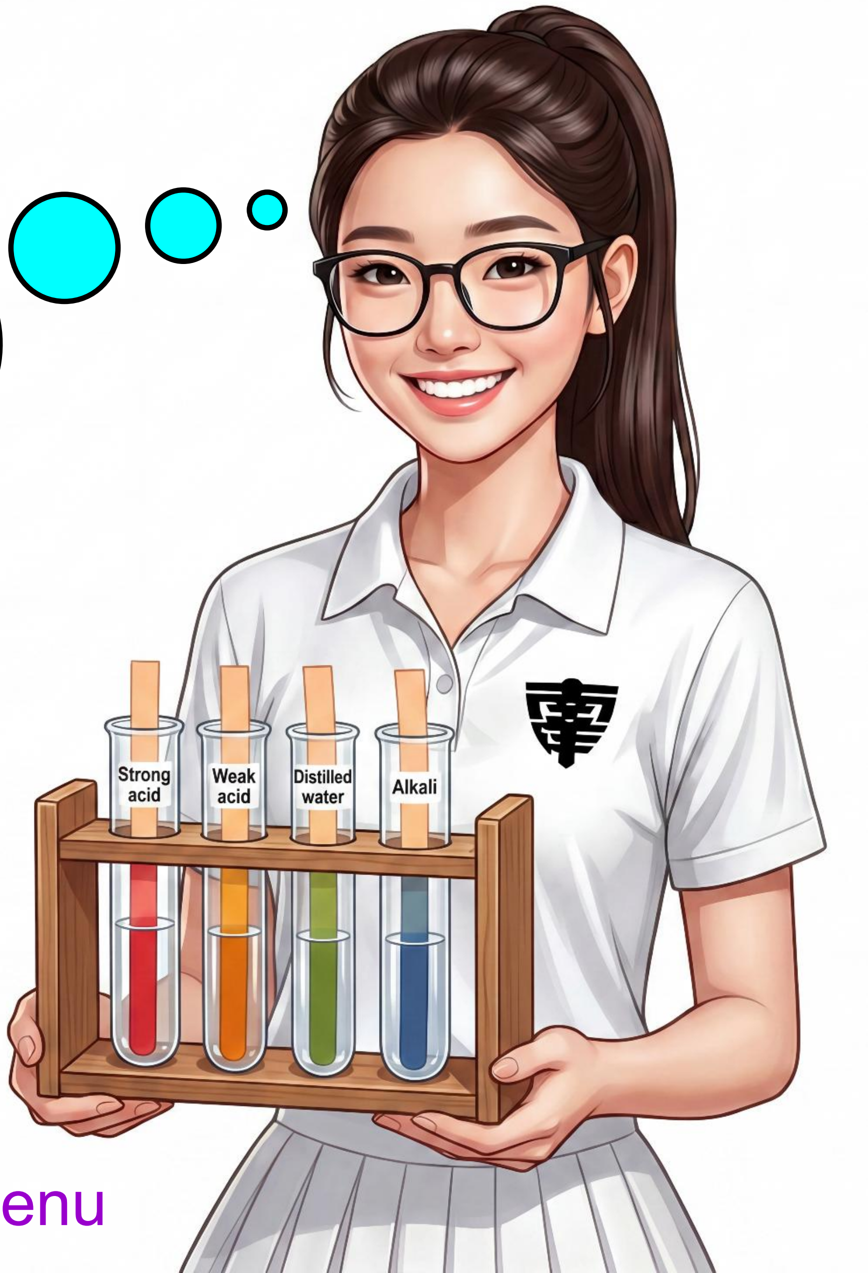
(h) Describe the characteristic properties of bases in reactions with acids and with ammonium salts.

(i) Classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character.

(j) Classify sulfur dioxide as an acidic oxide and state its uses as a bleach, in the manufacture of wood pulp for paper and as a food preservative (by killing bacteria).

Acids, Bases and Salts

1. Could I please have a brief *summary* of what we are going to study for this unit?



Main Menu

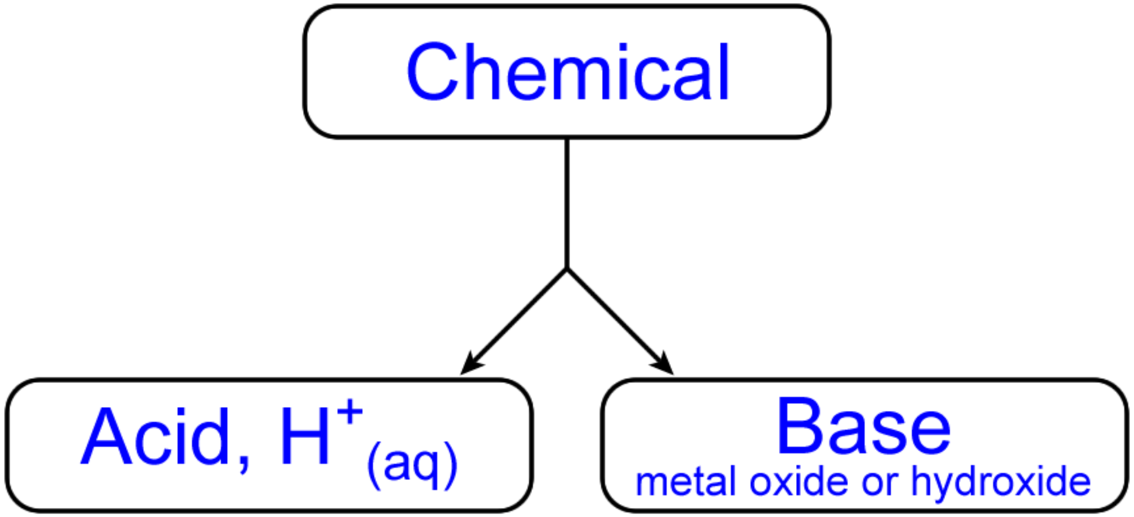
Acids, Bases and Salts

Overview of Acids and Bases

Chemical

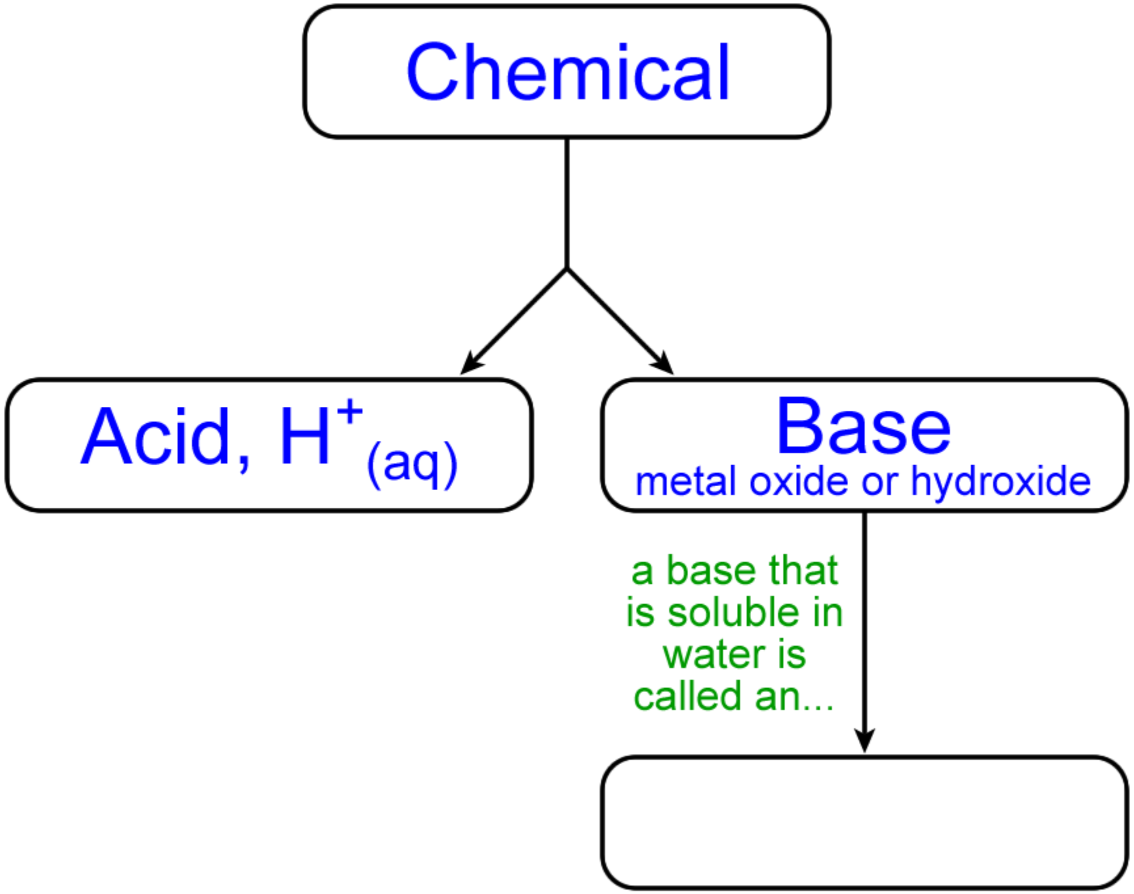
Acids, Bases and Salts

Overview of Acids and Bases



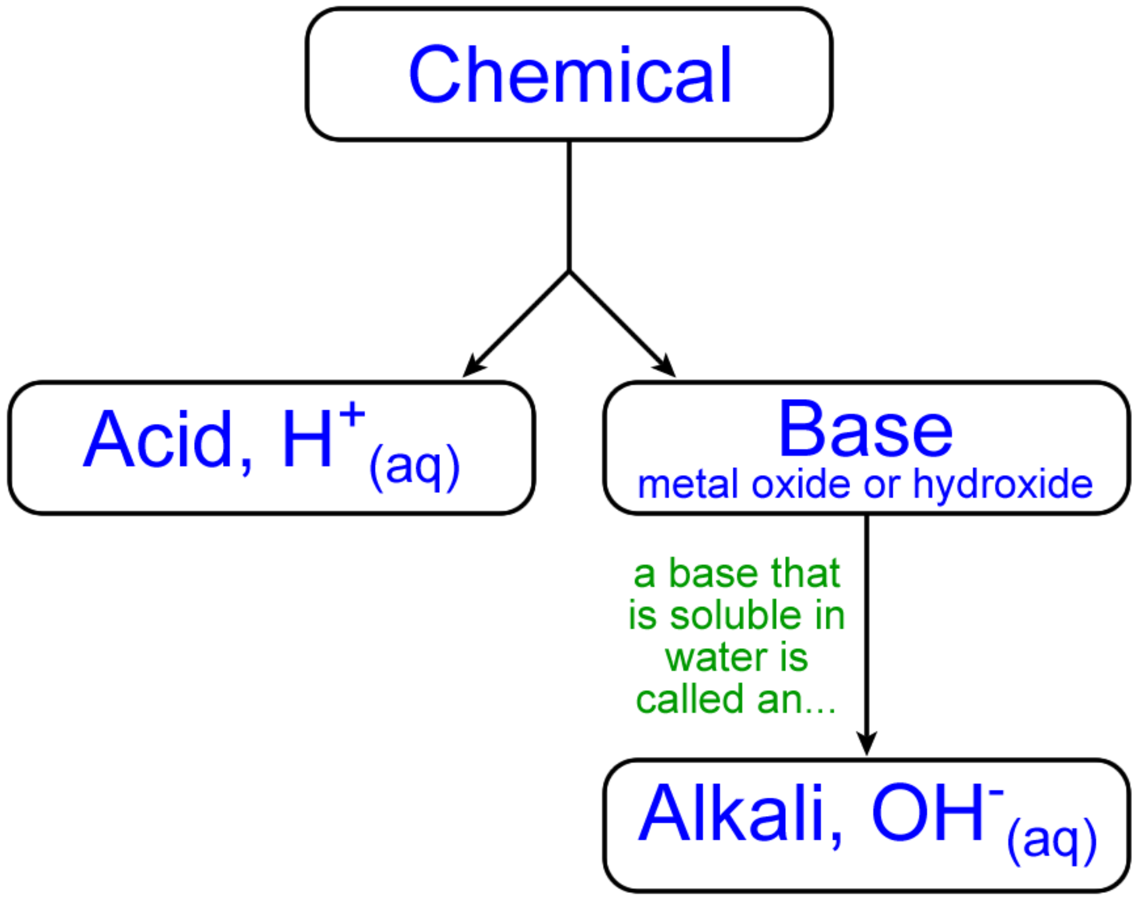
Acids, Bases and Salts

Overview of Acids and Bases



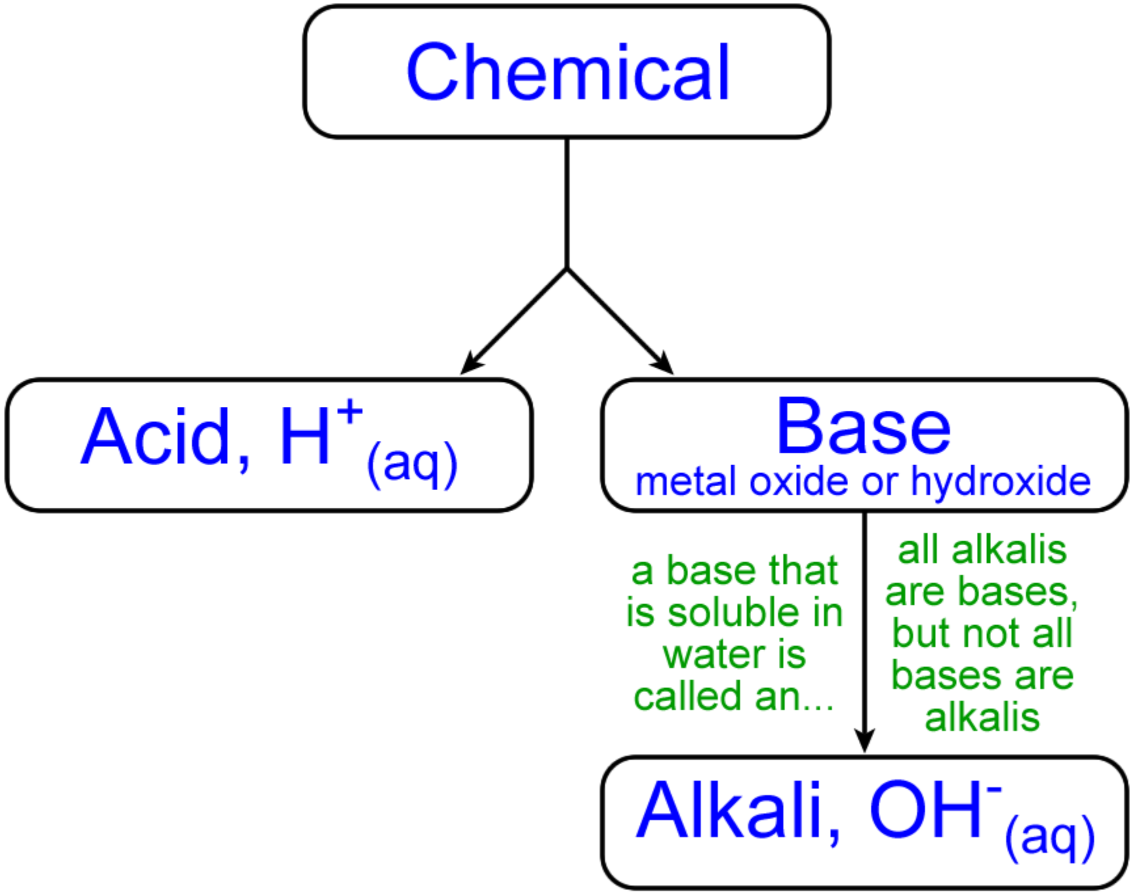
Acids, Bases and Salts

Overview of Acids and Bases



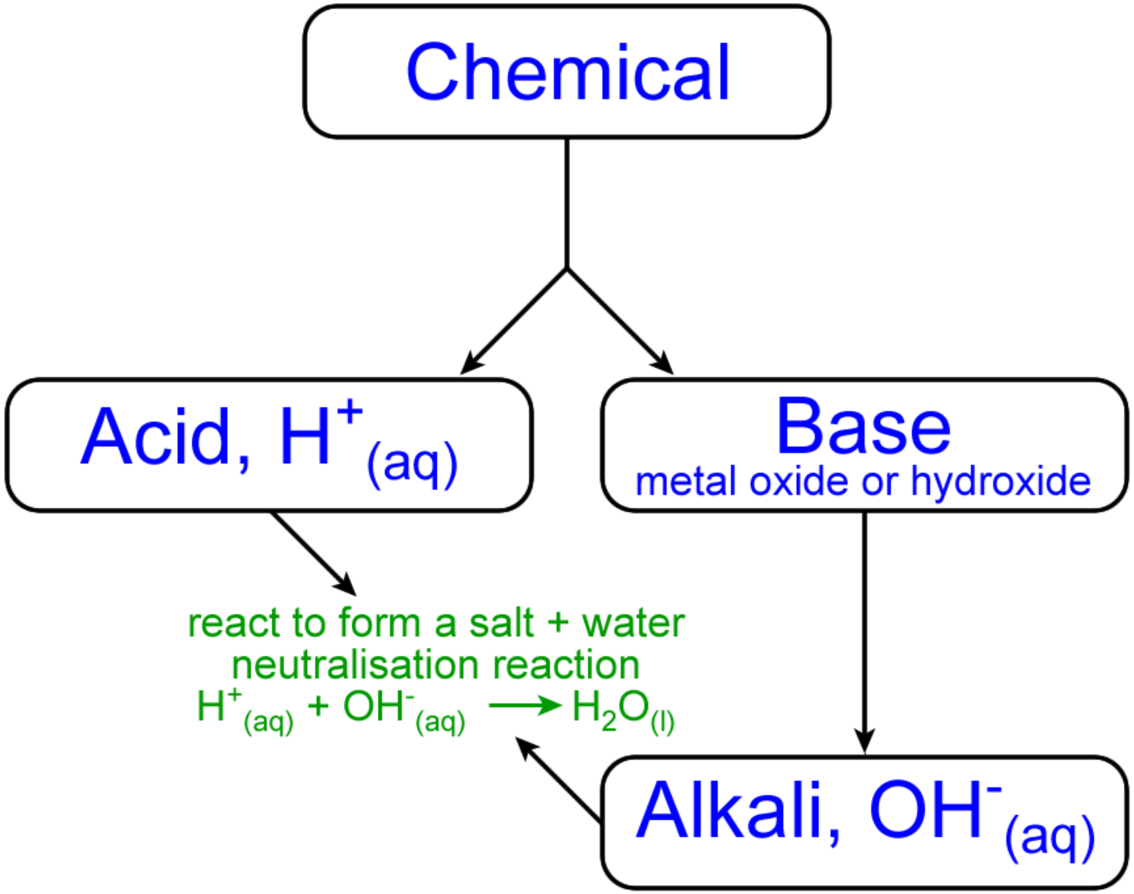
Acids, Bases and Salts

Overview of Acids and Bases



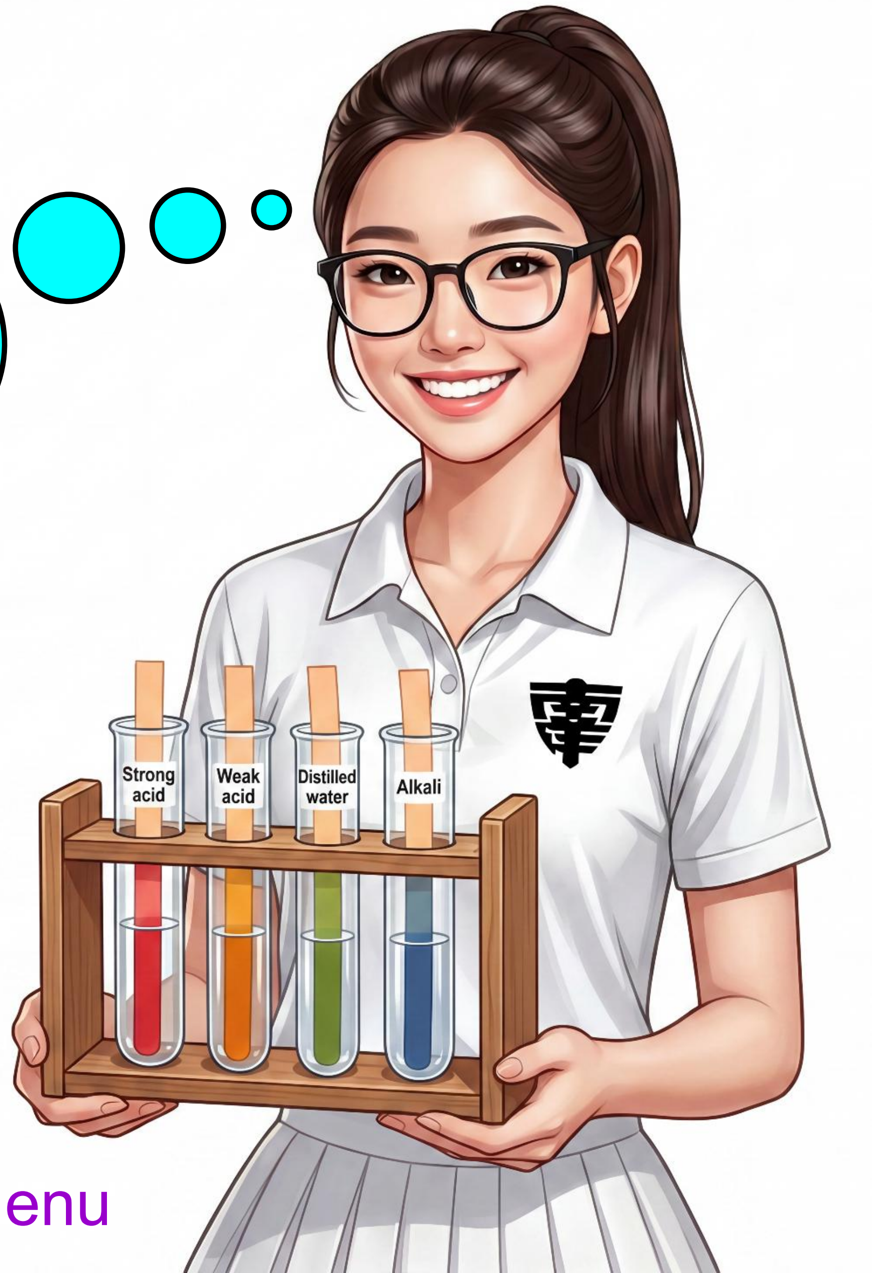
Acids, Bases and Salts

Overview of Acids and Bases



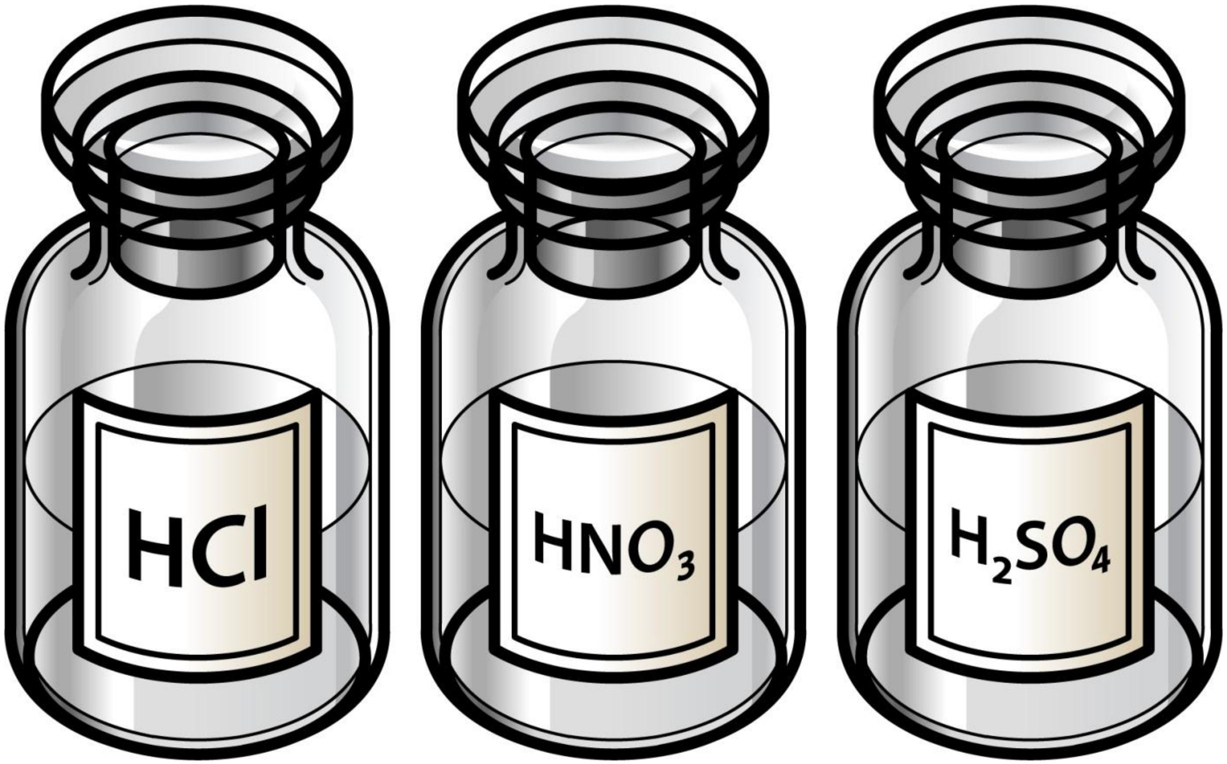
Acids, Bases and Salts

2. What are some common *examples* of *acids*?



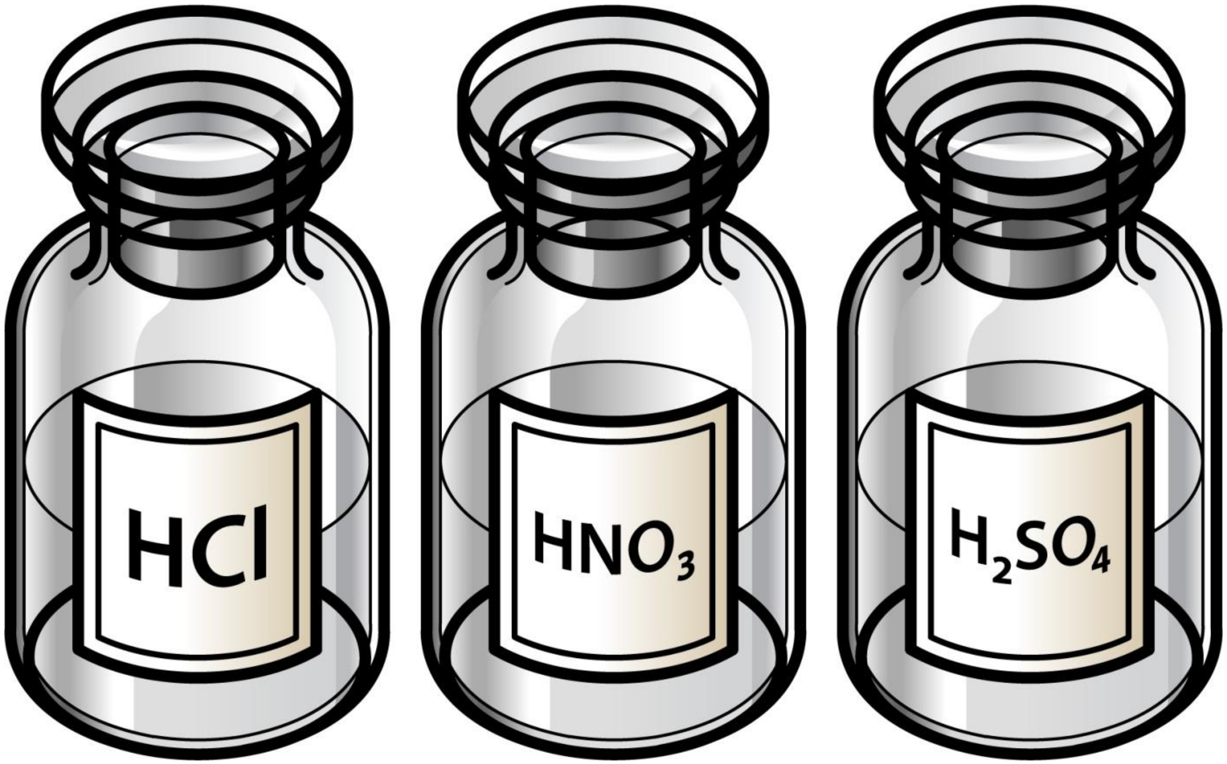
Main Menu

Acids, Bases and Salts



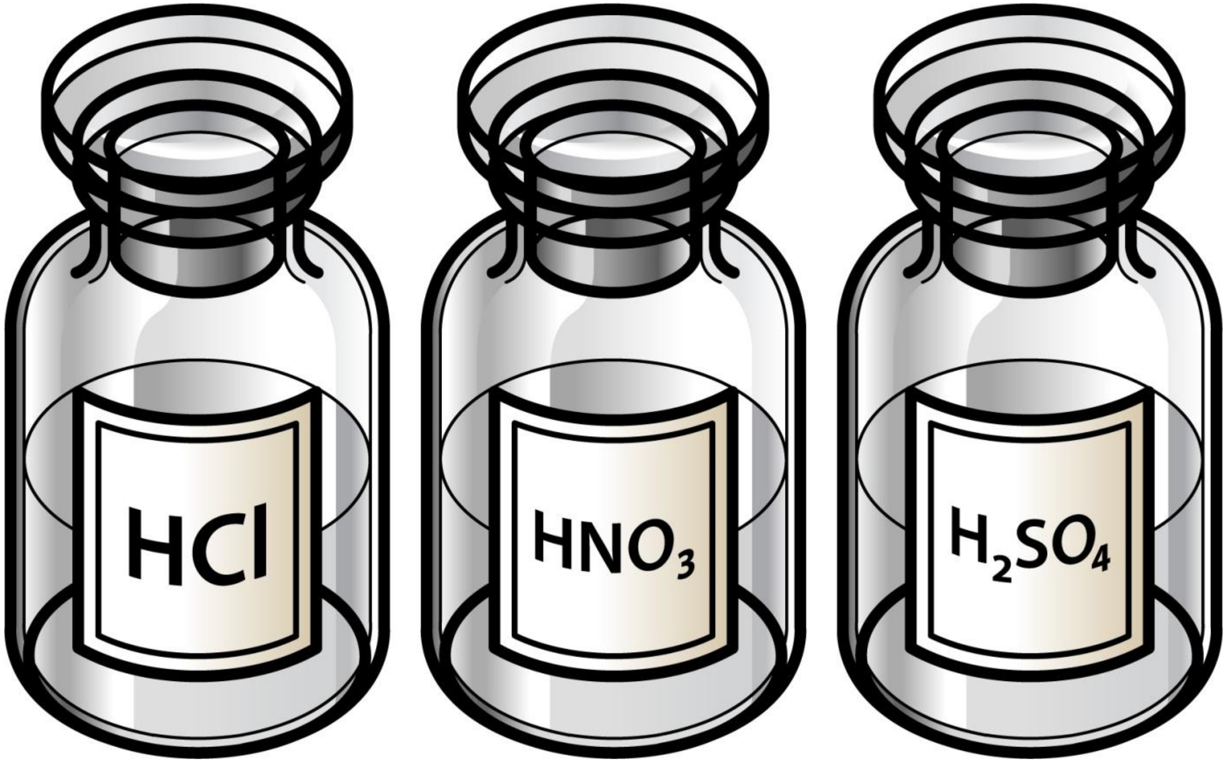
- Hydrochloric Acid, $HCl(aq)$
- Nitric Acid, $HNO_3(aq)$
- Sulfuric Acid, $H_2SO_4(aq)$

Acids, Bases and Salts



- **Note**: the labels on these bottles are a little misleading:
  → $HCl(aq)$ actually contains $H^+(aq)$ and $Cl^-(aq)$ ions.
  → $HNO_3(aq)$ actually contains $H^+(aq)$ and $NO_3^-(aq)$ ions.
  → $H_2SO_4(aq)$ actually contains $2H^+(aq)$ and $SO_4^{2-}(aq)$ ions.

Acids, Bases and Salts

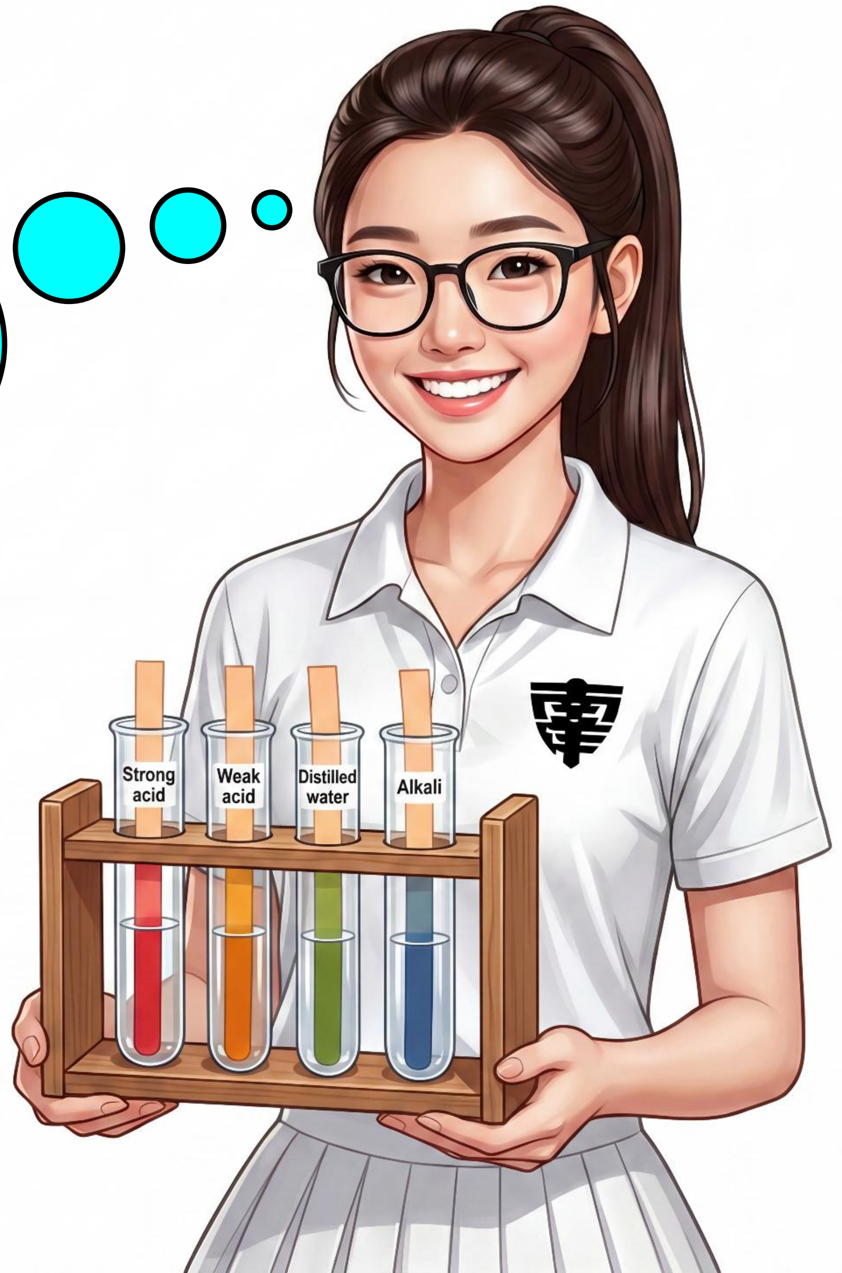


Other examples include:

- Phosphoric acid, $H_3PO_4(aq)$
- Ethanoic acid, $CH_3COOH(aq)$
- Citric acid, $C_6H_8O_7(aq)$

Acids, Bases and Salts

2. What *property* must a chemical have in order to be *classified* as an *acid*?



Acids, Bases and Salts

- Historically, acids were identified by their *sharp* and / or *sour taste*.

- Fizzy drinks have a sharp taste to them because they contain two different acids; *carbonic acid*, $H_2CO_3(aq)$, and *phosphoric acid*, $H_3PO_4(aq)$.

- The *carbonic acid* is formed when carbon dioxide gas (responsible for making the drink fizzy) dissolves in water. The *phosphoric acid* is used as a preservative.

Acids, Bases and Salts

- Historically, acids were identified by their *sharp* and / or *sour taste*.

- Vinegar tastes sour due to the *ethanoic acid*, $CH_3COOH(aq)$, that it contains.

Acids, Bases and Salts

- Historically, acids were identified by their *sharp* and / or *sour taste*.

- Lemons and limes taste sour due to the *citric acid*, $C_6H_8O_7(aq)$, that they contain. Lemons and limes are known as *citrus fruits*.

Acids, Bases and Salts

- Historically, Chemists also believed that all acids contained the chemical element *oxygen*.

→ Nitric acid – HNO_3(aq).

→ Sulfuric acid – H_2SO_4(aq).

→ Phosphoric acid – H_3PO_4(aq).

→ Ethanoic acid – CH_3COOH(aq).

- Oxygen actually takes its name from the Greek *oxys* meaning "acid" and *genes* meaning "producer". So oxygen literally means "acid producer".

Acids, Bases and Salts

- Historically, Chemists also believed that all acids contained the chemical element *oxygen*.

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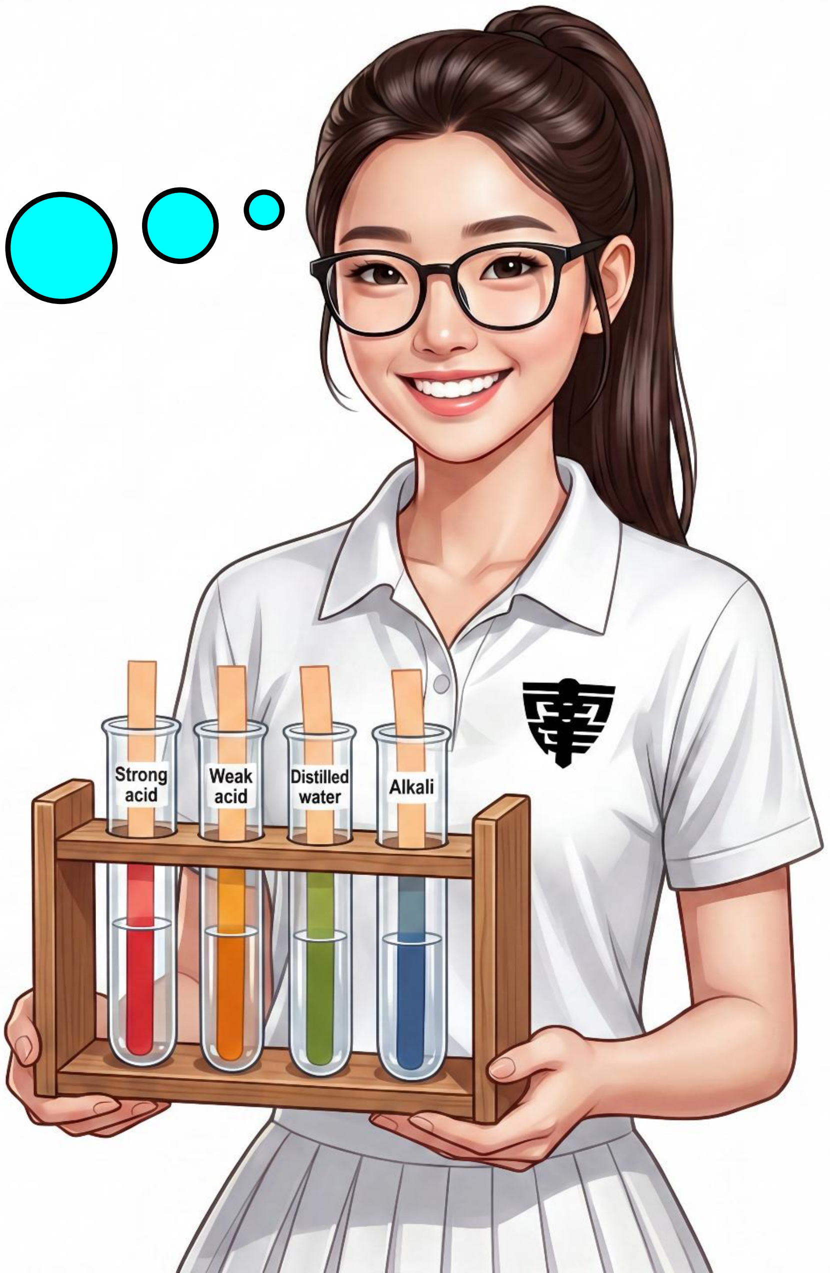
- Oxygen actually takes its name from the Greek *oxys* meaning "acid" and *genes* meaning "producer". So oxygen literally means "acid producer".

- But… …not all acids contain oxygen!

→ Hydrochloric acid – $HCl(aq)$.

Acids, Bases and Salts

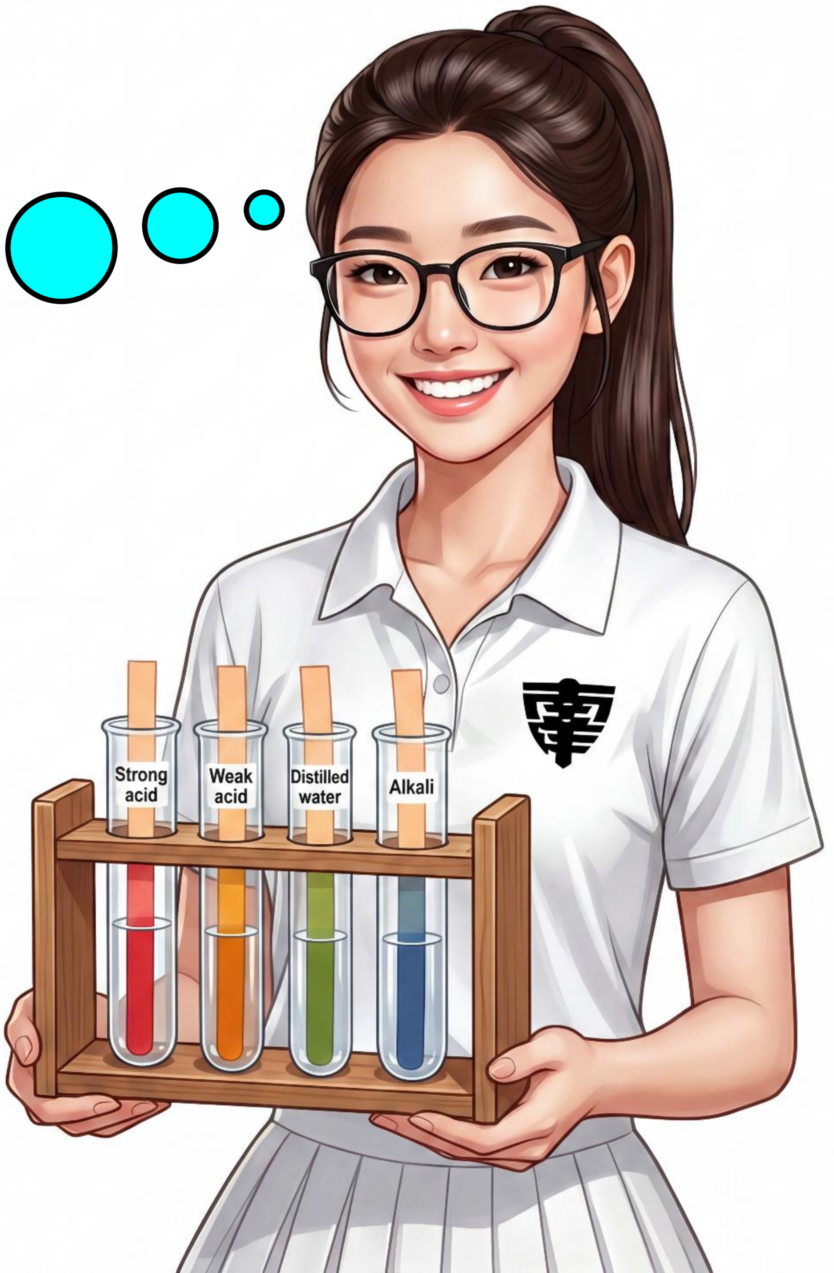
2. But it’s dangerous to taste chemicals in the laboratory! Is there a *modern definition* of acid?



Acids, Bases and Salts

2. But it's dangerous to taste chemicals in the laboratory! Is there a *modern definition* of acid?

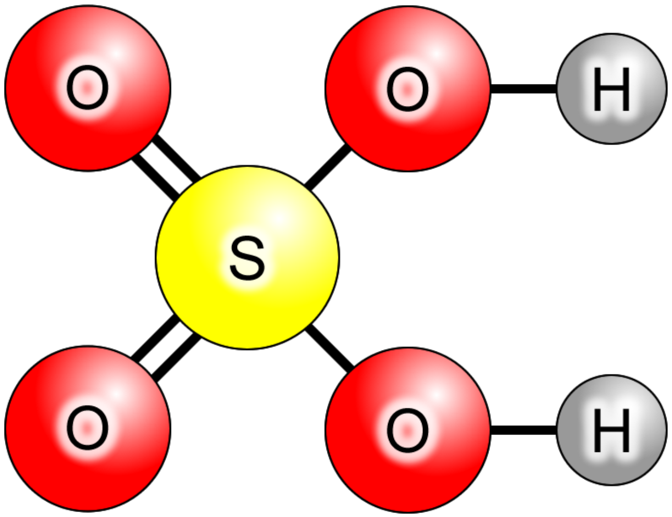
- Consider what the following acids all have in common.



Acids, Bases and Salts

Properties of Acids

- Pure sulfuric acid:

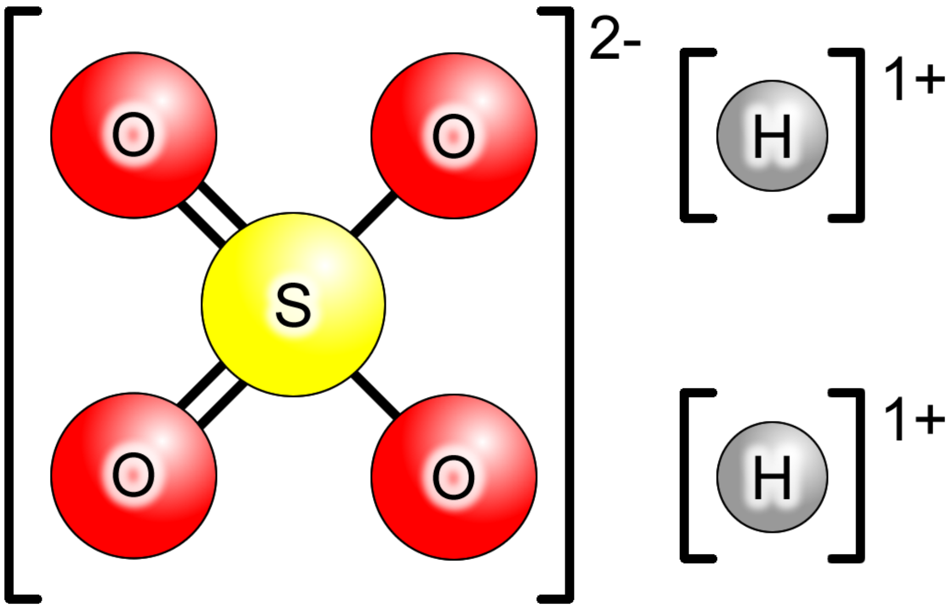


$H_2SO_4(l)$

Acids, Bases and Salts

Properties of Acids

- Sulfuric acid dissolved in water:

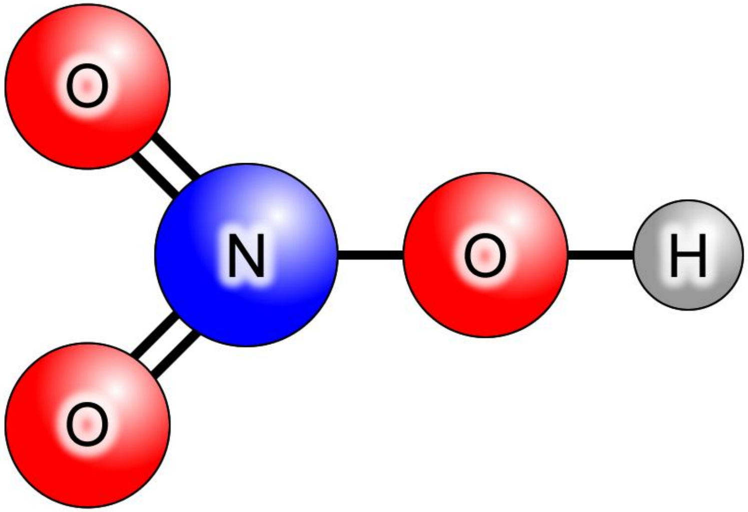


$H_2SO_4(aq)$

Acids, Bases and Salts

Properties of Acids

- Pure nitric acid:

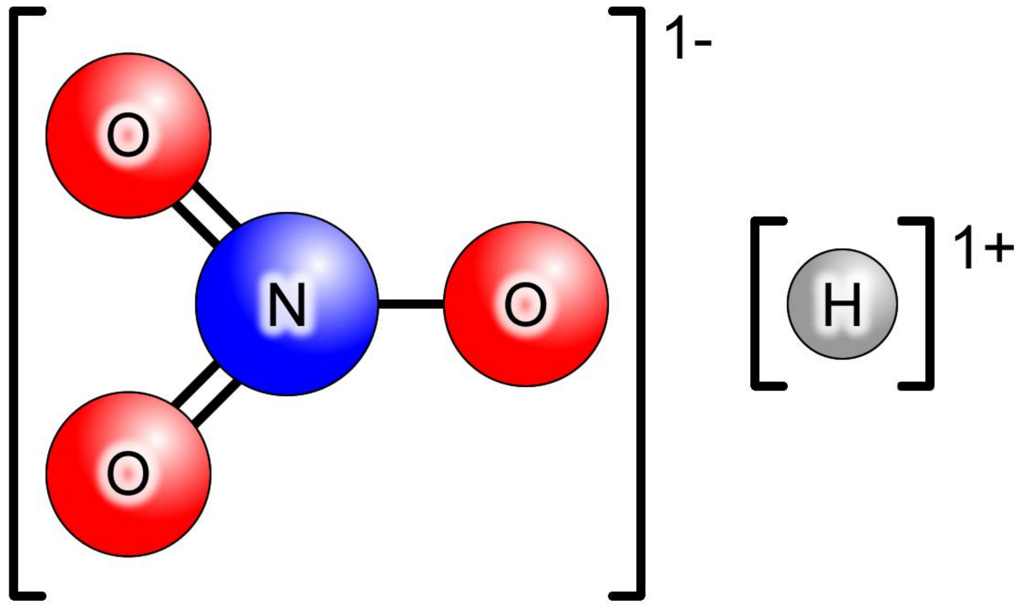


$HNO_3(l)$

Acids, Bases and Salts

Properties of Acids

- Nitric acid dissolved in water:

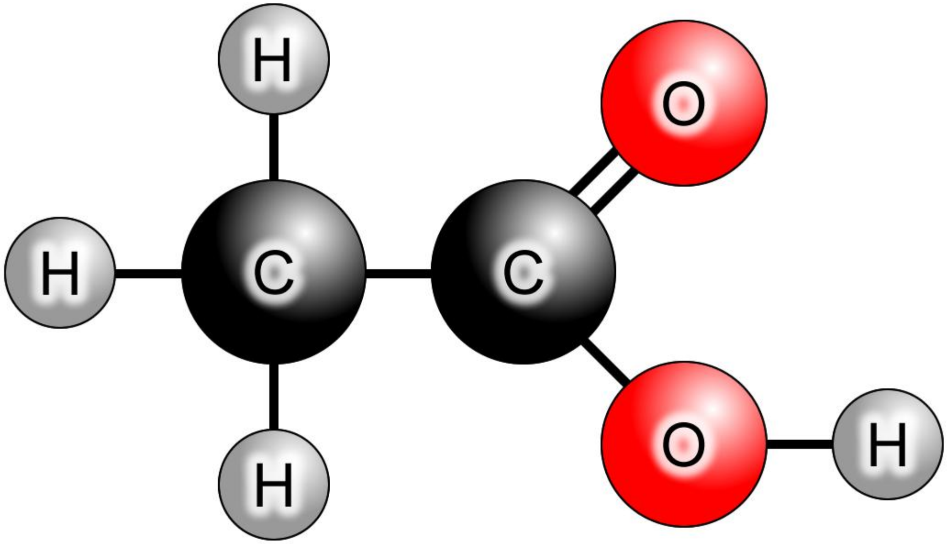


$HNO_3(aq)$

Acids, Bases and Salts

Properties of Acids

- Pure ethanoic acid:

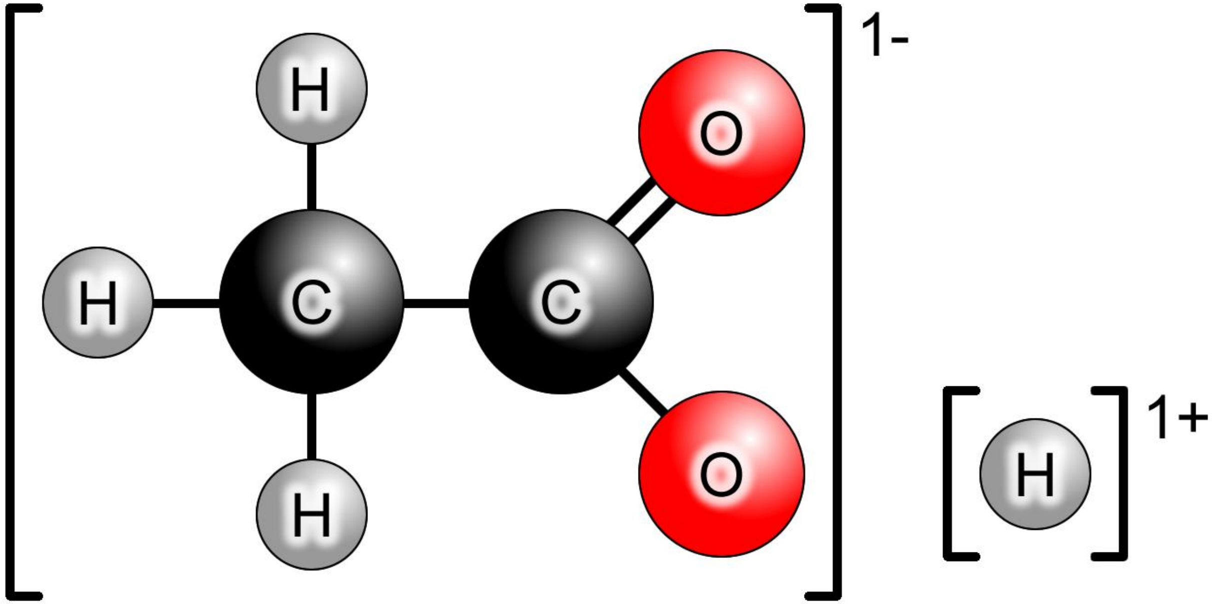


$CH_3COOH(l)$

Acids, Bases and Salts

Properties of Acids

- Ethanoic acid dissolved in water:

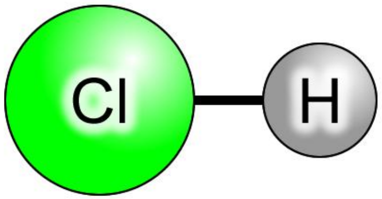


$CH_3COOH(aq)$

Acids, Bases and Salts

Properties of Acids

- Pure hydrogen chloride:

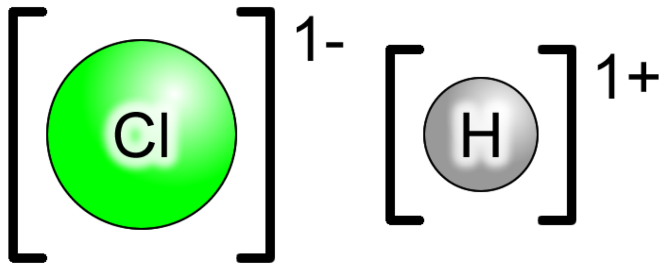


$HCl(g)$

Acids, Bases and Salts

Properties of Acids

- Hydrogen chloride dissolved in water (hydrochloric acid):

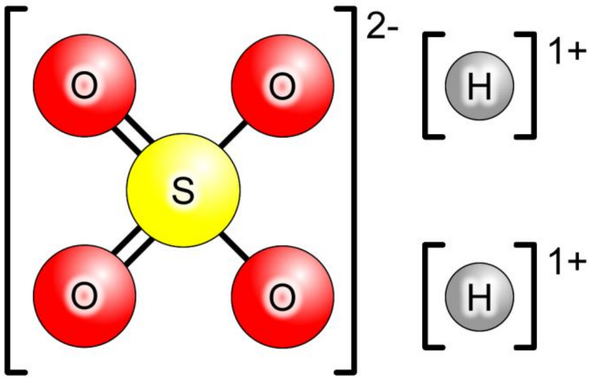


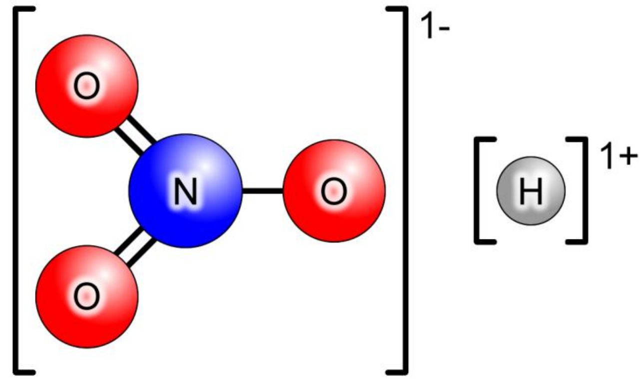
$HCl(aq)$

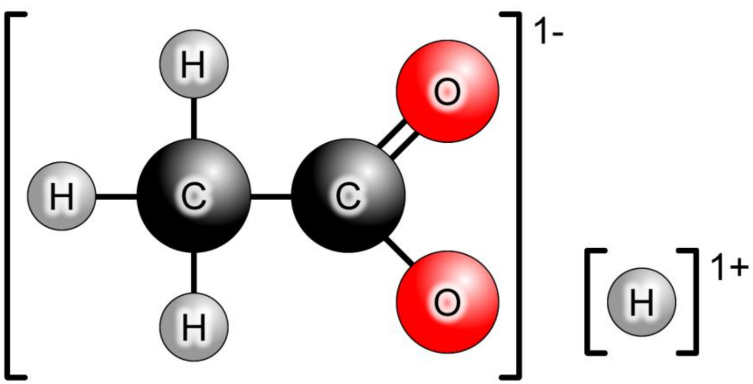
Acids, Bases and Salts

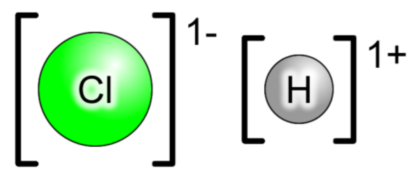
Properties of Acids

- In summary, all four chemicals dissolved in water.









- In what way(s) are they similar?

Acids, Bases and Salts

Properties of Acids

- An acid is a chemical that will ionize when dissolved in water to produce *hydrogen ions* (*$H^+(aq)$*) as the *only positive ion*.

- For example, hydrochloric acid:

hydrogen chloride → chloride ions + hydrogen ions

$$HCl(g) \rightarrow Cl^-(aq) + H^+(aq)$$

- For example, nitric acid:

nitric acid → nitrate ions + hydrogen ions

$$HNO_3(l) \rightarrow NO_3^-(aq) + H^+(aq)$$

- For example, sulfuric acid:

sulfuric acid → sulfate ions + hydrogen ions

$$H_2SO_4(l) \rightarrow SO_4^{2-}(aq) + 2H^+(aq)$$

Acids, Bases and Salts

Properties of Acids

- Test your understanding. Which of the following chemicals would you classify as an acid?

  - $NaCl$:

$$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$$

  - CH_3COOH

$$CH_3COOH(l) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

  - $NaHSO_4$:

$$NaHSO_4(s) \rightarrow Na^+(aq) + H^+(aq) + SO_4^{2-}(aq)$$

  - H_2O:

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

Acids, Bases and Salts

Properties of Acids

- Test your understanding. Which of the following chemicals would you classify as an acid?

  - $NaCl$: ✗

    $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

  - CH_3COOH ✓

    $CH_3COOH(l) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

  - $NaHSO_4$: ✗

    $NaHSO_4(s) \rightarrow Na^+(aq) + H^+(aq) + SO_4^{2-}(aq)$

  - H_2O: ?

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

Acids, Bases and Salts

A Brief Note about Water

- At room temperature and pressure, water molecules spontaneously ionise to form hydrogen ions (H^+) and hydroxide ions (OH^-). This change is reversible:

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

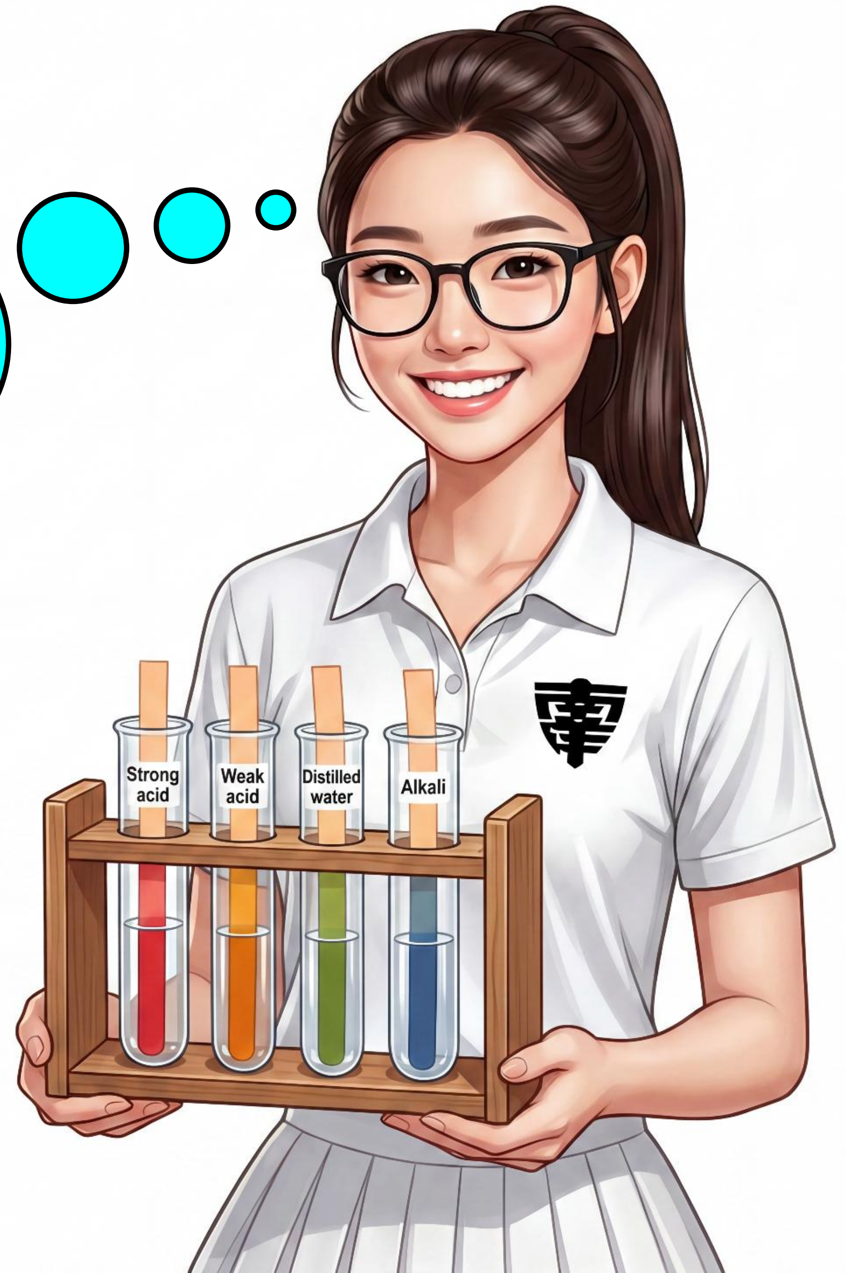
- The concentrations of the hydrogen ions and hydroxide ions are both very low at 1×10^{-7} mol/dm^3.

- Because of the ionisation of water, *acidic solutions* actually contain a very low concentration of *hydroxide ions* and *alkaline solutions* actually contain a very low concentration of *hydrogen ions*.

NANYANG GIRLS' HIGH

Acids, Bases and Salts

2. So all acids contain hydrogen. But is every compound that contains hydrogen an acid?



Acids, Bases and Salts

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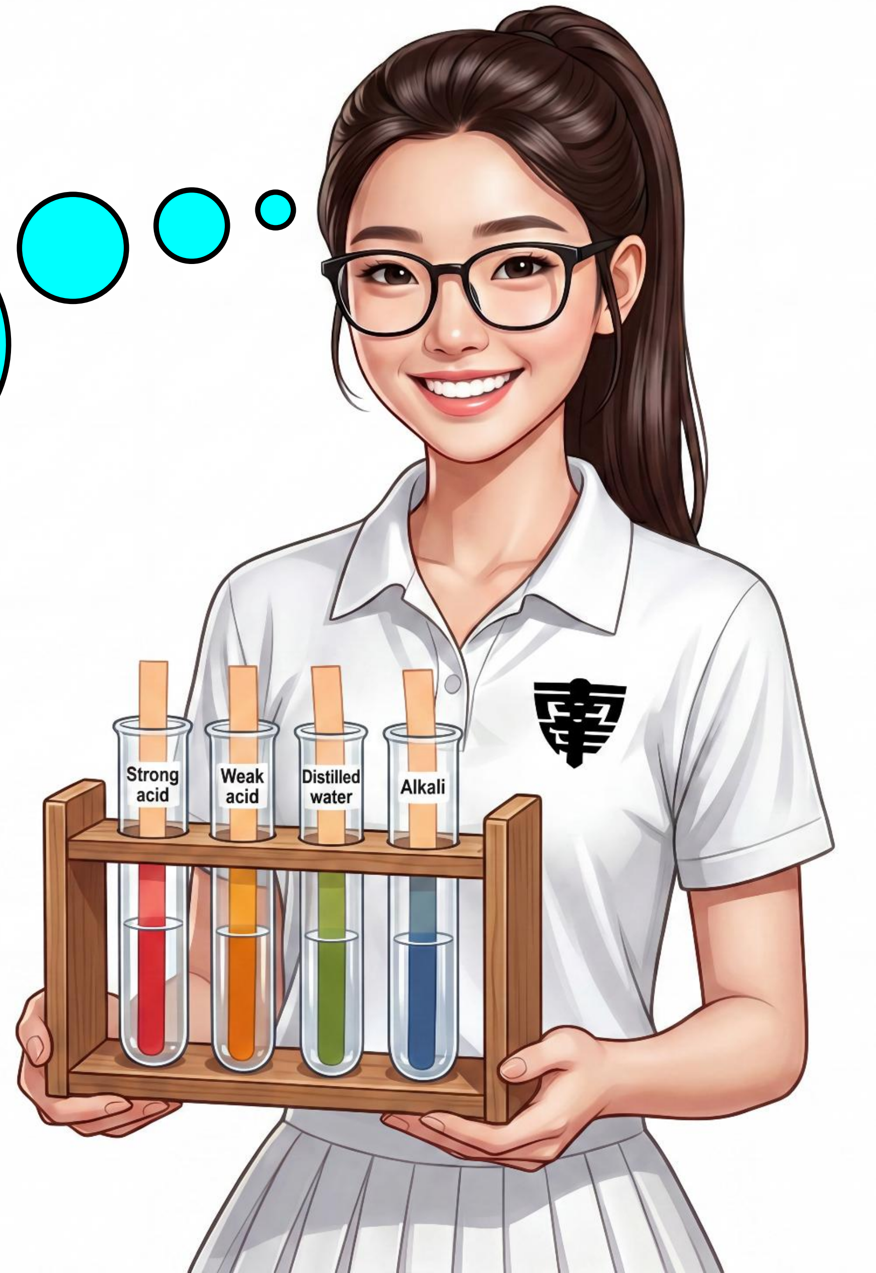
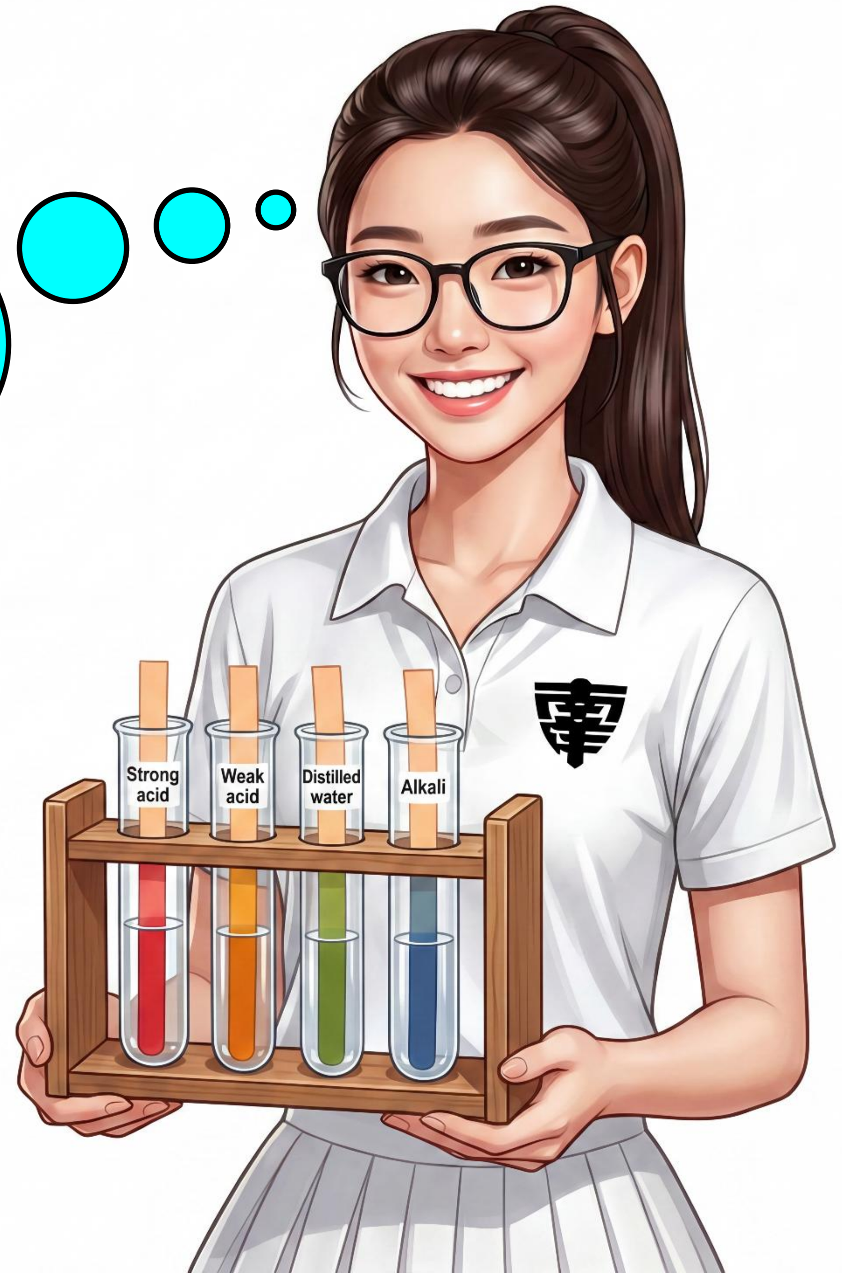


- *No*. For example, methane (CH_4) and ammonia (NH_3) are not acids.

Acids, Bases and Salts

2. Why is it important for the chemical to be *dissolved in water* before it exhibits its acidic properties?



Acids, Bases and Salts

- In reality, hydrogen ions are too unstable to exist on their own. A hydrogen ion will only be lost from an acid if a water molecule is available to accept it:

$$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$$

The polyatomic cation, $H_3O^+(aq)$, is known as the *hydroxonium ion*. It is stable in aqueous solution.

- For example, nitric acid:

nitric acid + water → nitrate ions + hydroxonium ions

$$HNO_3(l) + H_2O(l) \rightarrow NO_3^-(aq) + H_3O^+(aq)$$

- For example, sulfuric acid:

sulfuric acid + water → sulfate ions + hydroxonium ions

$$H_2SO_4(l) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 2H_3O^+(aq)$$

Acids, Bases and Salts

- Draw a dot and cross diagram to show the arrangement of the electrons, and hence the bonding, in the hydroxonium ion.

Acids, Bases and Salts

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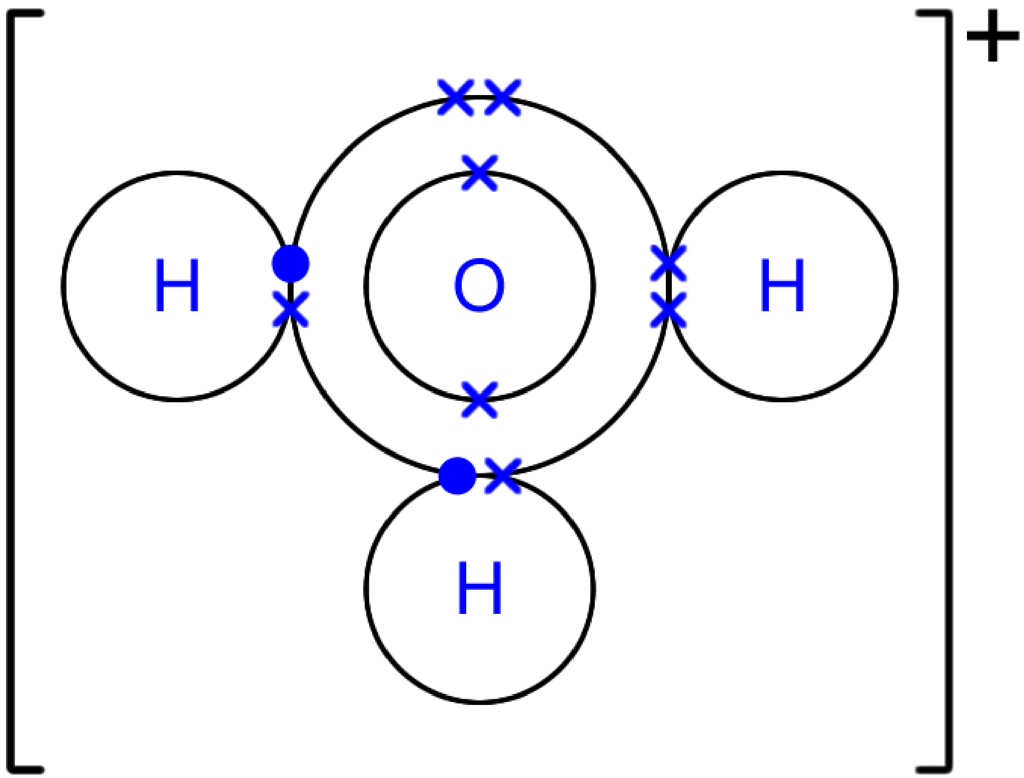
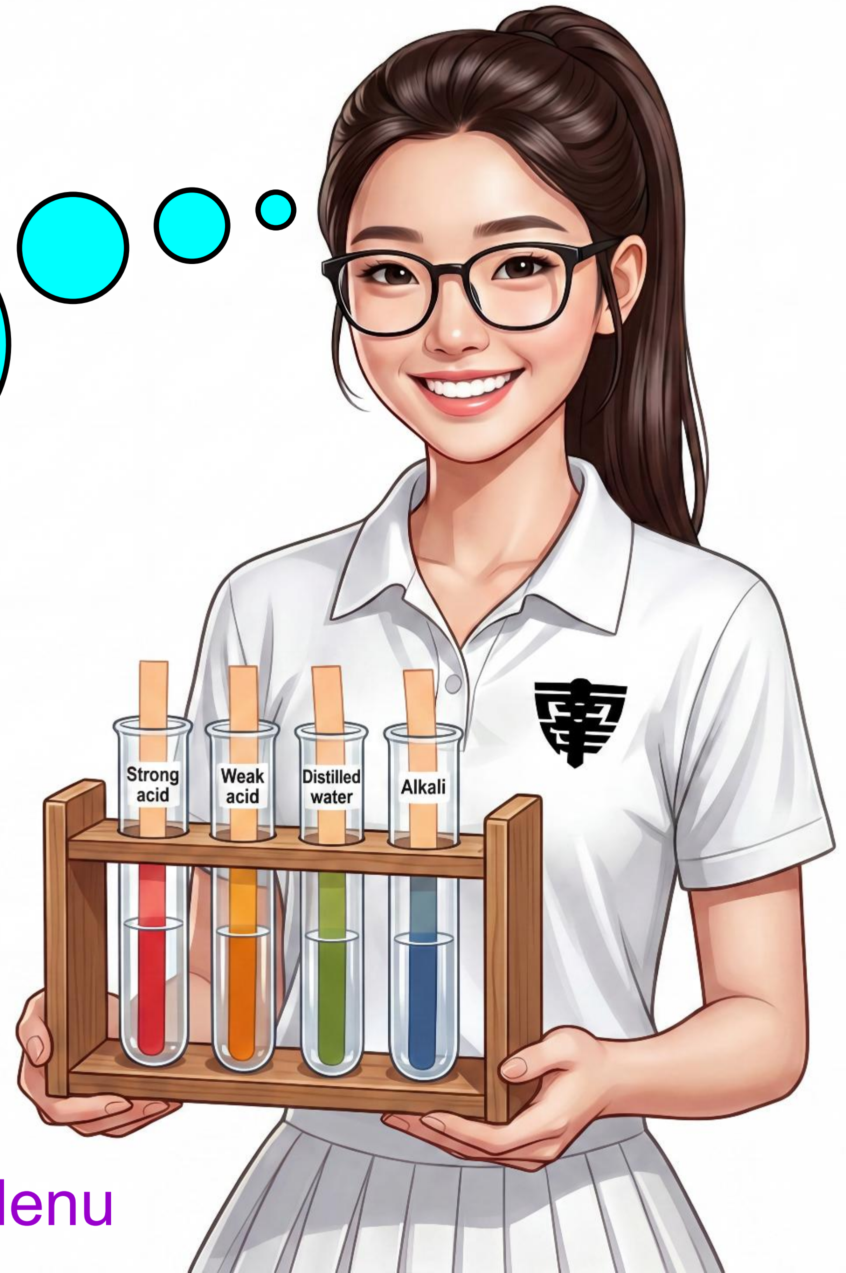


Acids, Bases and Salts

3. What are *monobasic* acids, *dibasic* acids and *tribasic* acids?



Main Menu

Acids, Bases and Salts

- **Monobasic Acid**: One molecule of the acid can produce / donate / replace a maximum of *one* hydrogen ion, *e.g.* nitric acid:

$$HNO_3(l) \rightarrow H^+(aq) + NO_3^-(aq)$$

- **Dibasic Acid**: One molecule of the acid can produce / donate / replace a maximum of *two* hydrogen ions, *e.g.* sulfuric acid:

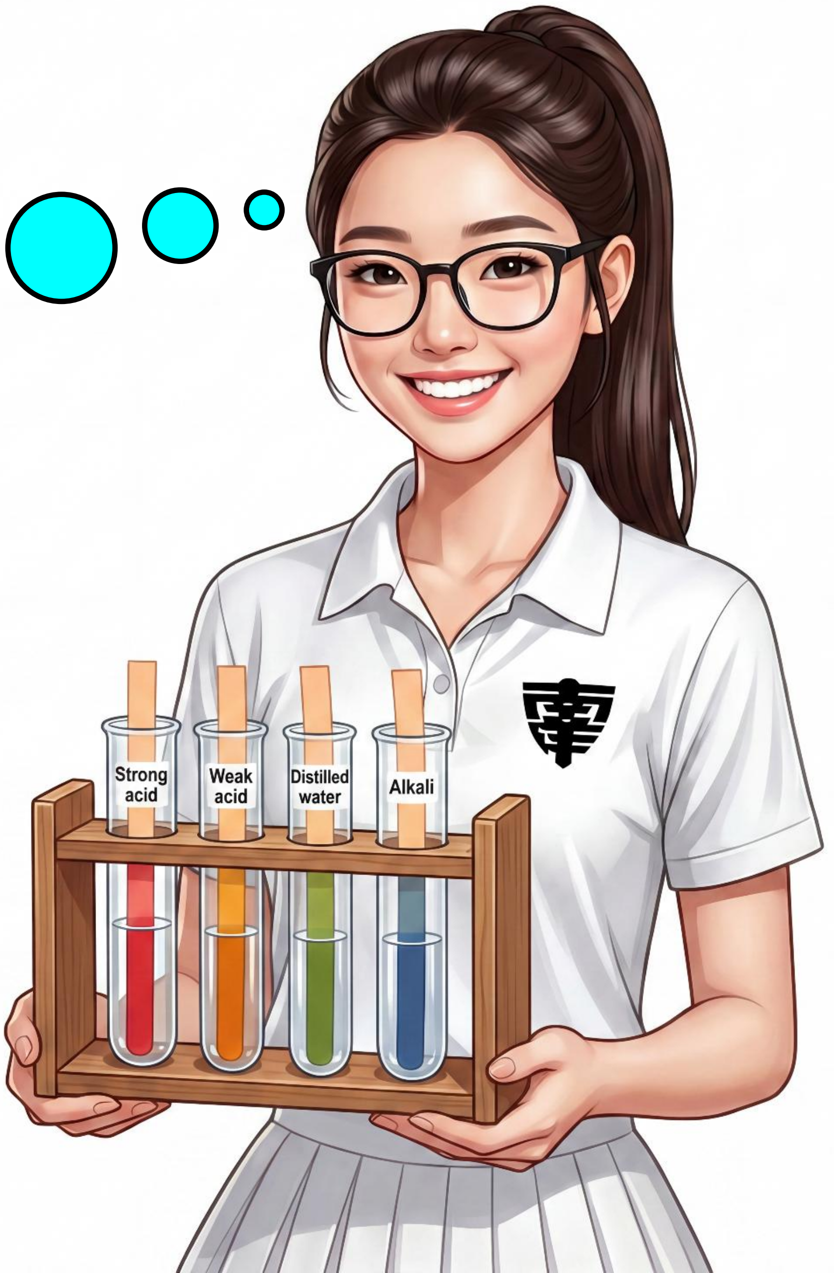
$$H_2SO_4(l) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

- **Tribasic Acid**: One molecule of the acid can produce / donate / replace a maximum of *three* hydrogen ions, *e.g.* phosphoric acid:

$$H_3PO_4(l) \rightleftharpoons 3H^+(aq) + PO_4^{3-}(aq)$$

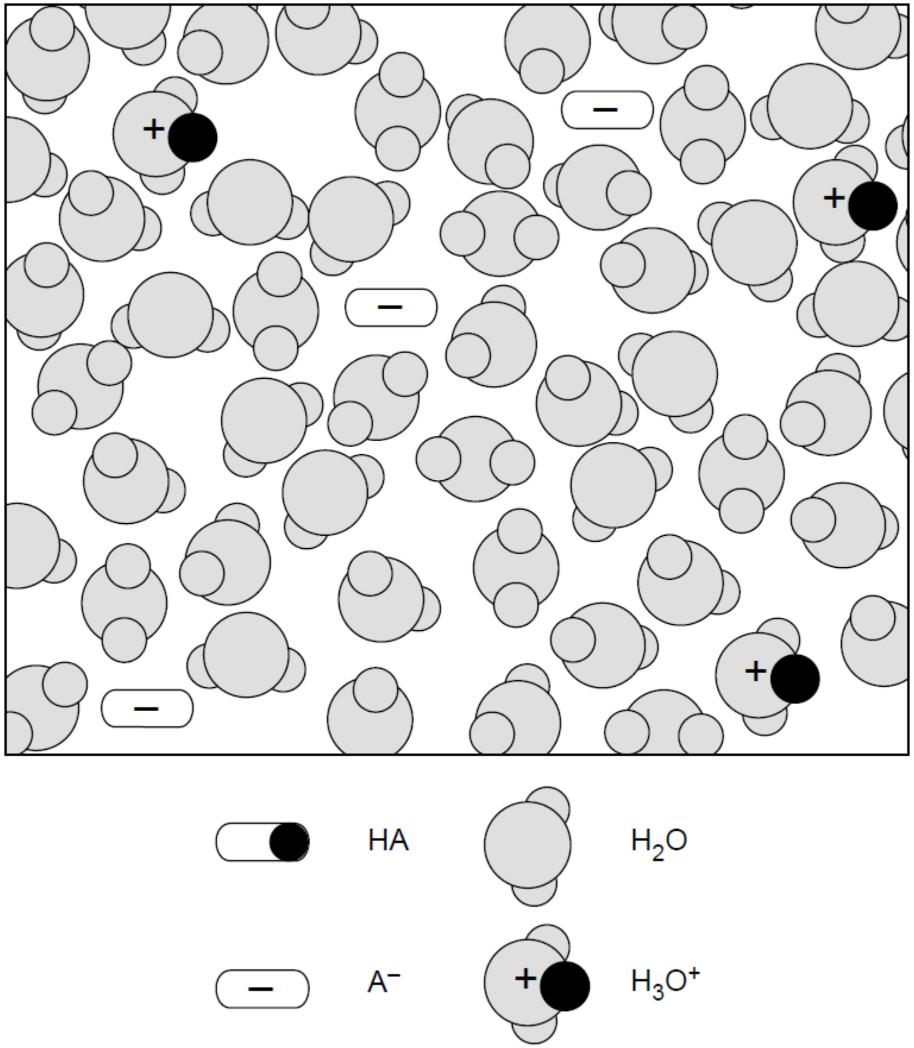
Acids, Bases and Salts

3. What are *strong* acids, *weak* acids, *concentrated* acids and *dilute* acids?



Acids, Bases and Salts

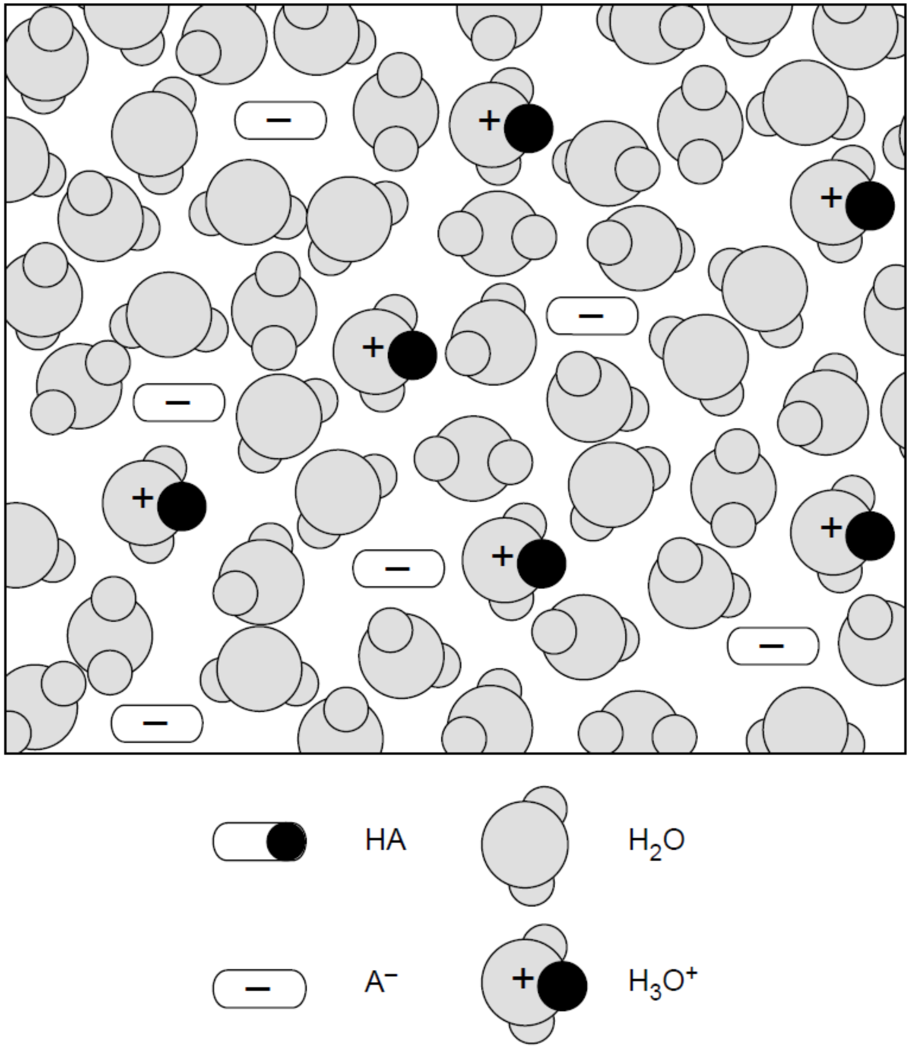
Acid Strength



- A *dilute*, *strong* acid:

Acids, Bases and Salts

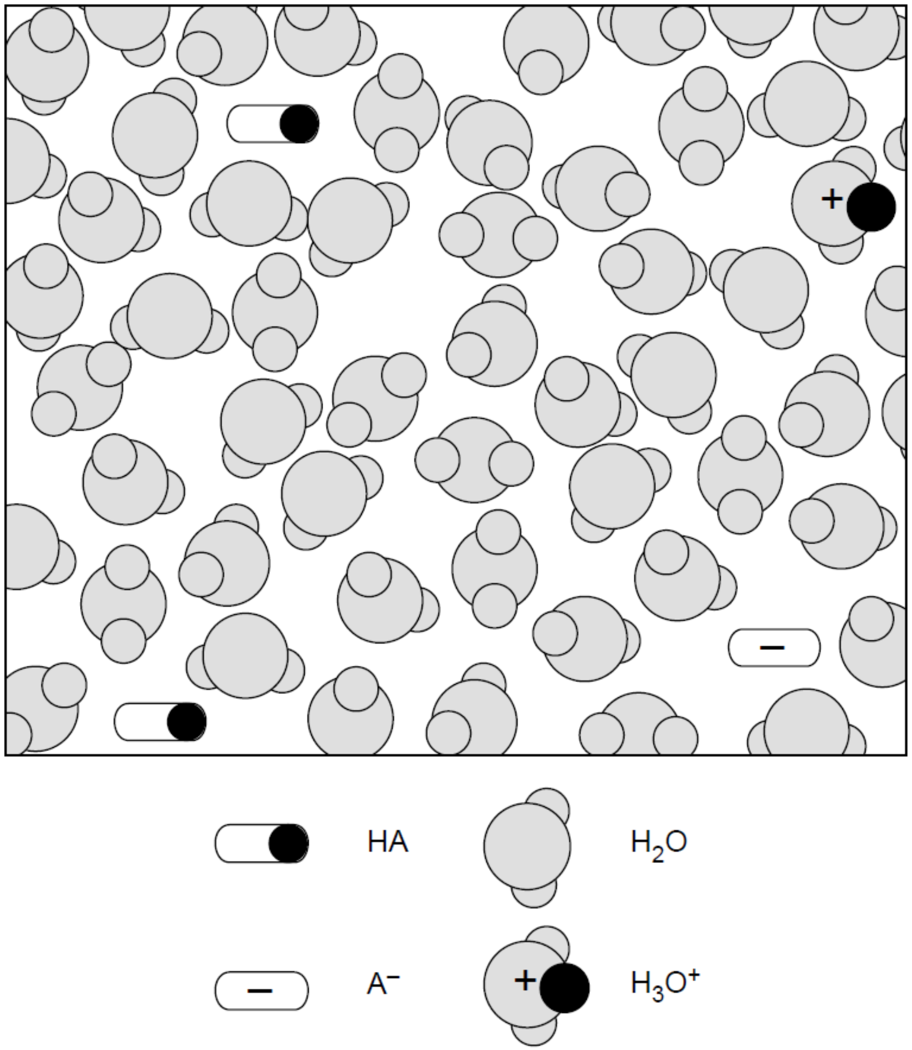
Acid Strength



- A *concentrated*, *strong* acid:

Acids, Bases and Salts

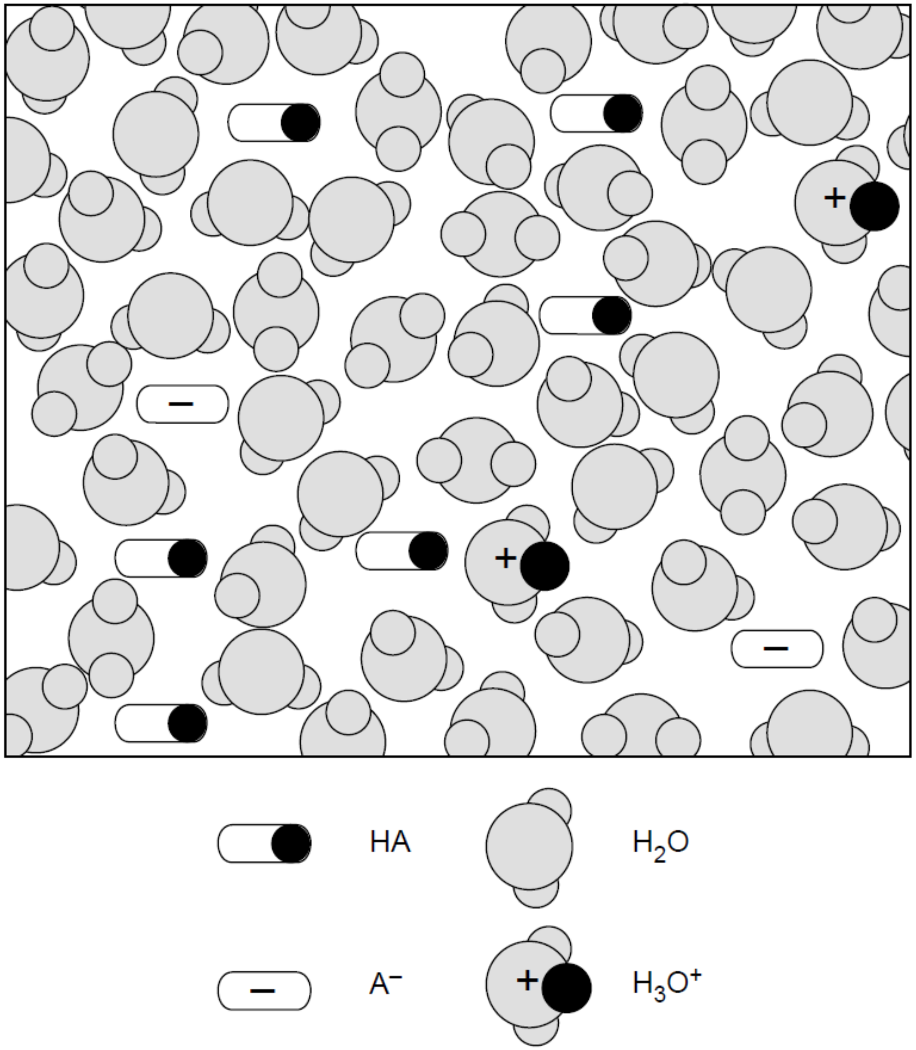
Acid Strength



- A *dilute*, *weak* acid:

Acids, Bases and Salts

Acid Strength

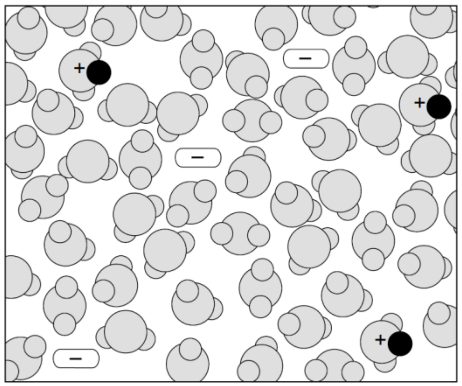


- A *concentrated*, *weak* acid:

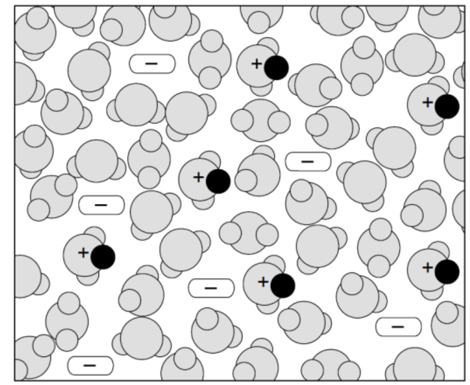
Acids, Bases and Salts

Acid Strength – Summary

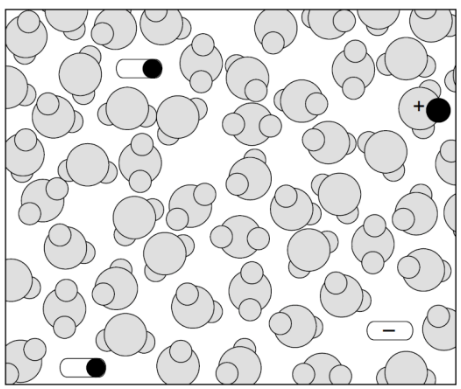
- A *dilute*, *strong* acid.



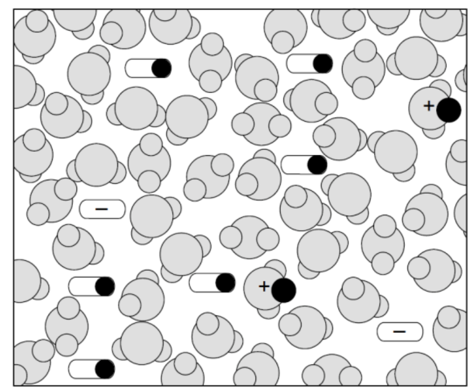
- A *concentrated*, *strong* acid.

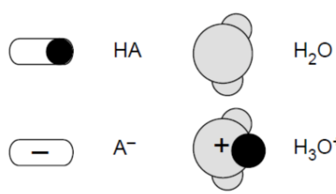


- A *dilute*, *weak* acid.



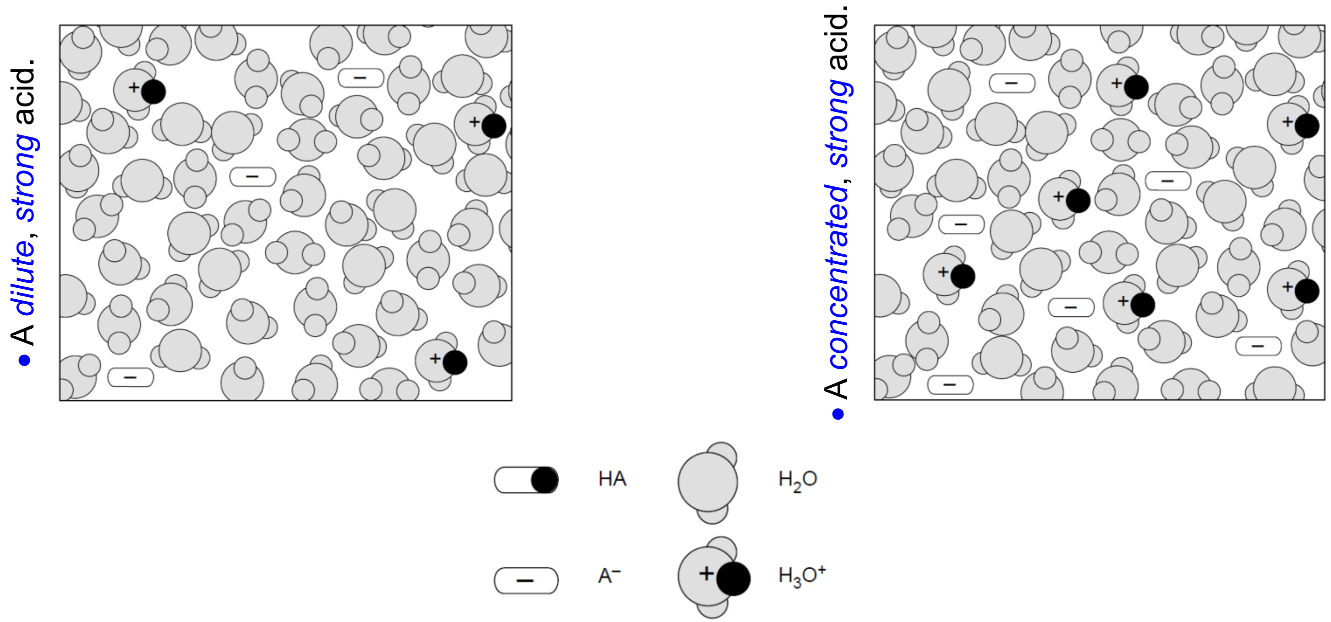
- A *concentrated*, *weak* acid.





Acids, Bases and Salts

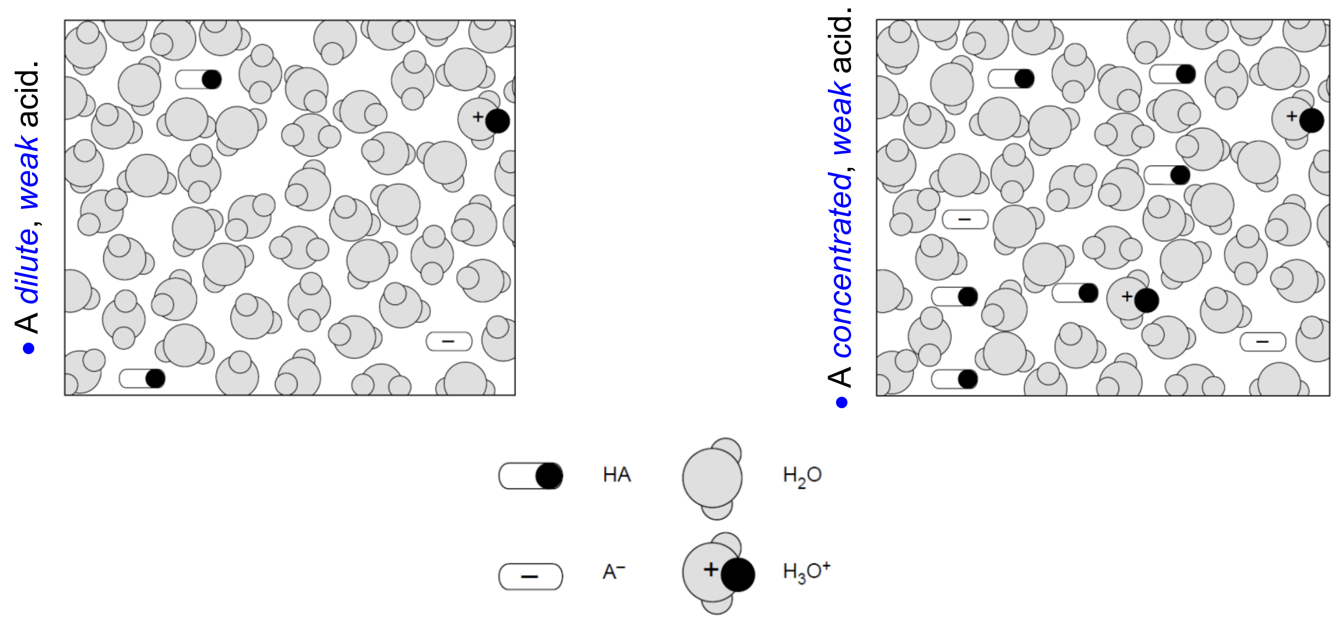
Acid Strength – Summary – Strong Acid



- A *strong acid* will *completely ionize* when dissolved in water to produce hydrogen ions as the only positive ion.
- Examples of strong acids include hydrochloric acid, nitric acid and sulfuric acid.

Acids, Bases and Salts

Acid Strength – Summary – Weak Acid



- A *weak acid* will *partially ionize* when dissolved in water to produce hydrogen ions as the only positive ion.
- Examples of weak acids include ethanoic acid and citric acid (Note: these are both *organic acids* that contain the element *carbon*).

Acids, Bases and Salts

Acid Strength

- **Note**: When writing equations to show *weak acids* ionising in water, the " $\rightleftharpoons$ " symbol is used in preference to the usual "$\rightarrow$" symbol.

- The " $\rightleftharpoons$ " symbol means that the reaction is *reversible*, meaning that once a hydrogen ion has been removed from a molecule of an acid, it can return to reform the acid once again.

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^{-}(aq) + H^{+}(aq)$$

- This indicates that the acid is never fully ionised when dissolved in water and is therefore a *weak acid*.

Acids, Bases and Salts

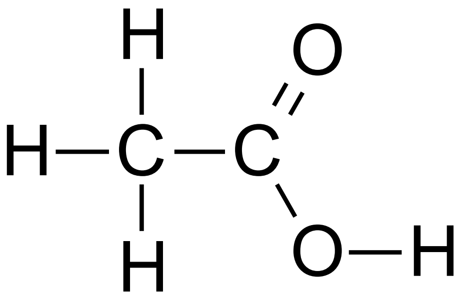
Acid Strength – Summary – Weak Acid

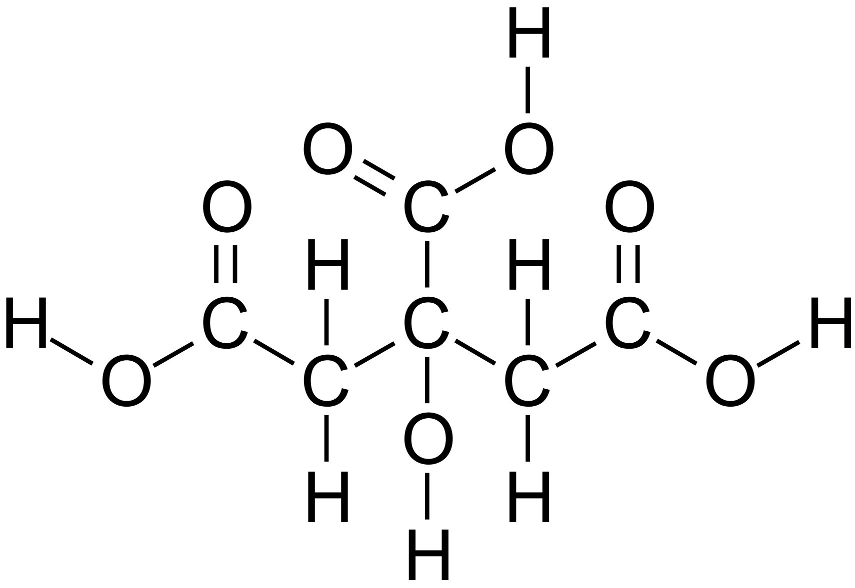
- Vinegar contains the weak acid *ethanoic acid*, formula CH_3COOH.

- Lemons and limes contain the weak acid *citric acid*, formula $C_6H_8O_7$.

Acids, Bases and Salts

Acid Strength – Summary – Weak Acid





- Vinegar contains the weak acid *ethanoic acid*, formula CH_3COOH.
- Lemons and limes contain the weak acid *citric acid*, formula $C_6H_8O_7$.

Acids, Bases and Salts

Acid Strength

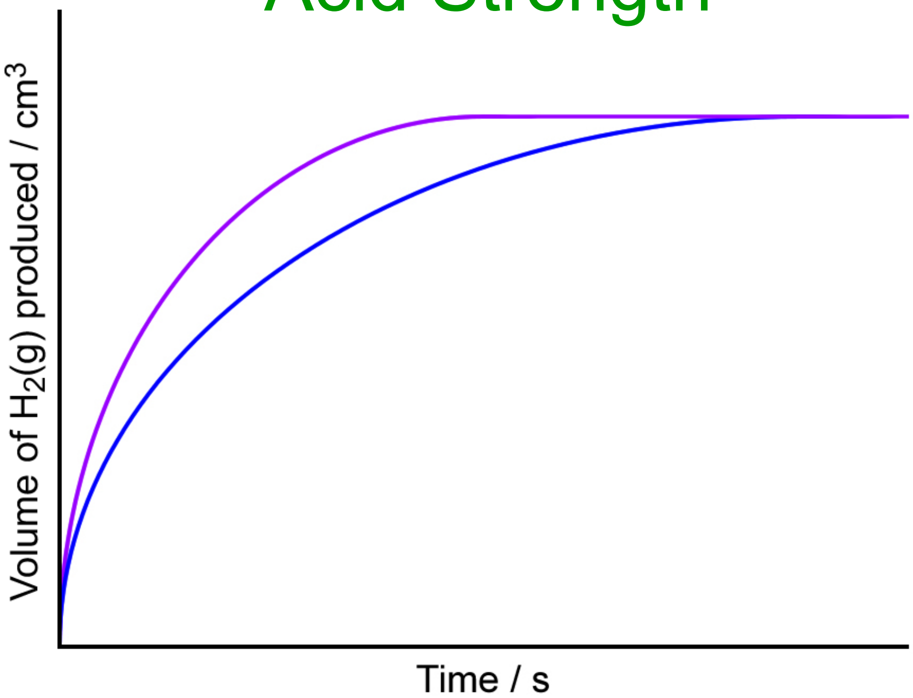
- For a *strong acid* and a *weak acid* of the same concentration, *e.g.* 1.00 mol/dm^3 hydrochloric acid (strong acid) and 1.00 mol/dm^3 ethanoic acid (weak acid):

→ Both acids will have pH values *less than 7*, but the pH value of the strong acid will be lower than the pH value of the weak acid, *e.g.* the pH value of the *strong acid* will be approximately *1 - 3* whereas the pH value of the *weak acid* will be approximately *4 - 6*.

→ Both acids will react with bases, metal carbonates and metals, but the *strong acid* will have a greater rate of reaction (will react faster) than the *weak acid*.

Acids, Bases and Salts

Acid Strength



- For example, both hydrochloric acid (a *strong acid*) and ethanoic acid (a *weak acid*) react with magnesium to produce hydrogen gas:

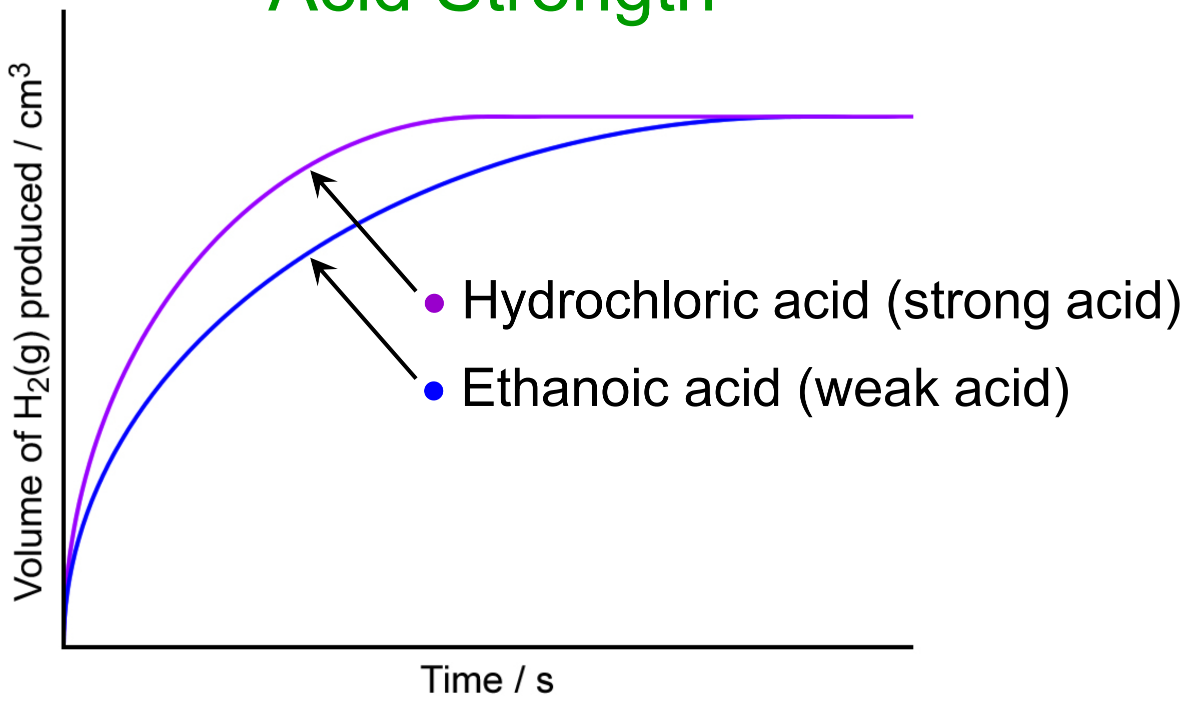
$$2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$$

$$2CH_3COOH(aq) + Mg(s) \rightarrow Mg(CH_3COO)_2(aq) + H_2(g)$$

Assuming that Mg(s) is the *limiting reagent*, for the same mass of Mg(s), both reactions will produce the same volume of H_2(g).

Acids, Bases and Salts

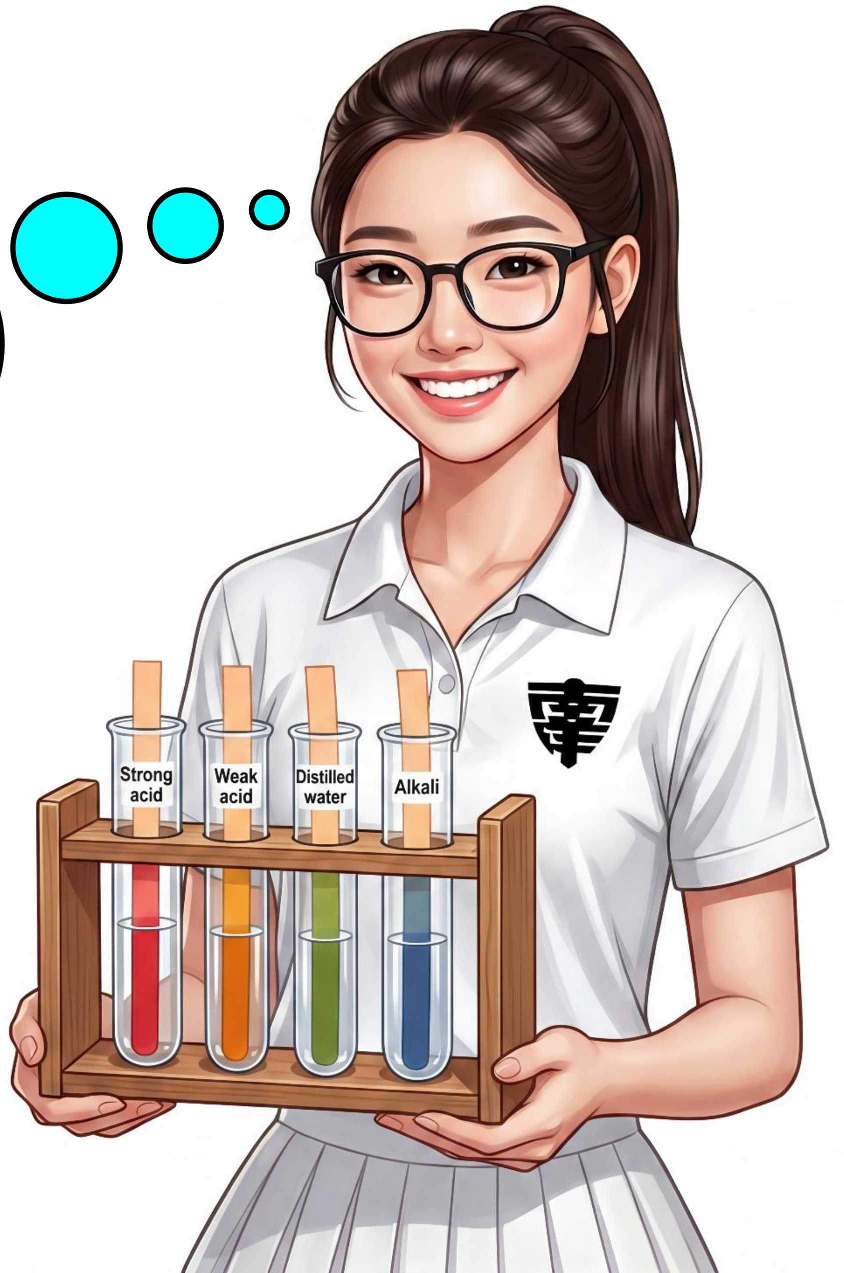
Acid Strength



- For the same volume and concentration of each acid reacting with the same mass of magnesium, the reaction between hydrochloric acid and magnesium will be *faster* (producing a larger volume of hydrogen gas per unit time) than the reaction between ethanoic acid and magnesium.

Acids, Bases and Salts

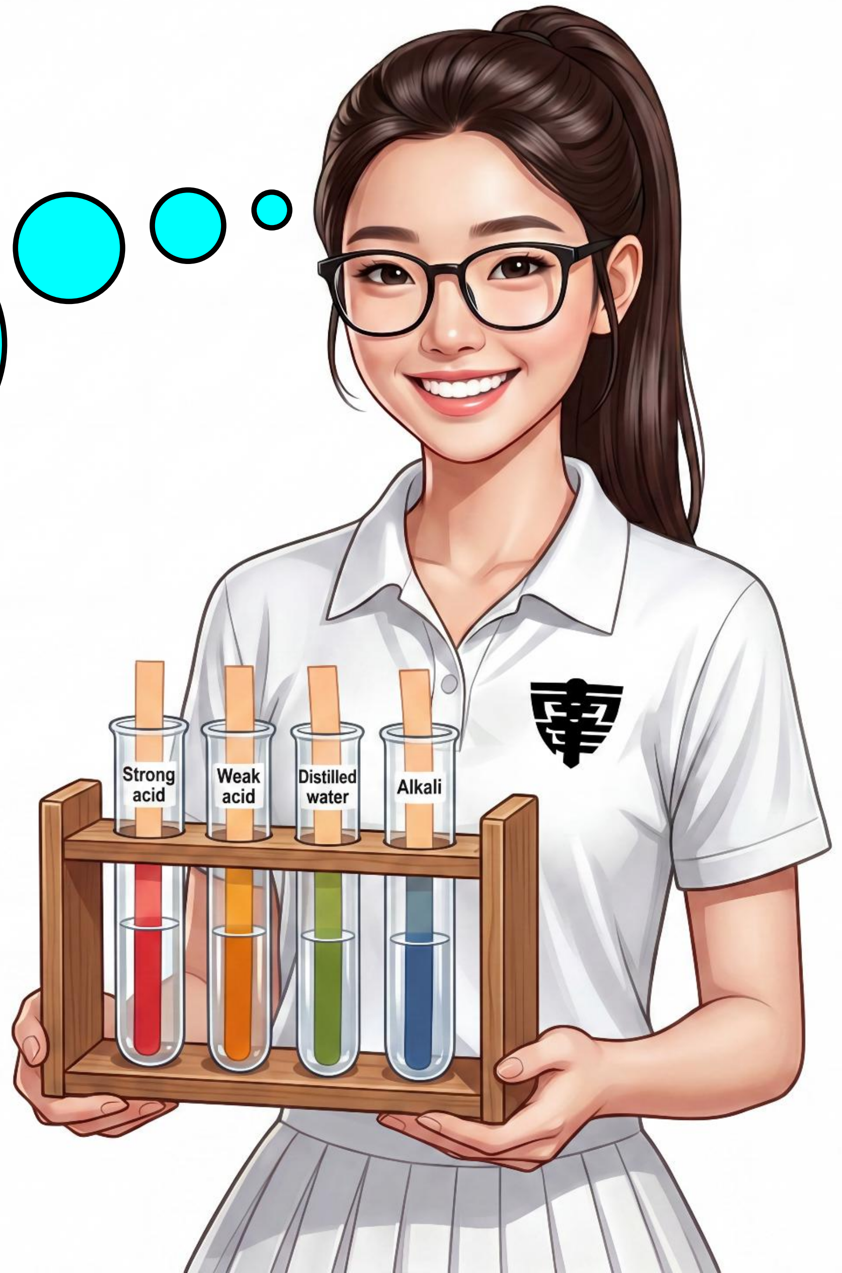
3. Is it possible for a weak acid to have a greater H^+ ion concentration than a strong acid?



Acids, Bases and Salts

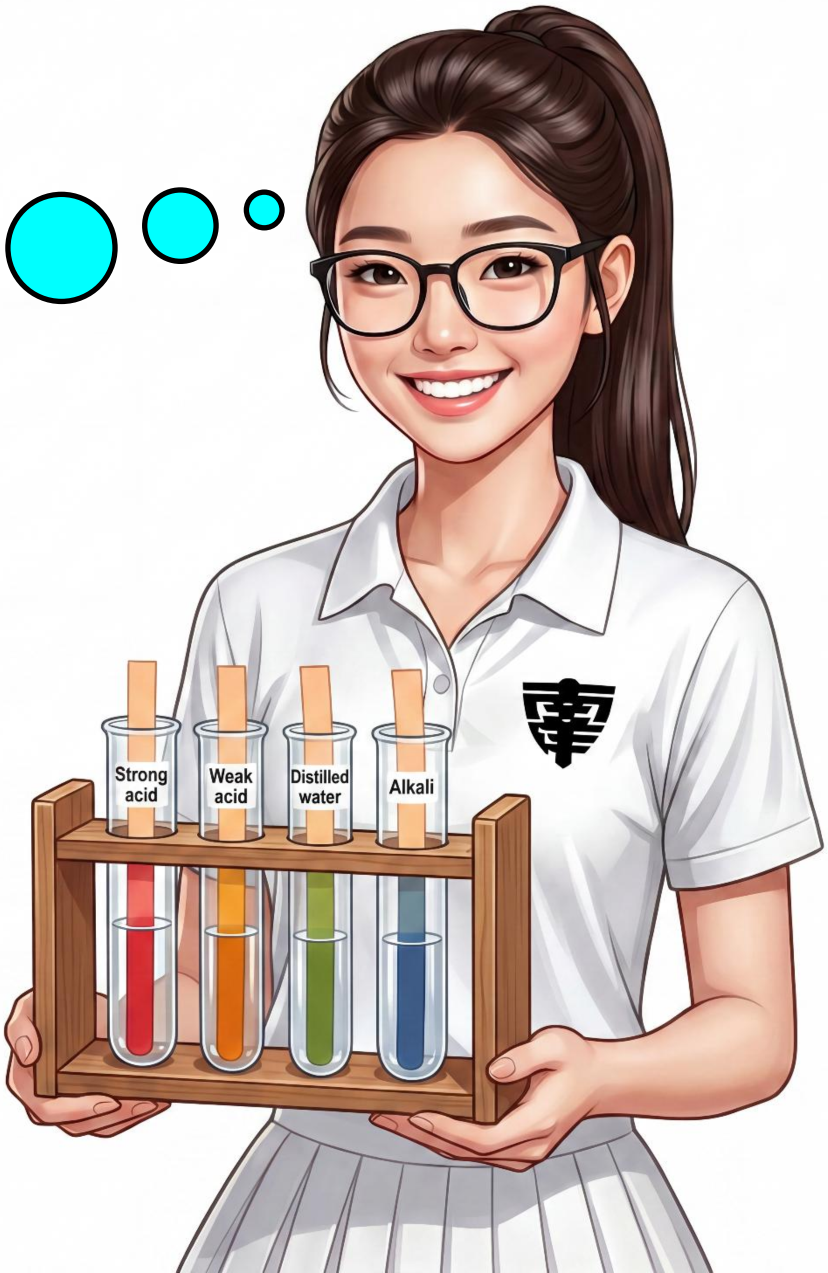
3. Is it possible for a weak acid to have a greater H^+ ion concentration than a strong acid?

- Yes, if the strong acid is *very dilute*, and the weak acid is *very concentrated*.



Acids, Bases and Salts

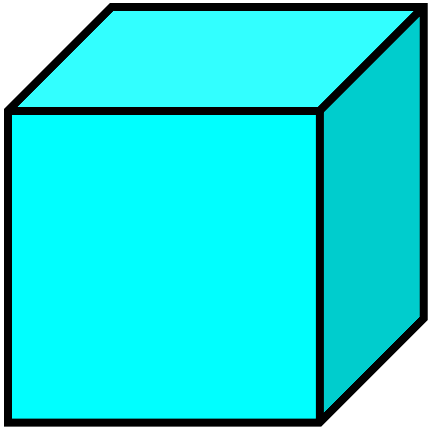
3. How far apart are the hydrogen ions in an aqueous solution of dilute acid?



Acids, Bases and Salts

- Consider a 1.00 mol/dm^3 aqueous solution of hydrochloric acid, $HCl(aq)$.

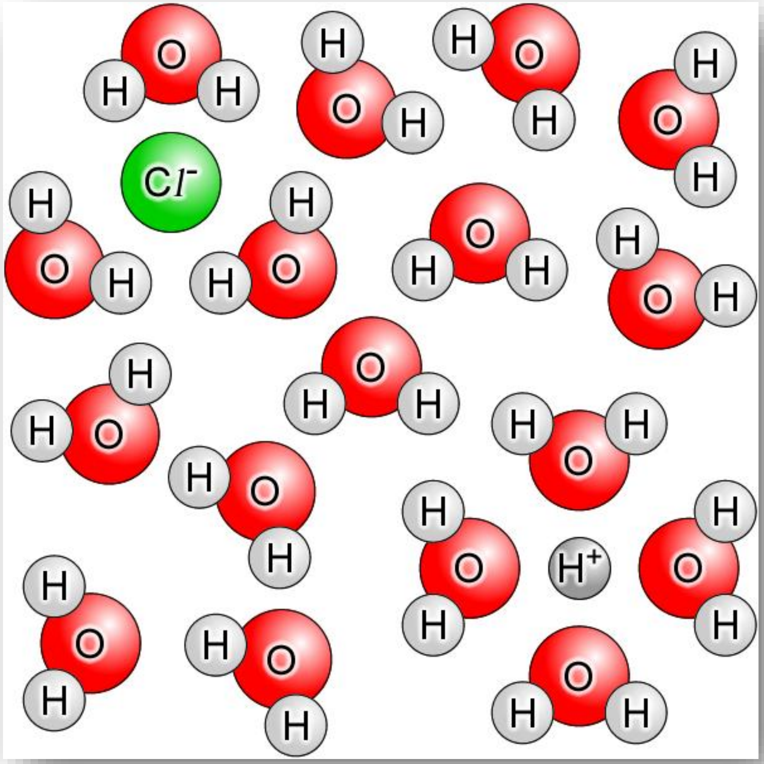
- For every 55 molecules of water, there will be one hydrogen ion, $H^+(aq)$, and one chloride ion, $Cl^-(aq)$.



- Put another way, a cube of the solution measuring approximately $4 \times 4 \times 4$ water molecules will contain one hydrogen ion, $H^+(aq)$, and one chloride ion $Cl^-(aq)$.

Acids, Bases and Salts

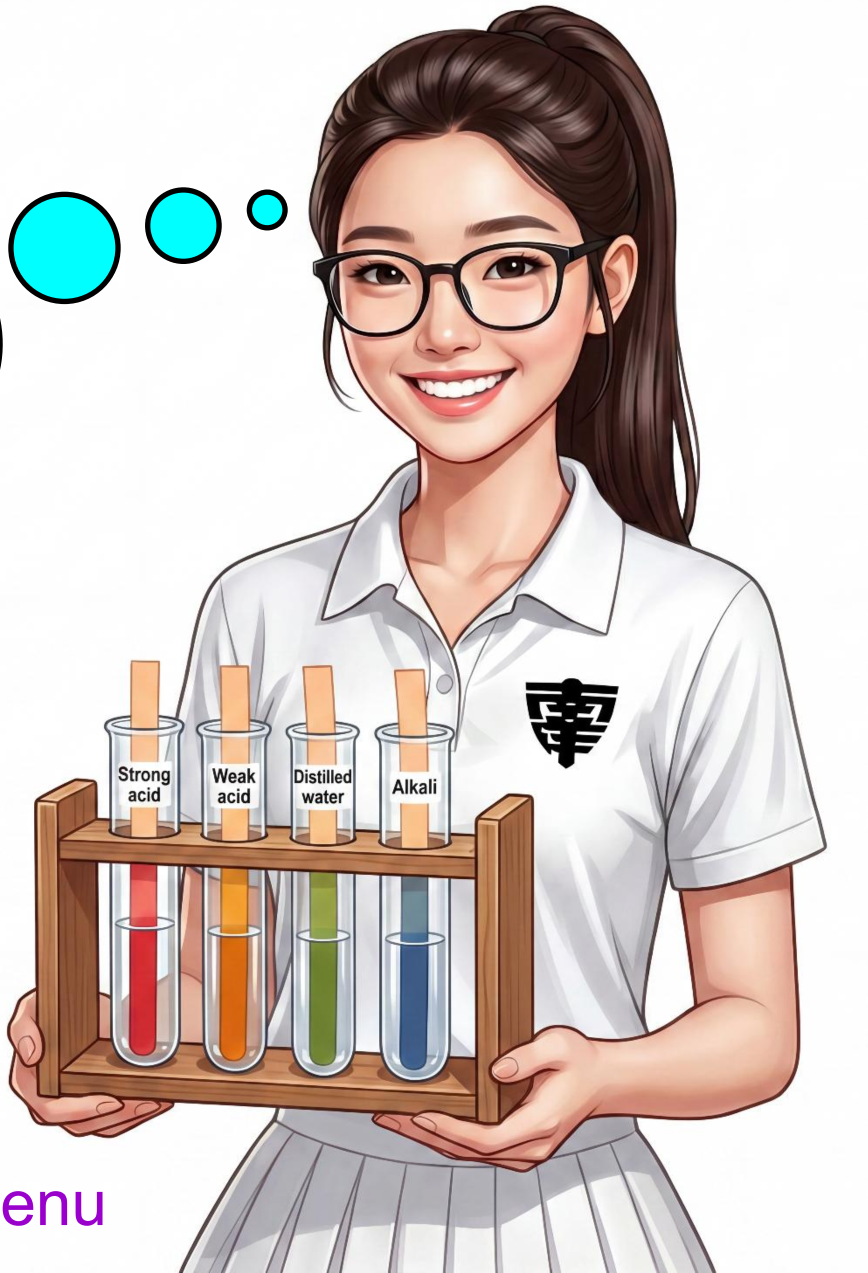
- A model representing the approximate distribution of ions in 1.00 mol/dm^3 hydrochloric acid, HCl(aq).



- On average, there are 2 – 4 water molecules in between the H$^+$(aq) and Cl^-(aq) ions.

Acids, Bases and Salts

4. What is *pH* and what information does it tell me about a solution?



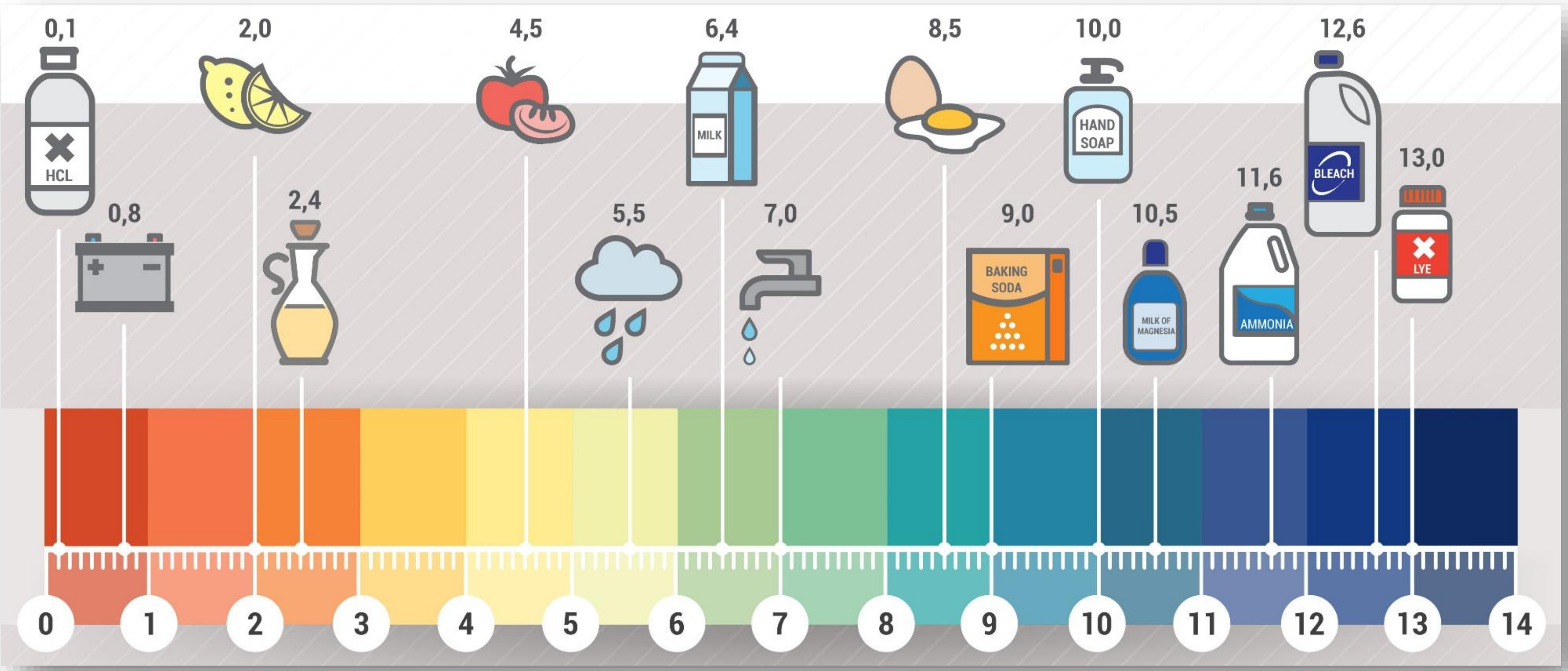
Main Menu

Acids, Bases and Salts

- pH is a numeric scale that is used to specify the acidity or alkalinity of an aqueous solution. *Acidic solutions* have pH values *less than 7* and *alkaline solutions* have pH values *greater than 7*. A chemical with a pH value of *exactly 7* is *neutral*, being neither acidic nor alkaline.
- In general, the pH scale runs from 1 to 14, although pH values less than 1 (for strong, concentrated acids) and greater than 14 (for strong, concentrated alkalis) are possible.

Acids, Bases and Salts

- pH values of some everyday chemicals.



Acids, Bases and Salts

- Many toiletries and skin-care products mention pH in their labelling and marketing.

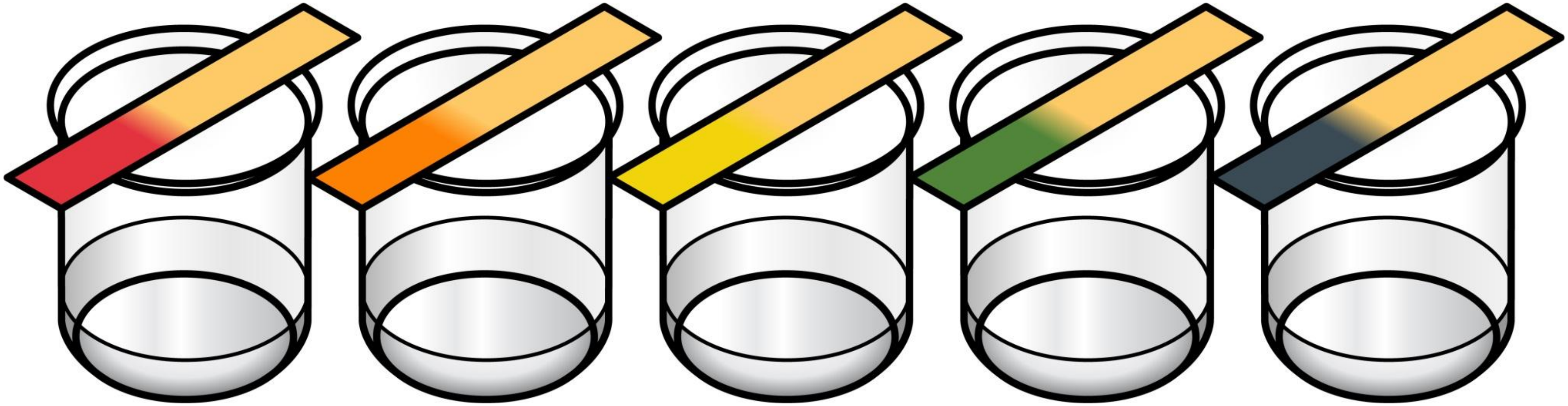
Acids, Bases and Salts

- The pH of a solution can be determined by testing the solution with Universal Indicator paper or solution. The resulting colour indicates the pH of the solution:

$1 \leftrightarrow 6$ acidic, 7 neutral, $8 \leftrightarrow 14$ alkaline.

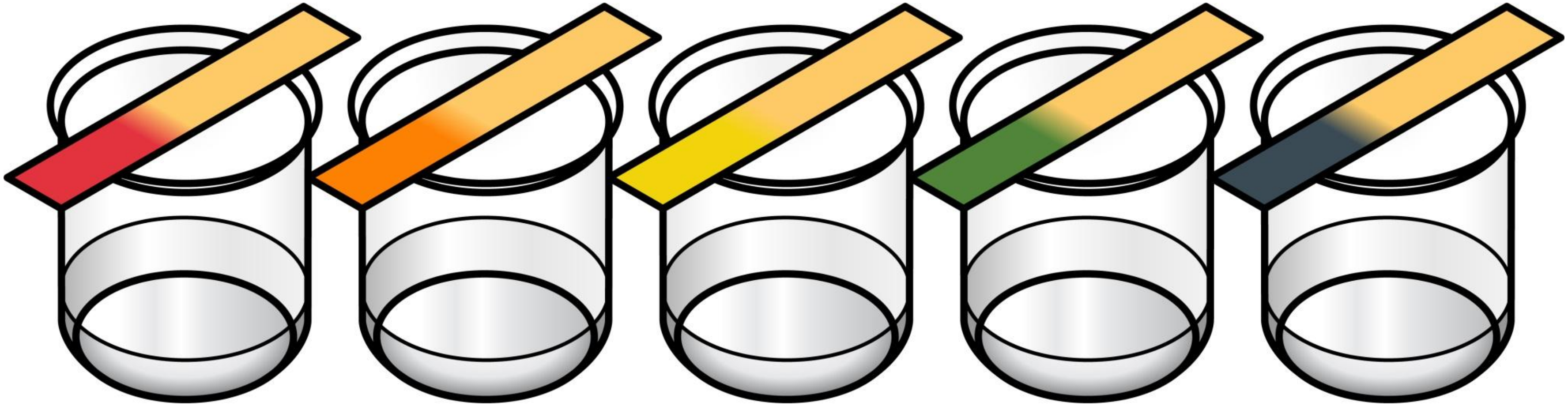
NANYANG GIRLS' HIGH

Acids, Bases and Salts



- Which of the above solutions is acidic, neutral, alkaline?

Acids, Bases and Salts



- Which of the above solutions is acidic, neutral, alkaline?

Red – Acidic (maybe a concentrated, strong acid).

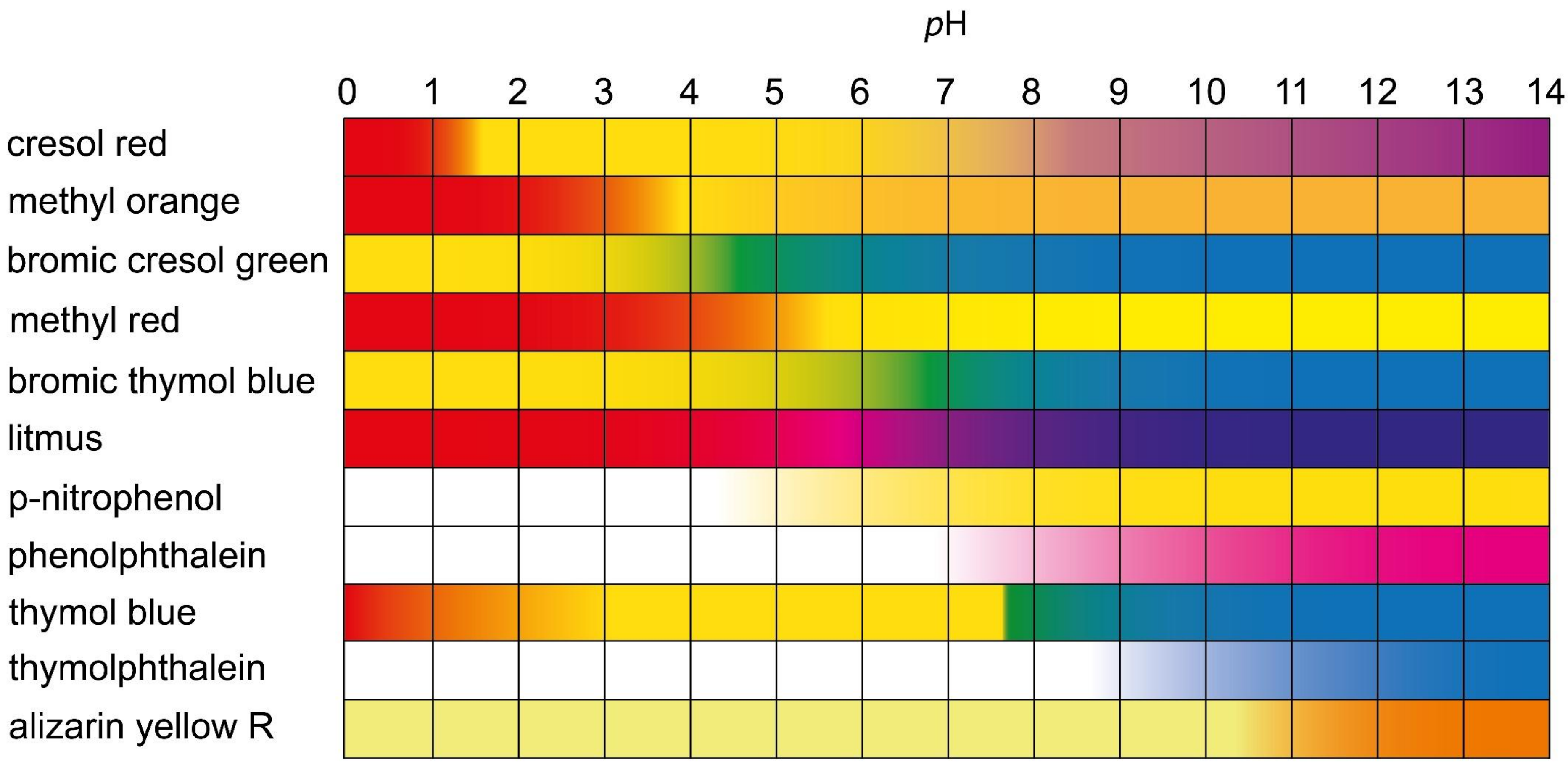
Orange – Acidic (maybe a dilute, strong acid or a concentrated weak acid).

Yellow – Acidic (maybe a dilute, weak acid).

Green – Neutral (maybe pure water).

Blue or **Purple** – Alkaline.

Acids, Bases and Salts

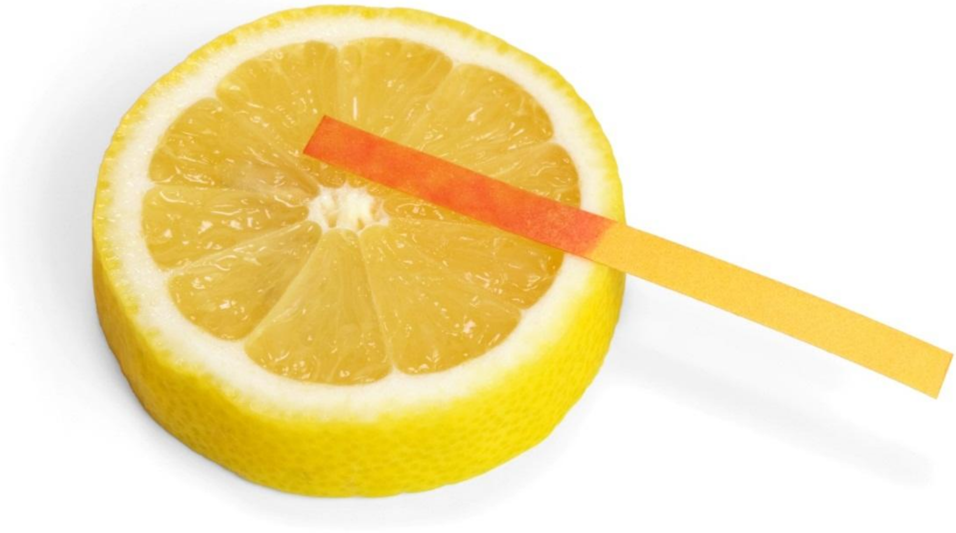


- In addition to Universal Indicator paper, there are many other indicators available.

Acids, Bases and Salts

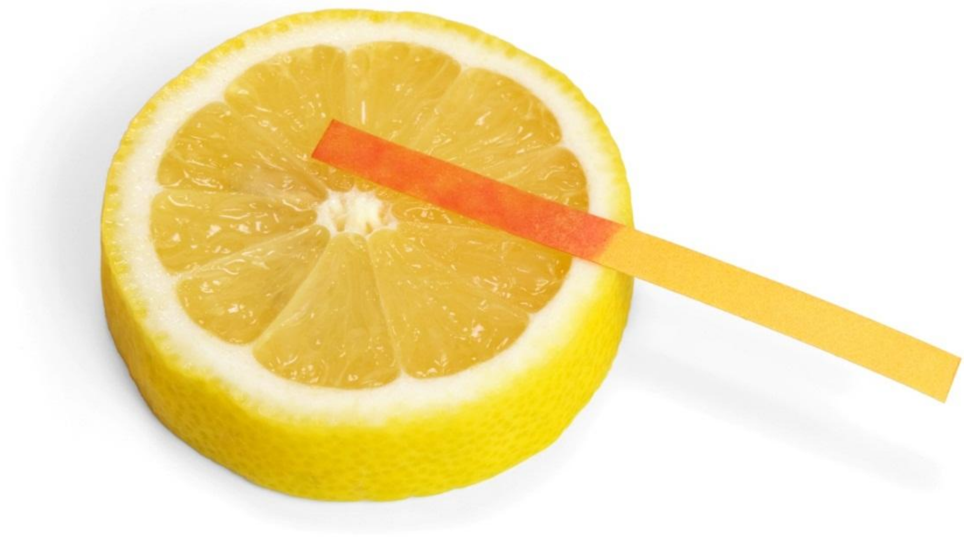
- Digital pH meters can give very accurate readings to two decimal places.

Acids, Bases and Salts



Question: Lemon juice has a pH value of 3. Explain this observation.

Acids, Bases and Salts



Question: Lemon juice has a pH value of 3. Explain this observation.

Answer: A pH value less than 7 indicates that lemon juice is acidic. Furthermore, the pH value of 3 indicates that the lemon juice contains either a relatively concentrated weak acid, or a relatively dilute strong acid. Lemon juice actually contains citric acid, which is a weak acid.

Acids, Bases and Salts

Exact definition of pH:

$$pH = -\log_{10}[H^+]$$

Where $[H^+]$ is the hydrogen ion concentration in mol/dm^3

- In simple terms, the greater the $H^+(aq)$ concentration, the lower the pH value of the solution. The lower the $H^+(aq)$ concentration, the higher the pH value of the solution.
- What is the pH of a solution in which the hydrogen ion concentration is 0.01 mol/dm^3?

Acids, Bases and Salts

Exact definition of pH:

$$pH = -\log_{10}[H^+]$$

Where $[H^+]$ is the hydrogen ion concentration in mol/dm^3

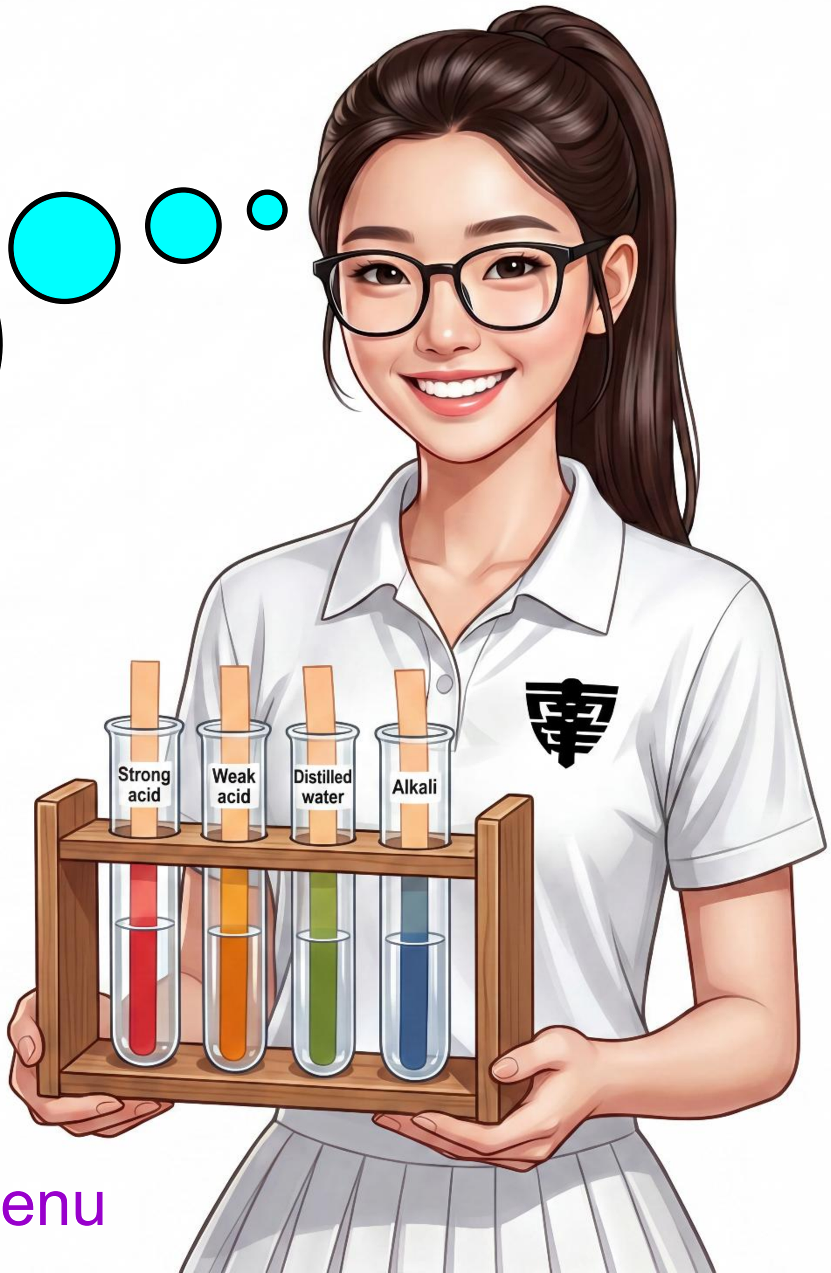
- In simple terms, the greater the $H^+(aq)$ concentration, the lower the pH value of the solution. The lower the $H^+(aq)$ concentration, the higher the pH value of the solution.

- What is the pH of a solution in which the hydrogen ion concentration is $0.01\ mol/dm^3$?

- $pH = -\log_{10}[H^+]$
  $pH = -\log_{10}[0.01]$
  $pH = -(-2)$
  $pH = 2.00$

Acids, Bases and Salts

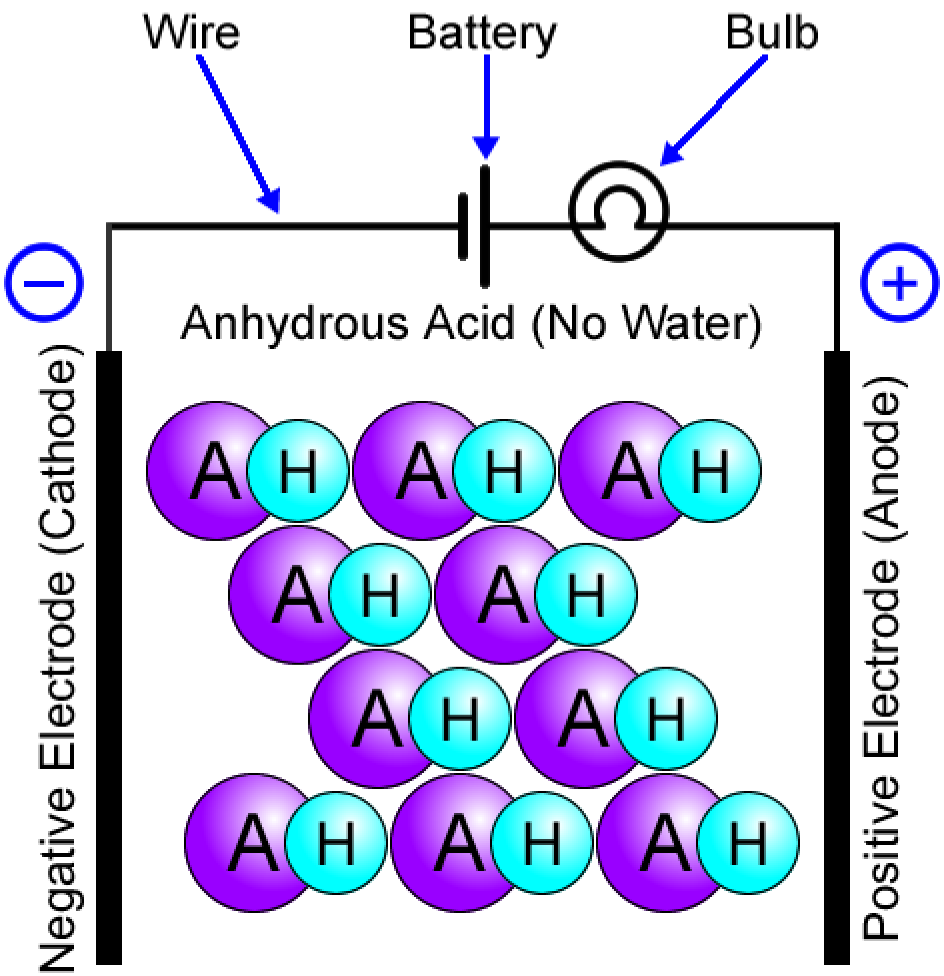
5. Are acids *electrical conductors* or *electrical insulators*?



Remember:
Electricity is the flow / movement of charged particles.

Main Menu

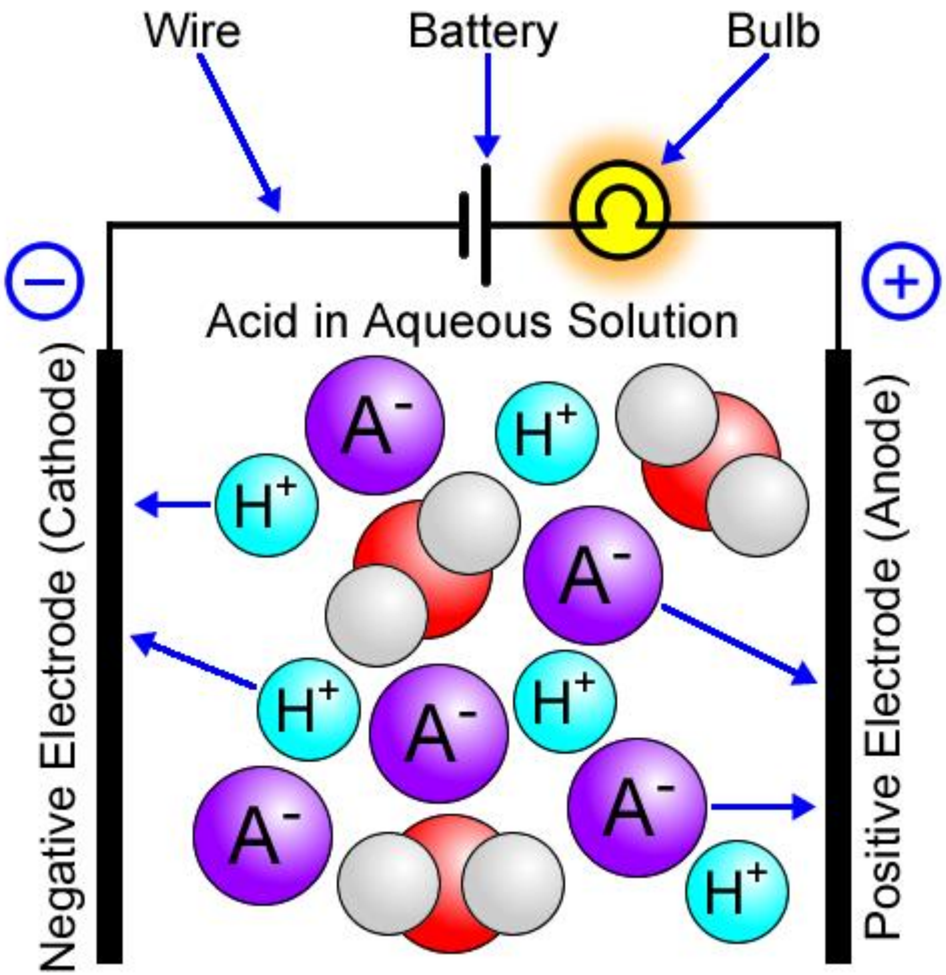
Acids, Bases and Salts



Electrical Conductivity

- A pure acid, one that has not dissolved in water, will be composed only of simple covalent molecules. There are *no mobile ions* to serve as charge carrying particles. The *pure acid is an electrical insulator*.

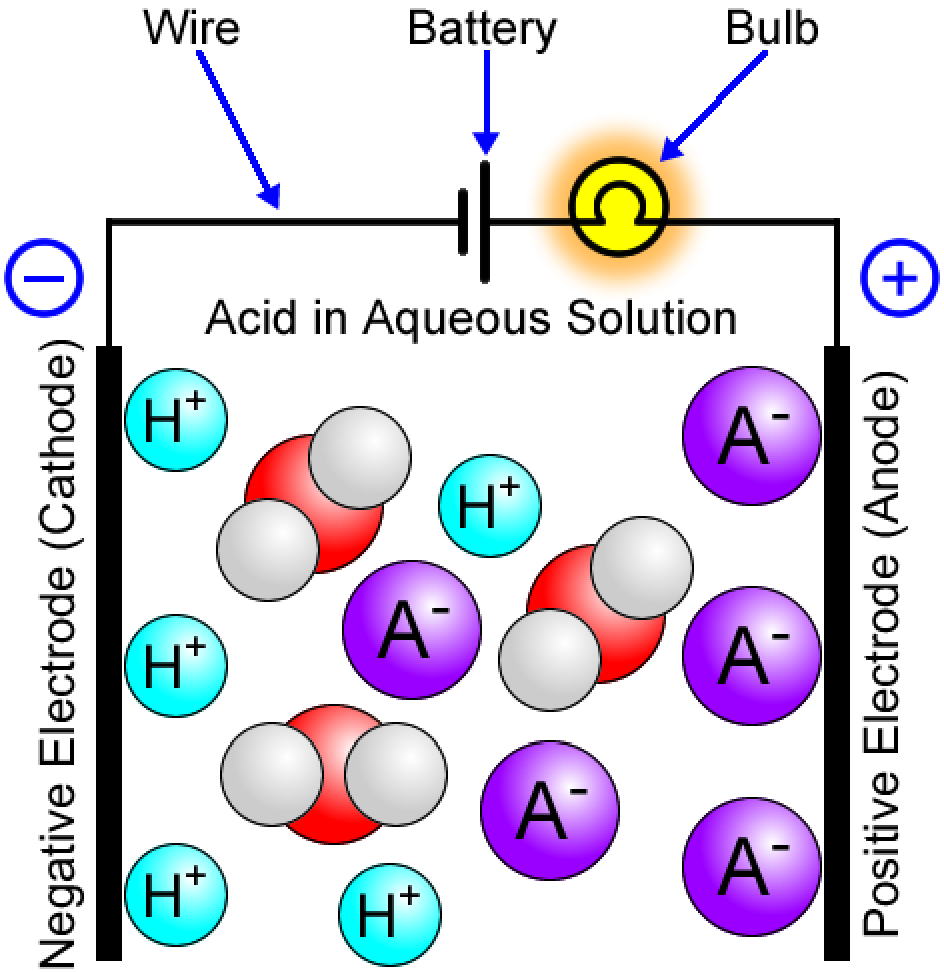
Acids, Bases and Salts



Electrical Conductivity

- Once dissolved in water, the acid will *ionize* to form positively charged hydrogen ions and anions. *The ions are free to move throughout the solution* and therefore serve as mobile charge carrying particles.

Acids, Bases and Salts



Electrical Conductivity

- When electrodes are inserted into the acidic solution, the *positively charged hydrogen ions are attracted towards the cathode*, while the *anions are attracted towards the anode*. The movement of ions towards the electrode of opposite charge constitutes the flow of electricity.

Acids, Bases and Salts

- Which one of the following solutions is a good conductor of electricity, and which one is a poor conductor of electricity?

→ A dilute strong acid.

→ A concentrated strong acid.

→ A dilute weak acid.

→ A concentrated weak acid.

Acids, Bases and Salts

- Which one of the following solutions is a good conductor of electricity, and which one is a poor conductor of electricity?

→ A dilute strong acid.

→ A concentrated strong acid.

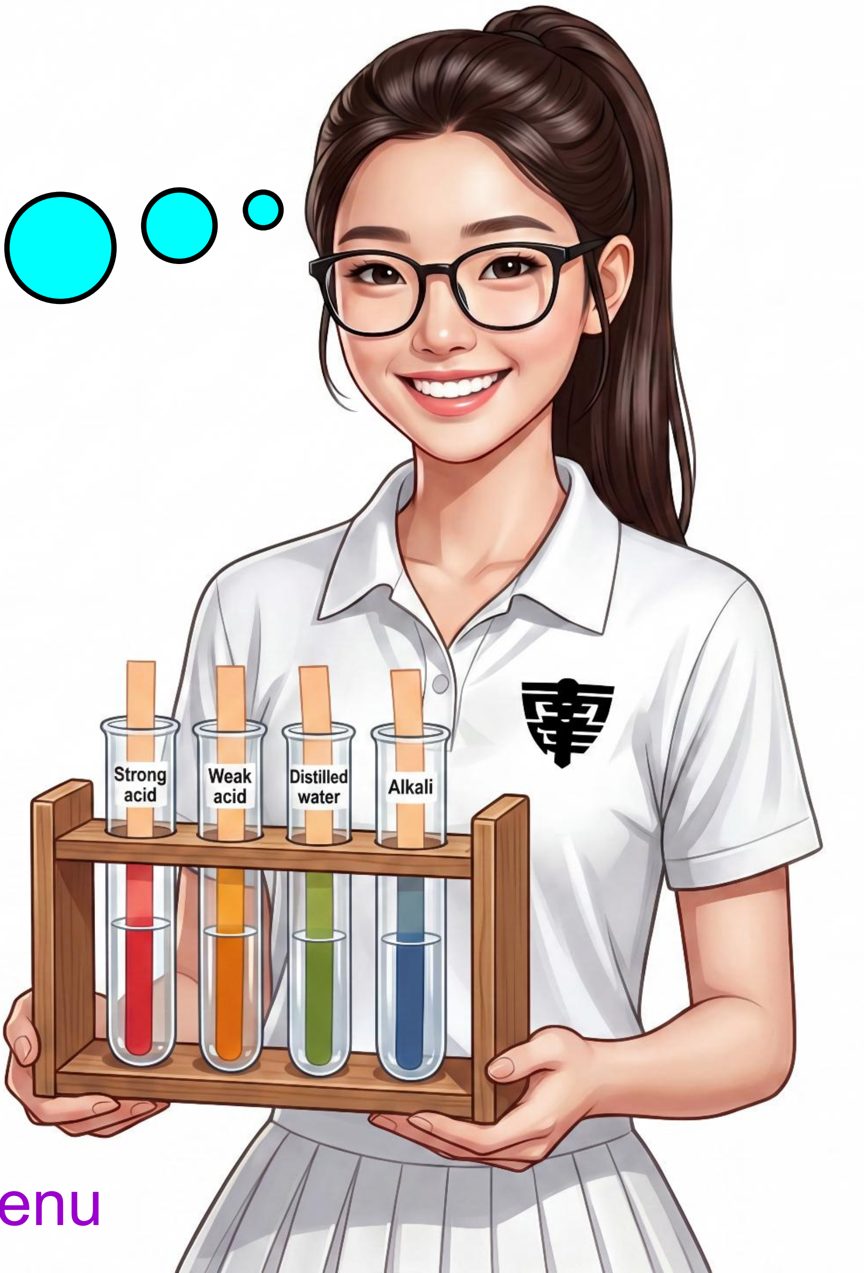
→ A dilute weak acid.

→ A concentrated weak acid.

- The *concentrated strong acid* is a *good conductor* of electricity because it has a *large* number of mobile ions per unit volume of the solution.
- The *dilute weak acid* is a *poor conductor* of electricity because it has a *small* number of mobile ions per unit volume of the solution.

Acids, Bases and Salts

6. What are the *typical reactions* of *acids*?



Main Menu

Acids, Bases and Salts

acid + reactive metal $\rightarrow$ salt + hydrogen

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc →

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc → zinc chloride + hydrogen

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc → zinc chloride + hydrogen

$$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$$

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

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$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$

nitric acid + calcium →

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc → zinc chloride + hydrogen

$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$

nitric acid + calcium → calcium nitrate + hydrogen

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc → zinc chloride + hydrogen

$$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$$

nitric acid + calcium → calcium nitrate + hydrogen

$$2HNO_3(aq) + Ca(s) \rightarrow Ca(NO_3)_2(aq) + H_2(g)$$

Acids, Bases and Salts

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hydrochloric acid + zinc → zinc chloride + hydrogen

$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$

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$2HNO_3(aq) + Ca(s) \rightarrow Ca(NO_3)_2(aq) + H_2(g)$

sulfuric acid + magnesium →

Acids, Bases and Salts

acid + reactive metal → salt + hydrogen

hydrochloric acid + zinc → zinc chloride + hydrogen

$$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$$

nitric acid + calcium → calcium nitrate + hydrogen

$$2HNO_3(aq) + Ca(s) \rightarrow Ca(NO_3)_2(aq) + H_2(g)$$

sulfuric acid + magnesium → magnesium sulfate + hydrogen

Acids, Bases and Salts

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Acids, Bases and Salts

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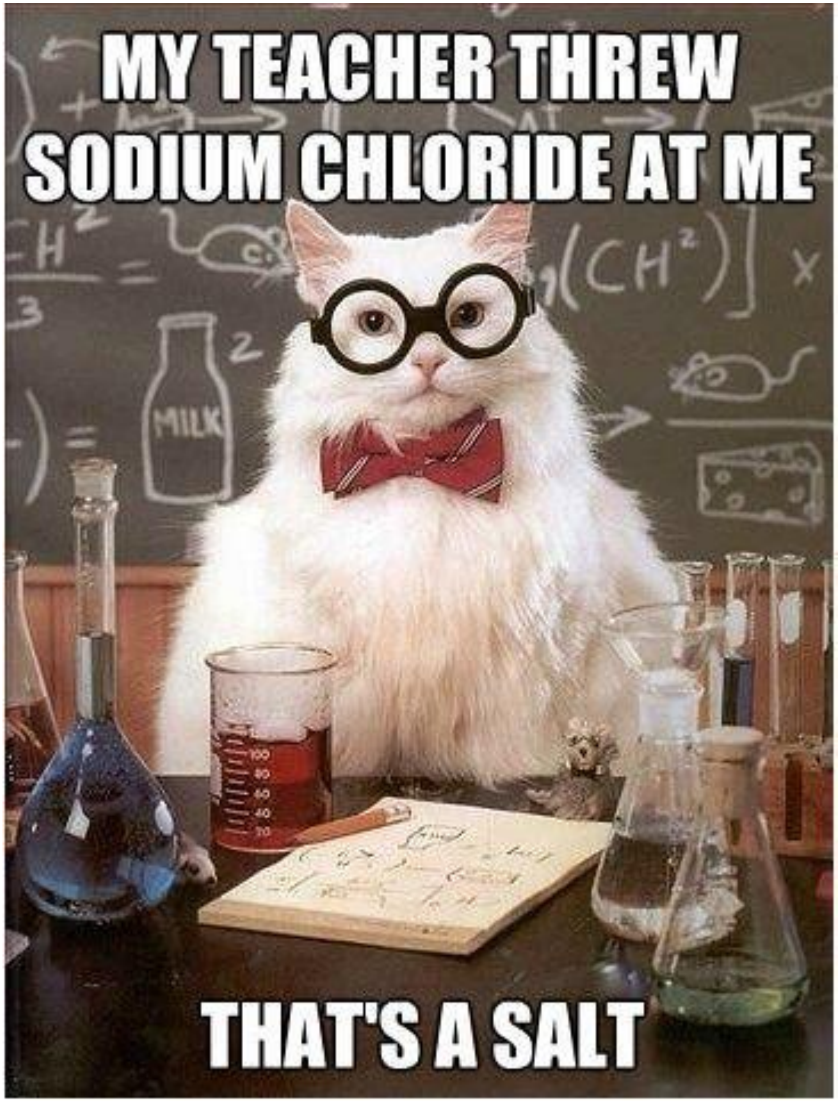
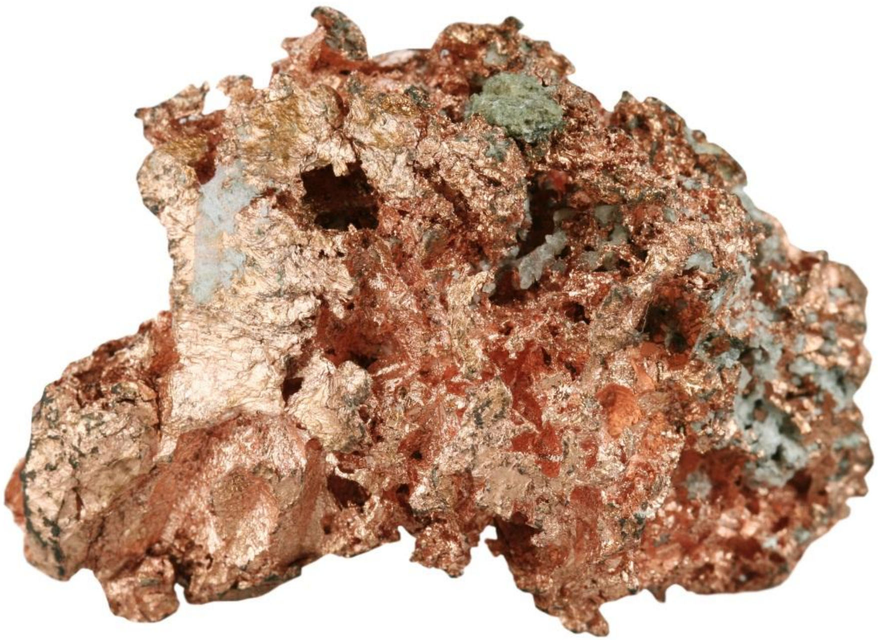
- Note: The *salt* is formed when the *hydrogen* of the acid is replaced by a *metal*.

Acids, Bases and Salts



Acids, Bases and Salts

acid + reactive metal → salt + hydrogen



- Copper ore.

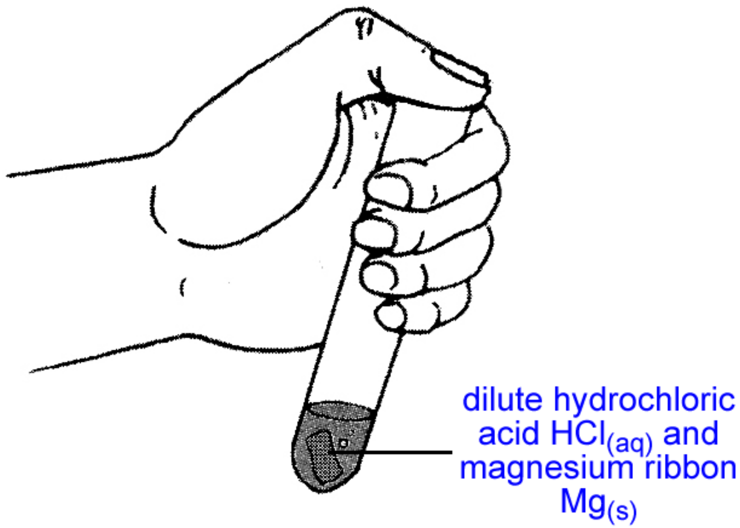
- Most, but *not all* metals react with acids.

- Metals *below hydrogen* in the reactivity series do *not* react with acids.

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

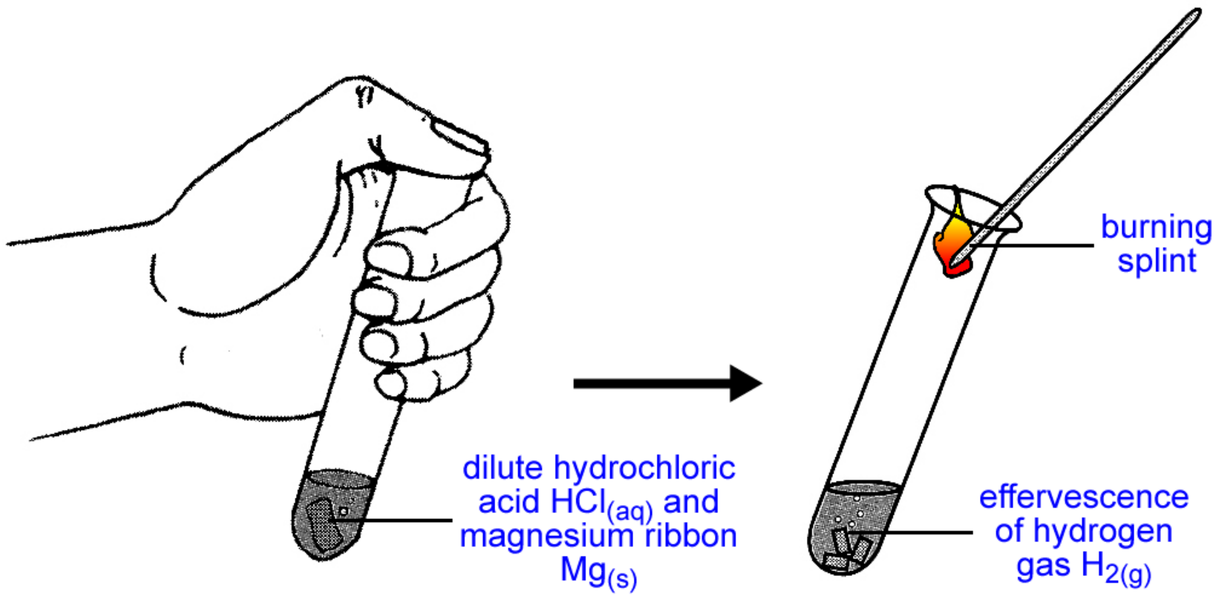
Acids, Bases and Salts

acid + reactive metal → salt + hydrogen



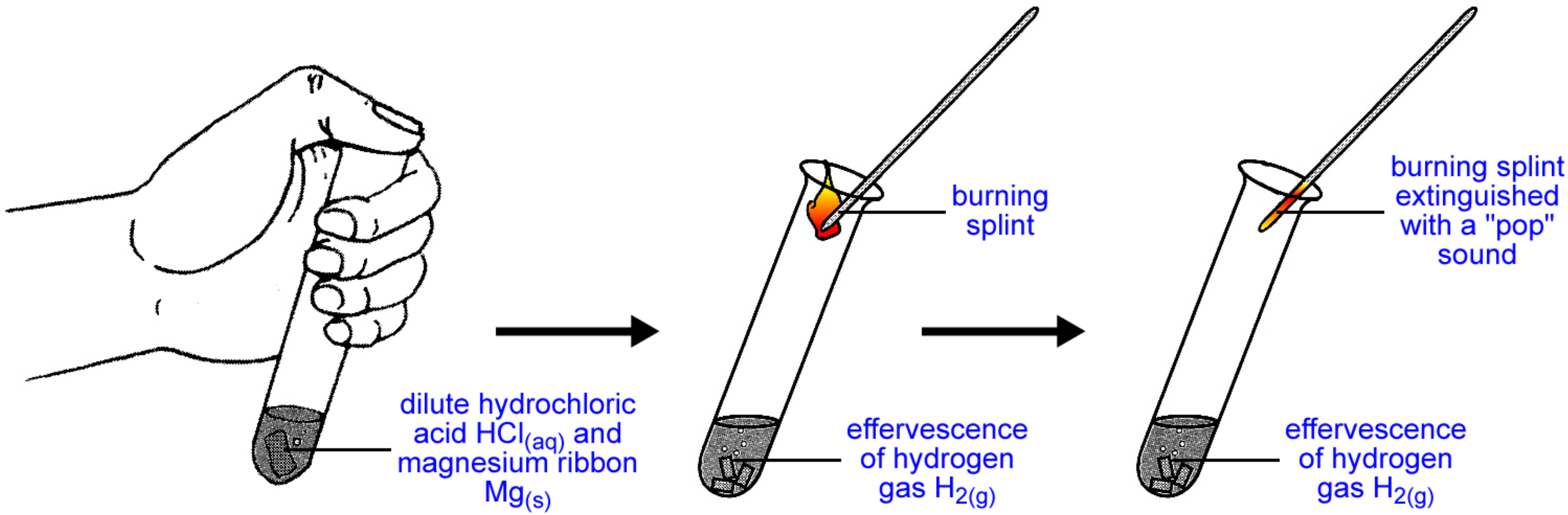
Acids, Bases and Salts

acid + reactive metal $\rightarrow$ salt + hydrogen



Acids, Bases and Salts

acid + reactive metal → salt + hydrogen



Hydrogen gas will **extinguish** a **burning** splint with a squeaky “pop” sound.

Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

hydrochloric acid + sodium hydroxide →

Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water

hydrochloric acid + sodium hydroxide $\rightarrow$ sodium chloride + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

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$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

Acids, Bases and Salts

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$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

nitric acid + calcium hydroxide →

Acids, Bases and Salts

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$$2HNO_3(aq) + Ca(OH)_2(s) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$$

Acids, Bases and Salts

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sulfuric acid + copper(II) oxide →

Acids, Bases and Salts

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Acids, Bases and Salts

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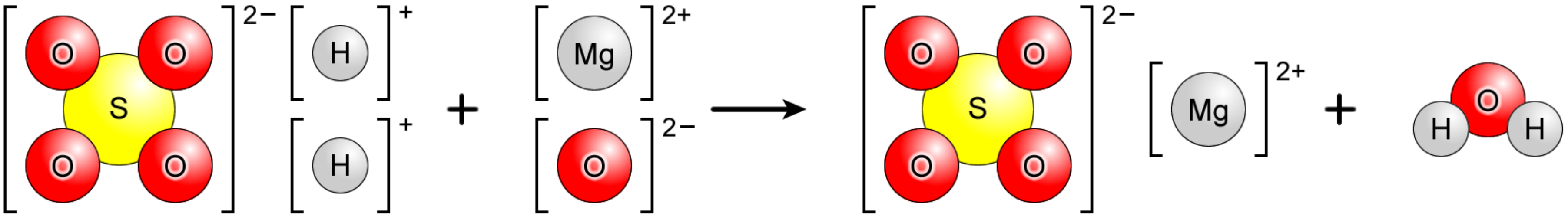
- Note: The *salt* is formed when the *hydrogen* of the acid is replaced by a *metal*.

- Note: *All* bases / alkalis will react with an acid.

Acids, Bases and Salts

- What does an acid-base reaction look like at a molecular level?



- Essentially, acid-base reactions involve the movement / transfer of hydrogen ions, $H^+(aq)$.

Acids, Bases and Salts

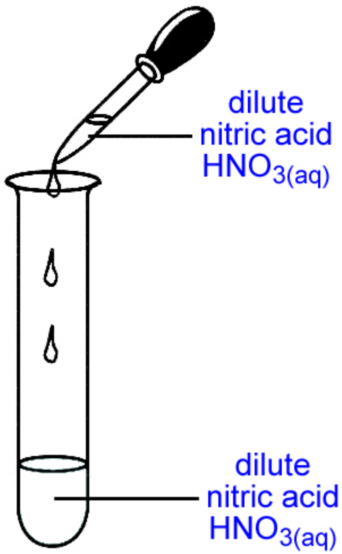
- The reaction between the hydrogen ions of an acid and the hydroxide ions of an alkali to form water is called *neutralisation*.

- The ionic equation for this reaction is:

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

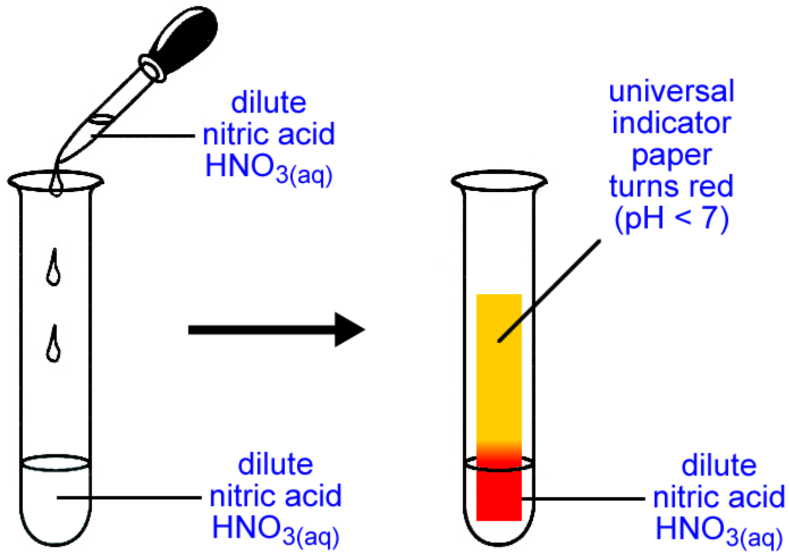
Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water



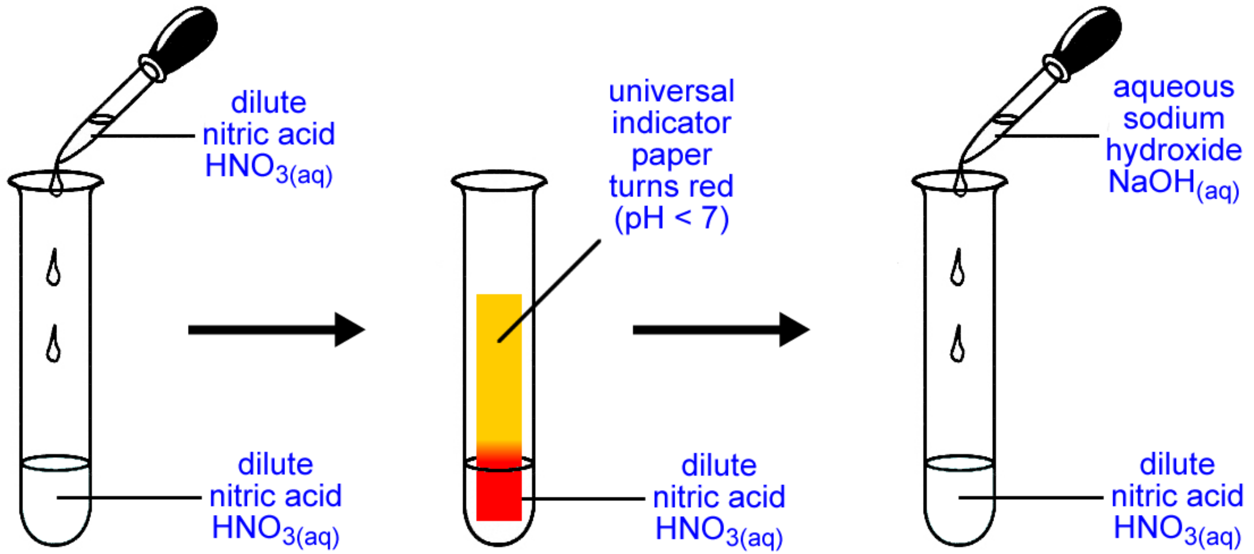
Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water



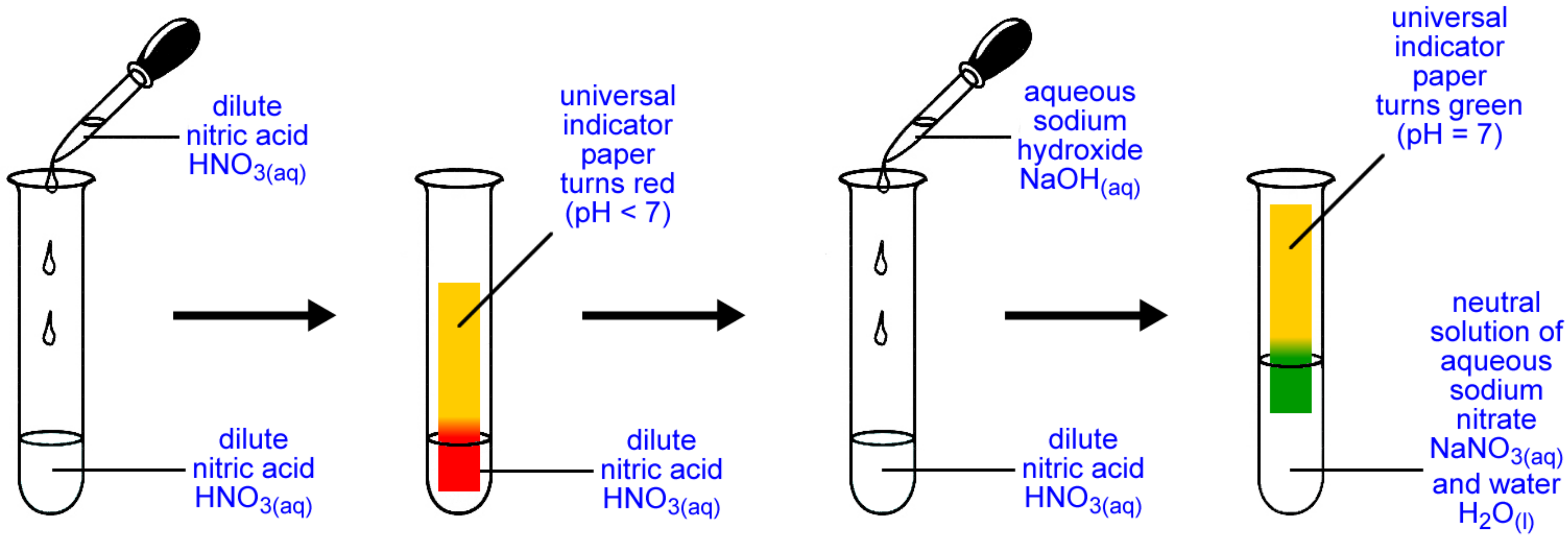
Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water



Acids, Bases and Salts

acid + base (alkali) → salt + water



nitric acid + sodium hydroxide → sodium nitrate + water

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

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

Acids, Bases and Salts

acid + carbonate $\rightarrow$ salt + water + carbon dioxide

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate
↓
sodium chloride + water + carbon dioxide

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

sodium chloride + water + carbon dioxide

$$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

sodium chloride + water + carbon dioxide

$$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

nitric acid + copper(II) carbonate

↓

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

sodium chloride + water + carbon dioxide

$$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

nitric acid + copper(II) carbonate

↓

copper(II) nitrate + water + carbon dioxide

NANYANG GIRLS' HIGH

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

sodium chloride + water + carbon dioxide

$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

nitric acid + copper(II) carbonate

↓

copper(II) nitrate + water + carbon dioxide

$2HNO_3(aq) + CuCO_3(s) \rightarrow Cu(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide

hydrochloric acid + sodium carbonate

↓

sodium chloride + water + carbon dioxide

$$2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

nitric acid + copper(II) carbonate

↓

copper(II) nitrate + water + carbon dioxide

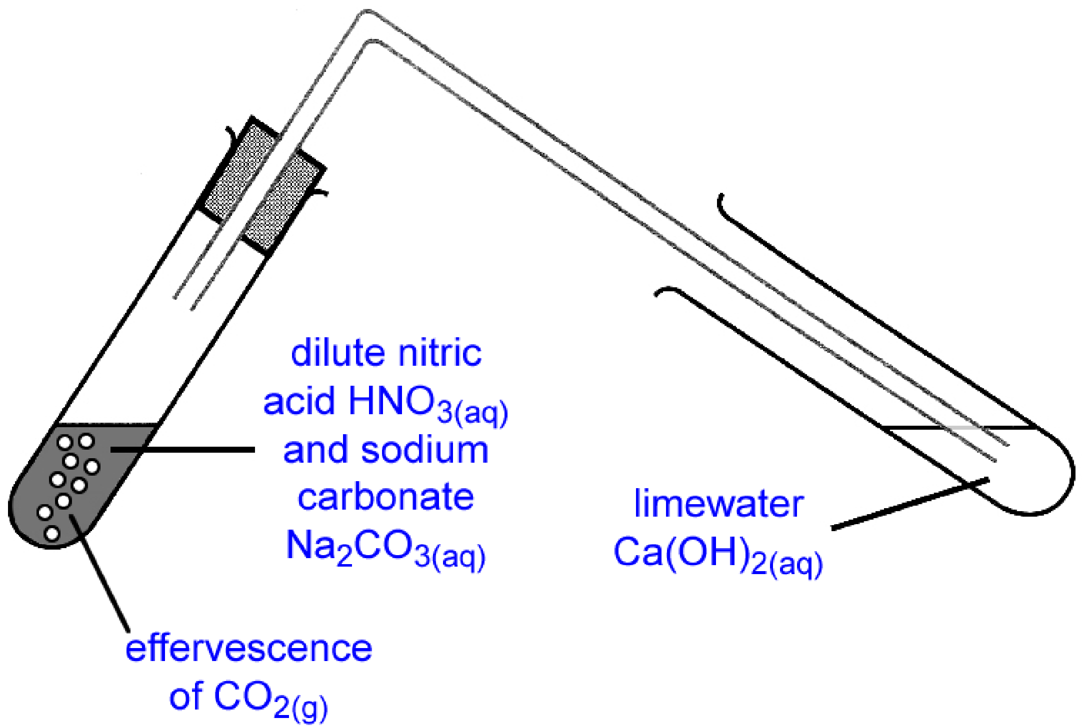
$$2HNO_3(aq) + CuCO_3(s) \rightarrow Cu(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

- Note: The *salt* is formed when the *hydrogen* of the acid is replaced by a *metal*.

- Note: *All* metal carbonates will react with an acid.

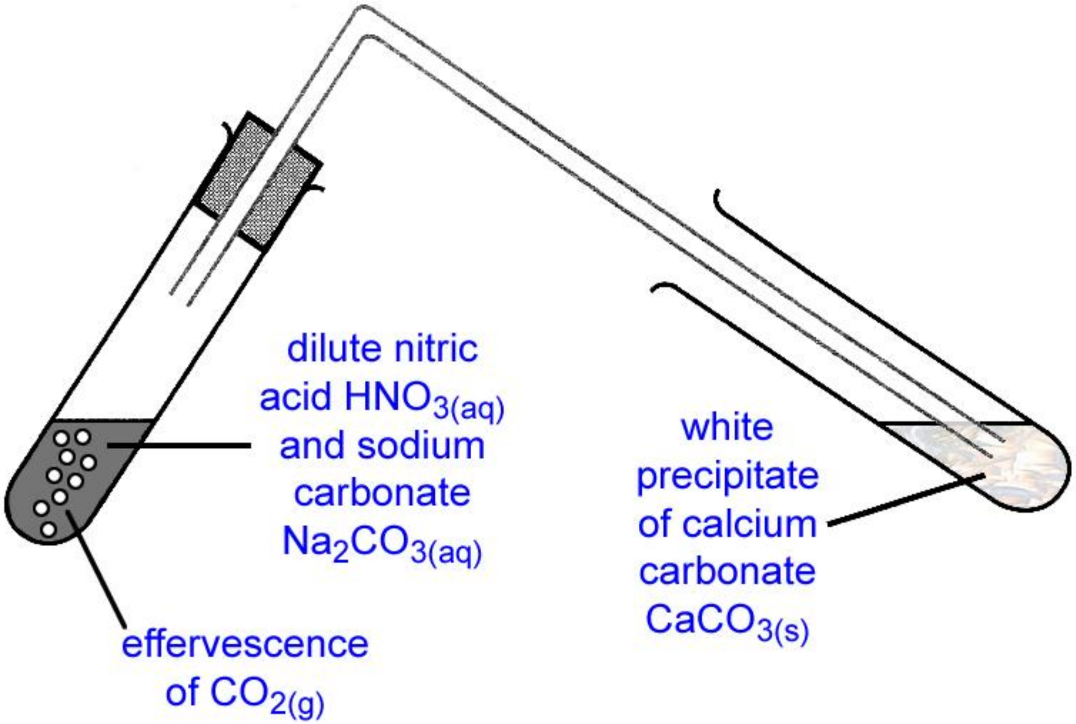
Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide



Acids, Bases and Salts

acid + carbonate → salt + water + carbon dioxide



Calcium Hydroxide + Carbon Dioxide → Calcium Carbonate + Water

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

$$Ca^{2+}(aq) + 2OH^-(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Acids, Bases and Salts

Note: When a *dibasic* or *tribasic* acid reacts, it is possible for the hydrogen ions of the acid to be replaced by metal ions *one-at-a-time*, *i.e.* the hydrogen ions of a dibasic or tribasic acid *do not* need to be replaced *all-at-once*.

- Example, phosphoric acid reacting with sodium hydroxide:

$$H_3PO_4(aq) + NaOH(aq) \rightarrow NaH_2PO_4(aq) + H_2O(l)$$

monosodium dihydrogen phosphate
an acid salt

$$NaH_2PO_4(aq) + NaOH(aq) \rightarrow Na_2HPO_4(aq) + H_2O(l)$$

disodium monohydrogen phosphate
an acid salt

$$Na_2HPO_4(aq) + NaOH(aq) \rightarrow Na_3PO_4(aq) + H_2O(l)$$

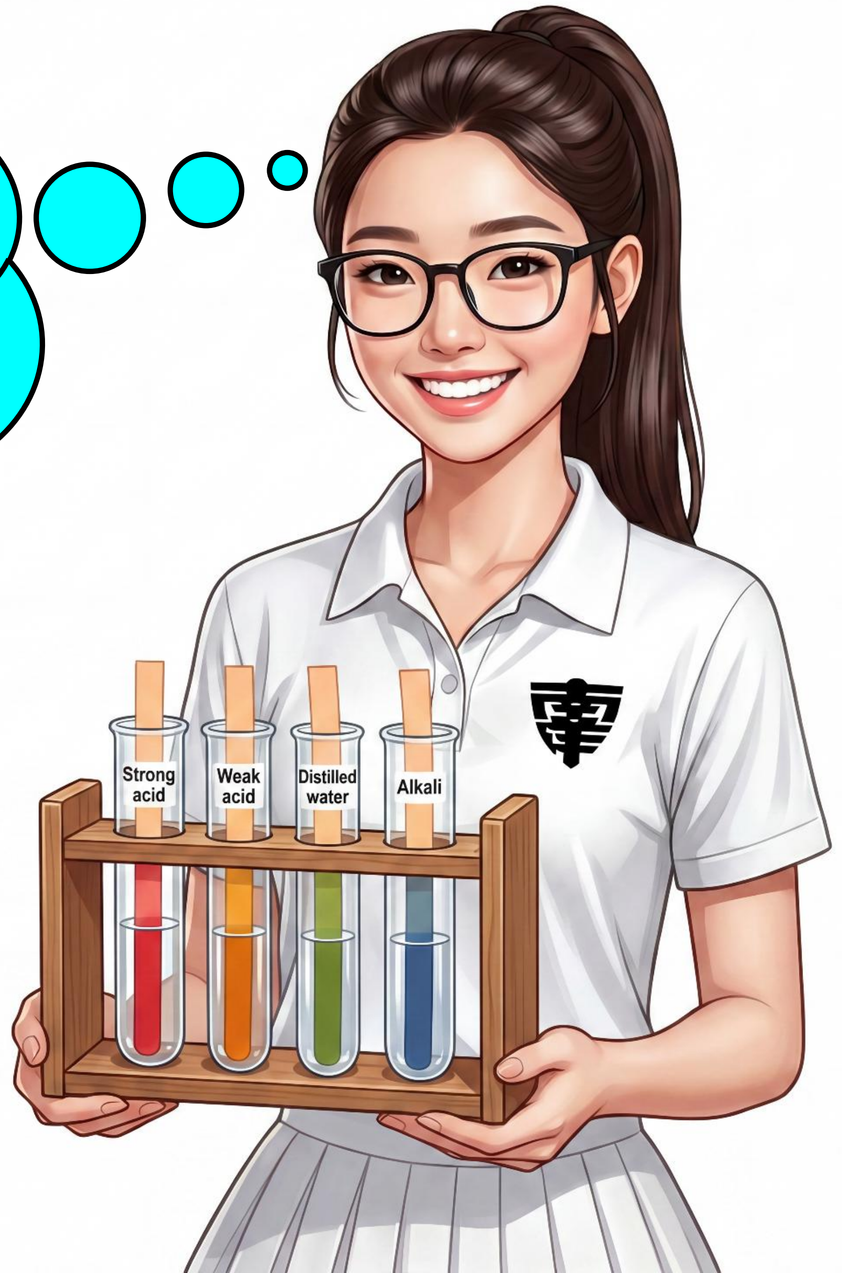
trisodium phosphate (sodium phosphate)

- The overall reaction is:

$$H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

Acids, Bases and Salts

6. Given an *unknown solution*, what chemical tests can I perform to determine if it is an *acid*?



Acids, Bases and Salts

- Using blue litmus paper (blue → red) is *not* considered as a chemical test for an acid.

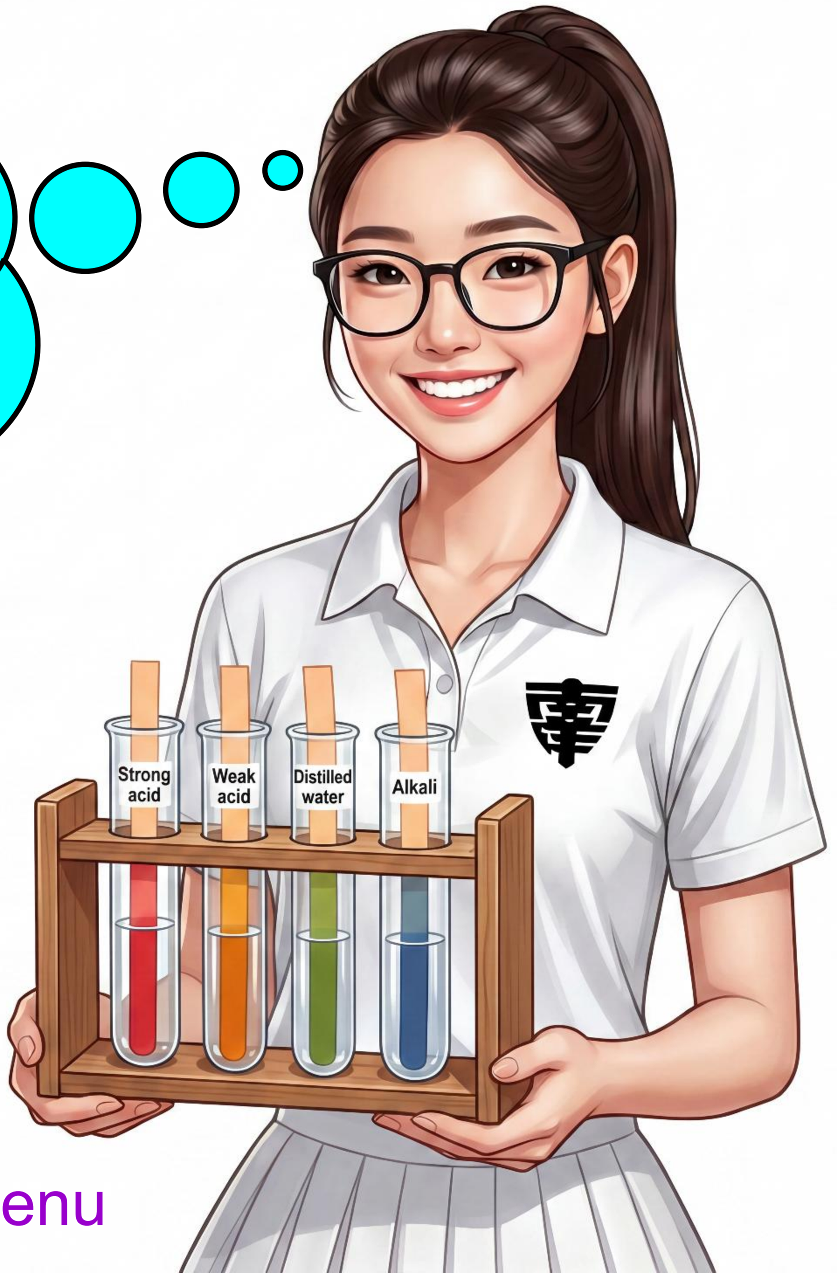
- Using universal indicator solution (green → red / orange / yellow) is *not* considered as a chemical test for an acid.

- Adding a reactive metal, *e.g.* magnesium or zinc, to the acid, observing effervescence, and then testing the gas with a burning splint (it should be extinguished with a "pop" sound) *is* considered as a chemical test for an acid.

- Adding a metal carbonate, *e.g.* sodium carbonate, to the acid, observing effervescence, and then testing the gas with limewater (a white precipitate should be produced) *is* considered as a chemical test for an acid.

Acids, Bases and Salts

7. The reactions of acids all produce salts. How do I know which salts are *soluble* (aq) and *insoluble* (s) in water?



Main Menu

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

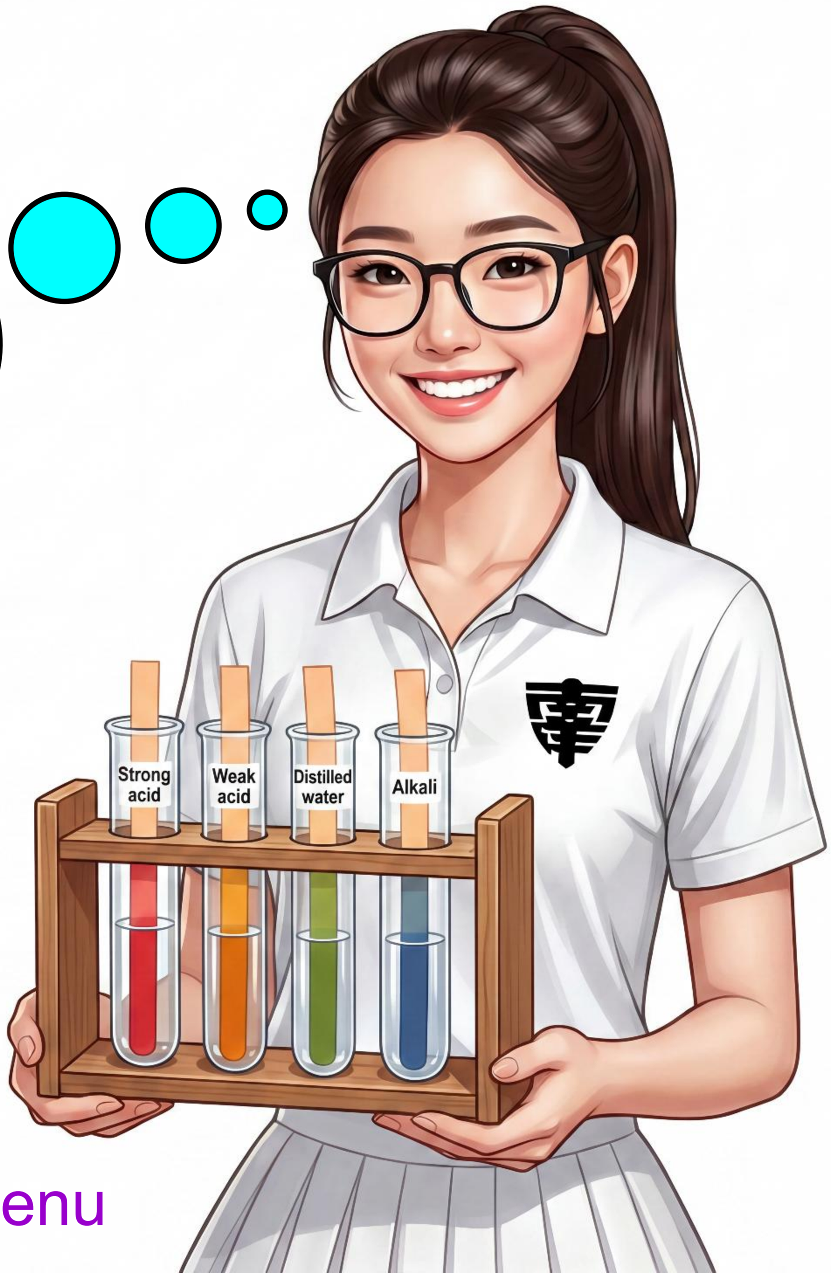
- All ammonium salts are _soluble_ in water.
- All potassium salts* are _soluble_ in water.
- All sodium salts* are _soluble_ in water.
- All carbonates are _insoluble_ in water, except Na_2CO_3, K_2CO_3, $(NH_4)_2CO_3$
- All chlorides* are _soluble_ in water, except $AgCl$, $PbCl_2$
- All ethanoates (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

8. What is an *acid salt* ?



Main Menu

Acids, Bases and Salts

- *Acid salt* is the name given to a group of salts that are formed by the *partial neutralisation* of a dibasic or tribasic (polybasic) acid.
- Because the polybasic acid has only been partially neutralised, *one or more replaceable hydrogen atoms* remain.
- Typical acid salts contain one or more metal ions and one or more hydrogen atoms.
- Typical examples include sodium hydrogen carbonate, $NaHCO_3$, and sodium hydrogen sulfate, $NaHSO_4$.
- Acid salts can be either *acidic* or *alkaline* in nature and are often used as *buffers* (chemicals that maintain / regulate the pH of a solution).

Acids, Bases and Salts

- Formation of the acid salt, sodium hydrogen sulfate:

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

- Formation of the acid salt, sodium hydrogen carbonate:

$$H_2CO_3(aq) + NaOH(aq) \rightarrow NaHCO_3(aq) + H_2O(l)$$

- Formation of the acid salt, sodium hydrogen phosphate:

$$H_3PO_4(aq) + NaOH(aq) \rightarrow NaH_2PO_4(aq) + H_2O(l)$$

- **Note**: Acid salts are *not* true acids because they do *not* dissolve in water to produce hydrogen ions as the *only positive ion*, *e.g.*

$$NaHSO_4(s) \rightarrow Na^+(aq) + H^+(aq) + SO_4^{2-}(aq)$$

Acids, Bases and Salts

- Acid salts contain hydrogen that can be replaced by a metal, allowing the acid salt to react like an acid to form a salt and water, *e.g.*

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

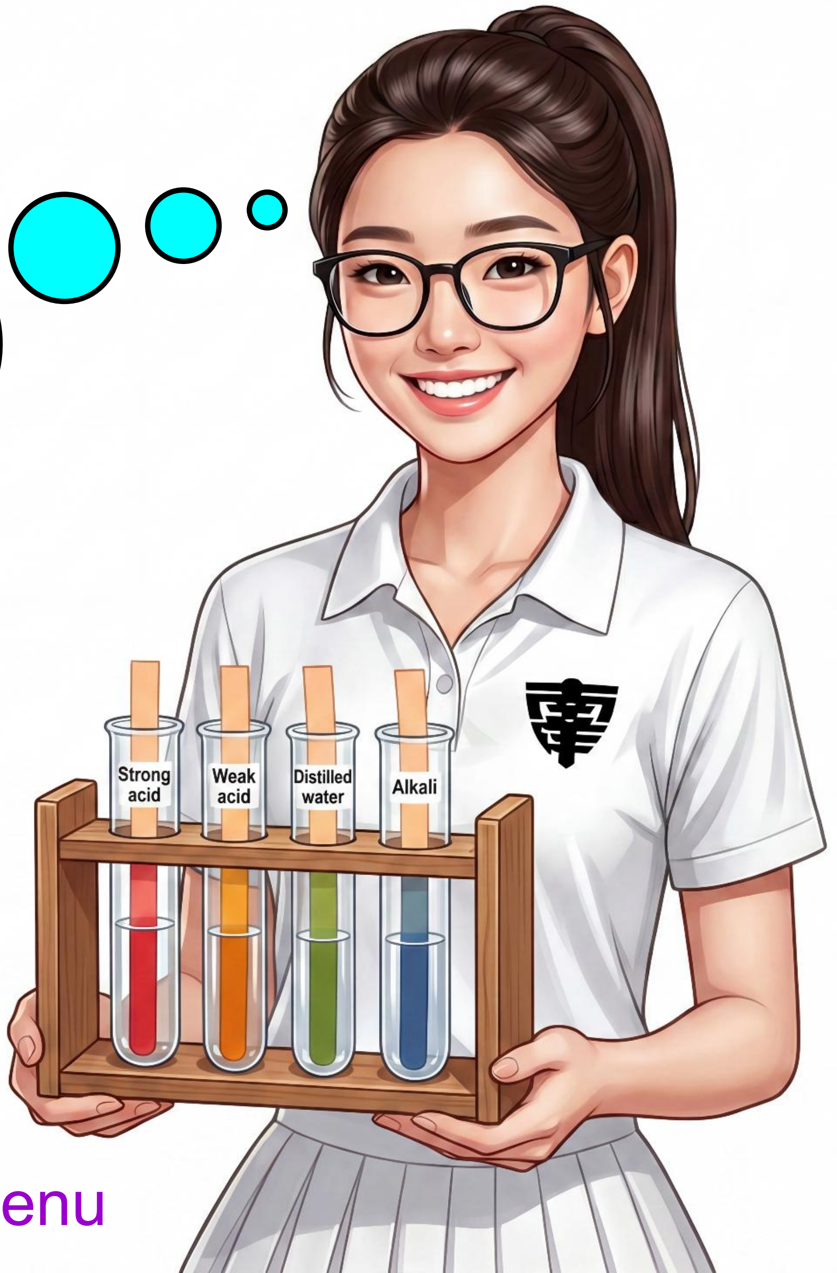
- Acid salts contain a metal that can be replaced by hydrogen, allowing the acid salt to react like a base, *e.g.*

$$NaHSO_4(aq) + HCl(aq) \rightarrow H_2SO_4(aq) + NaCl(aq)$$

- Because acid salts can remove both H^+ and OH^- from aqueous solution, they are able to regulate the pH of a solution. Chemicals that are able to maintain / regulate the pH of a solution are referred to as *buffers*.

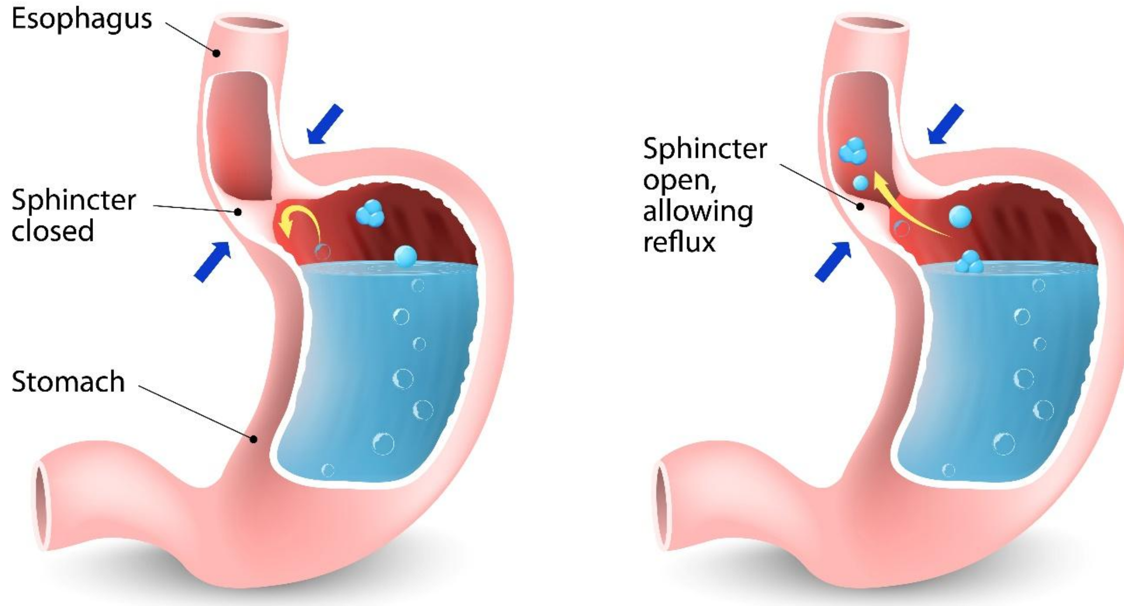
Acids, Bases and Salts

9. How are *bases* and *metal carbonates* used in everyday *medicine*?



Main Menu

Acids, Bases and Salts



- Acid reflux is a painful condition that occurs when hydrochloric acid in the stomach passes through the esophageal sphincter and irritates the delicate lining of the esophagus.

Acids, Bases and Salts

- Antacids that contain *calcium carbonate* react with and neutralise the hydrochloric acid, easing the discomfort.

$$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Acids, Bases and Salts

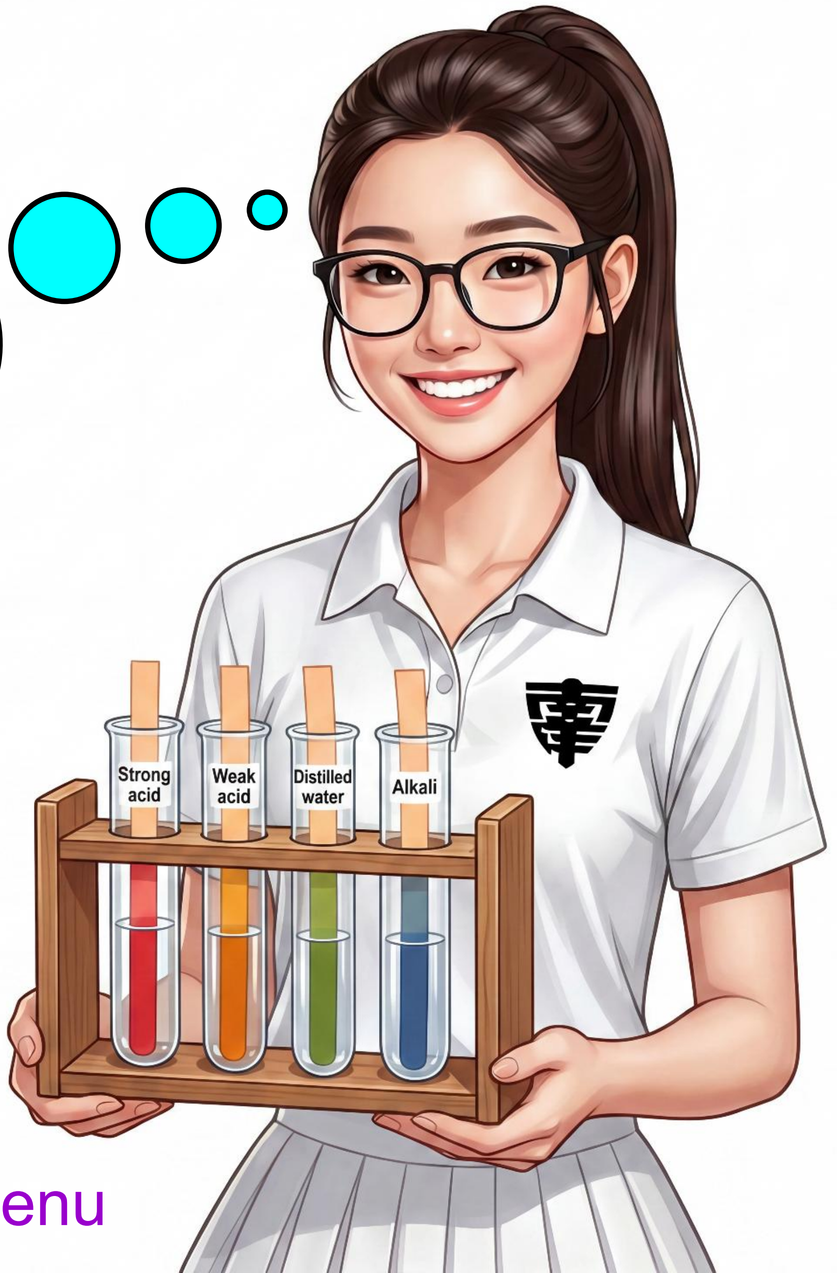
- Antacids that contain *magnesium hydroxide* react with and neutralise the hydrochloric acid, easing the discomfort.

$$2HCl(aq) + Mg(OH)_2(s) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

NANYANG GIRLS' HIGH

Acids, Bases and Salts

10. What are *acids* typically used for?



Acids, Bases and Salts

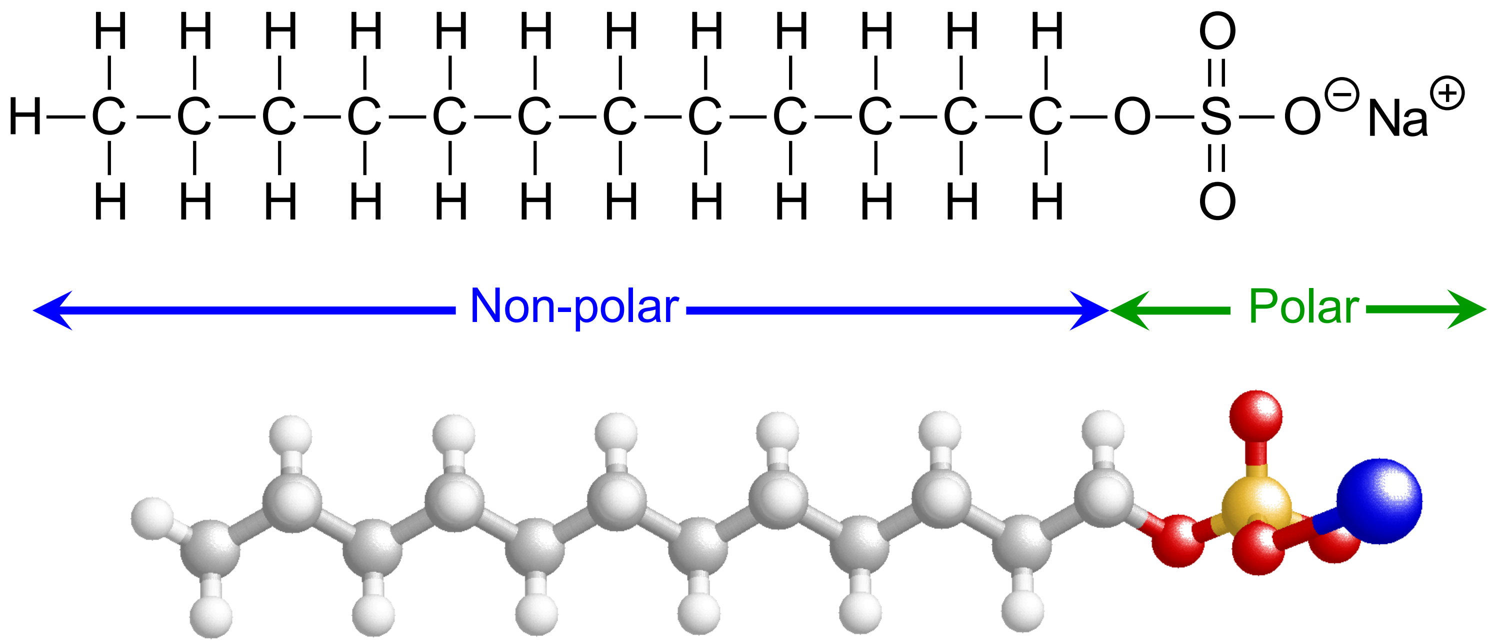
- Sulfuric acid is used to manufacture *detergents*.

Acids, Bases and Salts

- Detergents are used to remove *non-polar* chemicals, such as oil and grease, from clothing and dirty dishes.

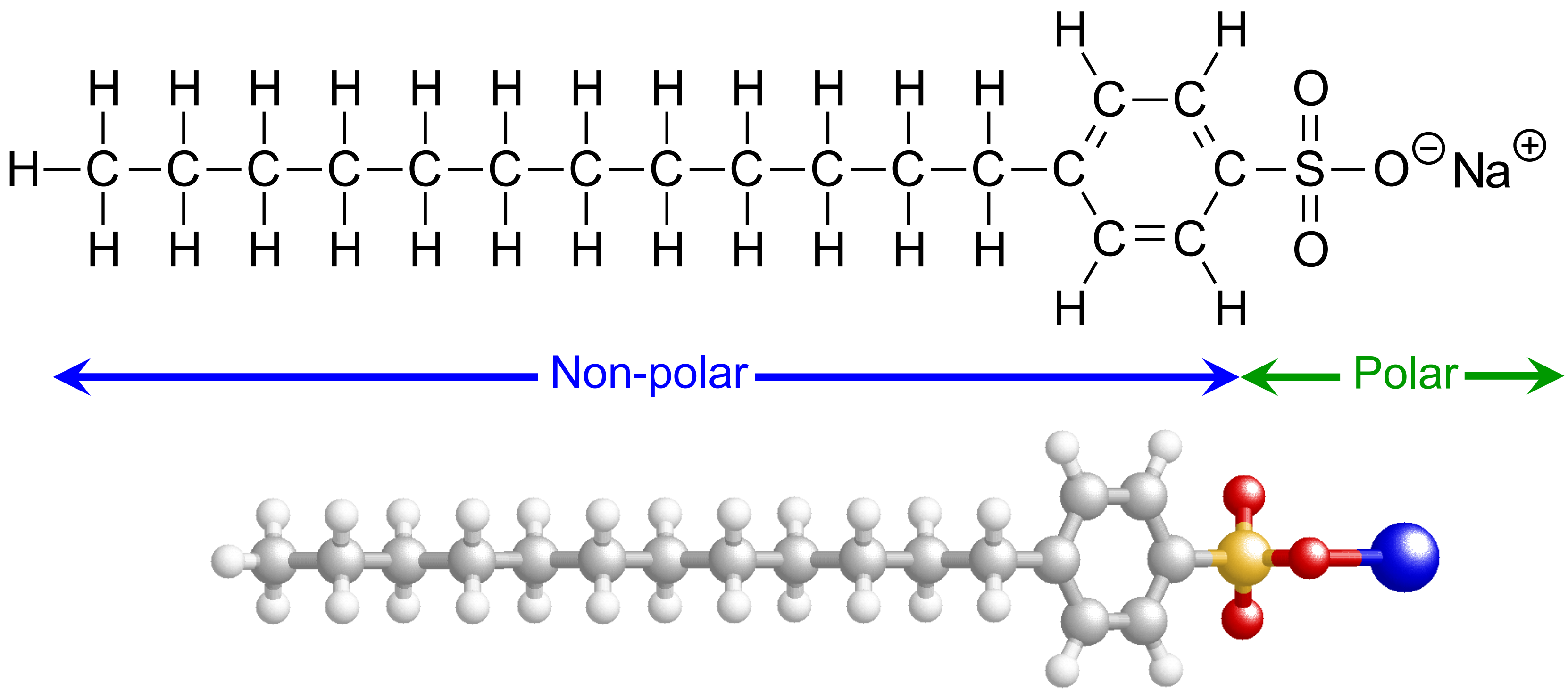
- The detergent molecule will have a *non-polar region* to attract the oil and grease, and a *polar region* to attract water.

Acids, Bases and Salts



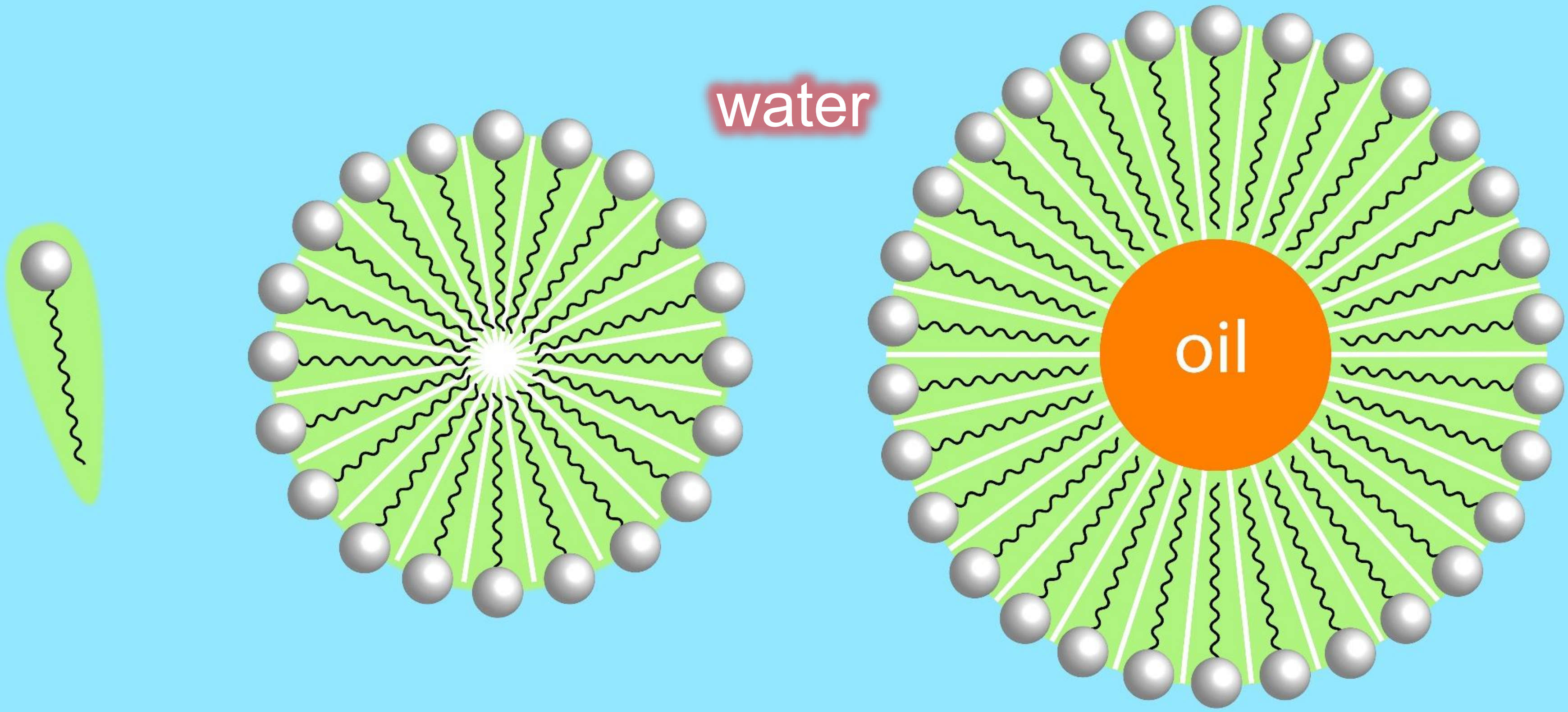
sodium dodecyl sulfate

Acids, Bases and Salts



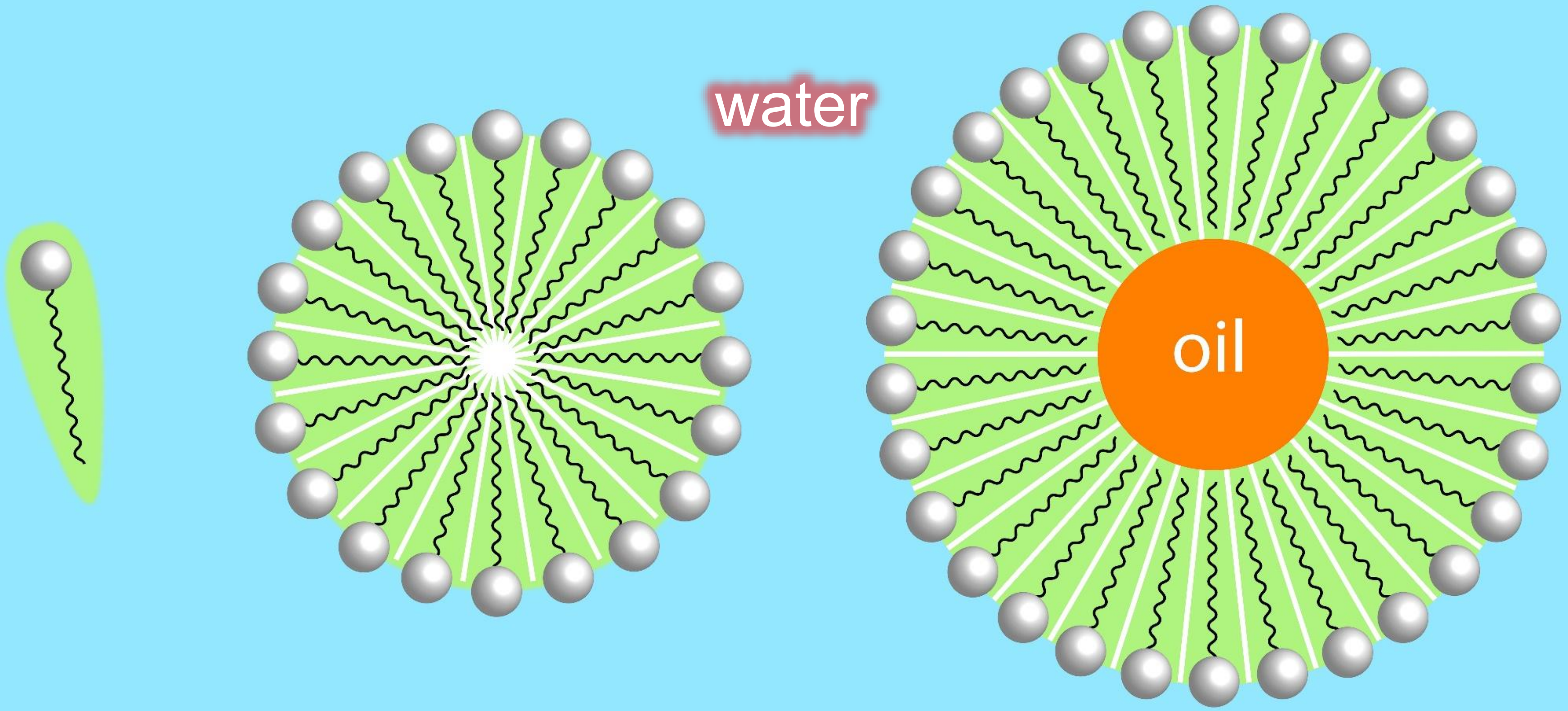
sodium dodecylbenzenesulfonate

Acids, Bases and Salts



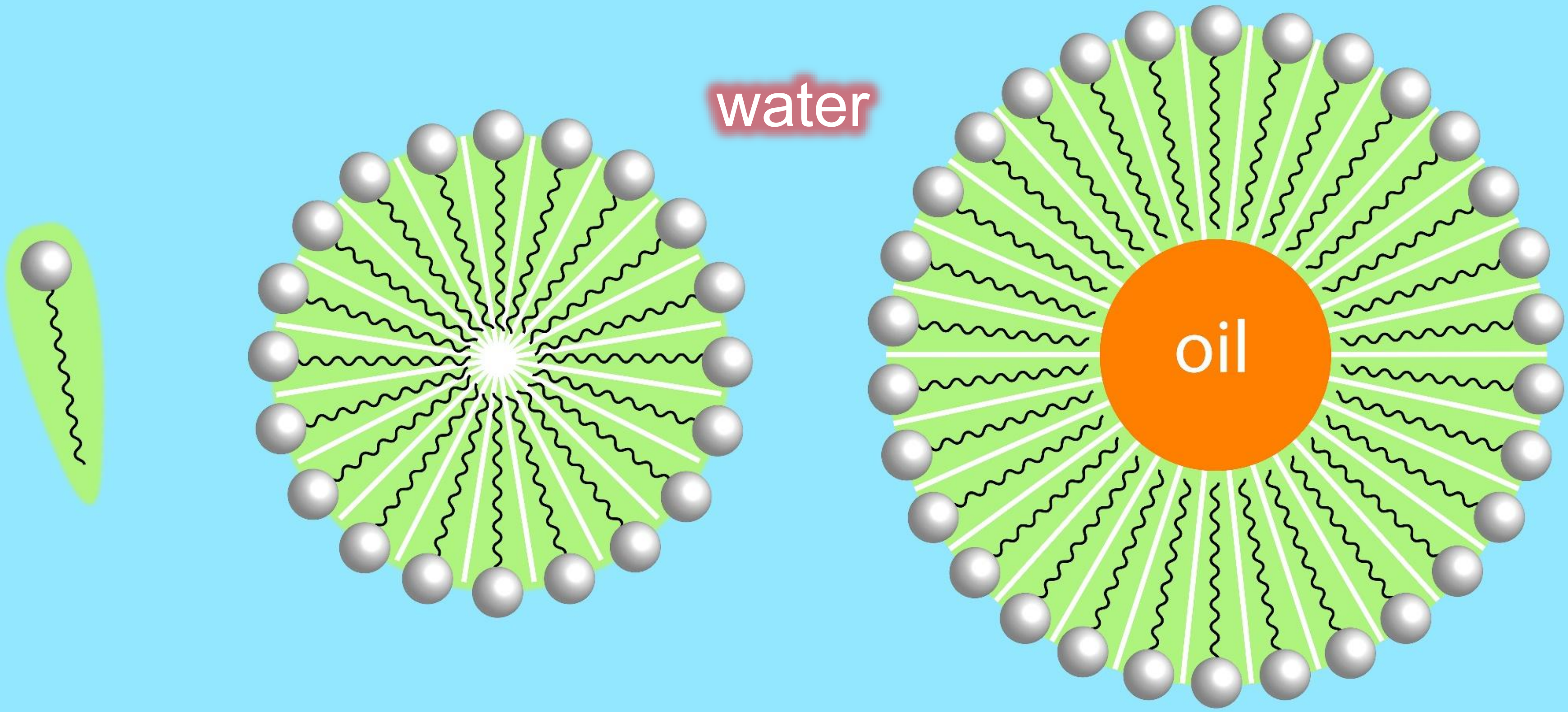
- The *non-polar* region (~) of the detergent does not dissolve in polar solvents such as water, but does dissolve in other *non-polar* chemicals such as oil. The *non-polar* region of the detergent molecule therefore binds to oil.

Acids, Bases and Salts



- The *polar* region (•) of the detergent does not dissolve in non-polar solvents such as oil, but does dissolve in other *polar* chemicals such as water. The *polar* region of the detergent molecule therefore binds to water.

Acids, Bases and Salts



- This combination of a non-polar *hydrophobic* region (literally "*does not like water*") and a polar *hydrophilic* region (literally "*likes water*") in the same molecule allows detergents to dissolve oil and grease from fabrics.

Acids, Bases and Salts

- Sulfuric acid is used to manufacture fertilizers, *e.g.* ammonium sulfate (formula, $(NH_4)_2SO_4$).
- Fertilizers contain nutrients that are essential for the healthy growth of plants, such as potassium, nitrogen and phosphorus.

Acids, Bases and Salts

- Sulfuric acid is used as the *electrolyte* in car batteries.

Acids, Bases and Salts

- Sulfuric acid is used in the manufacture of paint.

Acids, Bases and Salts

Acids, Bases and Salts

- Sulfuric acid is used in the manufacture of plastics.

Acids, Bases and Salts

Acids, Bases and Salts

- Sulfuric acid is used to clean the surface of metals.
- The sulfuric acid will react with, and remove, any basic metal oxides from the surface of the metal.
- This leaves a clean surface for paints and other materials to bond to.

Acids, Bases and Salts

- Non-metal oxides, such as sulfur dioxide, react with water to form acidic solutions.

sulfur dioxide + water → sulfurous acid

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

- Due to its acidic properties, sulfur dioxide is used as a preservative, to prevent the growth of mould and bacteria, in food products such as dried fruits and white wine.

Acids, Bases and Salts

Acids, Bases and Salts

- Sulfur dioxide is a reducing agent that is used as a mild bleach during the manufacture of white paper.

sulfur dioxide + water

↓

sulfur trioxide + hydrogen ions + electrons

$$SO_2(g) + H_2O(l) \rightarrow SO_3(g) + 2H^+(aq) + 2e^-$$

- Sulfur dioxide is used to bleach materials that cannot be treated using strong bleaches that contain chlorine.

Acids, Bases and Salts

Acids, Bases and Salts

- Rain water is naturally acidic due to the carbon dioxide gas that is present in the Earth's atmosphere.
- Carbon dioxide gas dissolves in rain water to form carbonic acid, $H_2CO_3(aq)$.

water + carbon dioxide → carbonic acid

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

Acids, Bases and Salts

Acids, Bases and Salts

- Sulfur dioxide is released into the Earth's atmosphere during volcanic eruptions and during the combustion of fossil fuels, such as coal and oil. Sulfur dioxide can be removed from power station fumes by reacting it with calcium oxide.

sulfur dioxide + calcium oxide → calcium sulfite

$$SO_2(g) + CaO(s) \rightarrow CaSO_3(s)$$

Acids, Bases and Salts

Acids, Bases and Salts

- When sulfur dioxide is released into the Earth's atmosphere, it reacts with rainwater and oxygen to form acid rain, which is a dilute solution of sulfuric acid.

sulfur dioxide + water + oxygen → sulfuric acid

$$2SO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 2H_2SO_4(aq)$$

Acids, Bases and Salts

- Acid rain (sulfuric acid) reacts with the marble and limestone (calcium carbonate) that many ancient monuments and statues are made of. This results in the formation of white, powdery calcium sulfate which flakes away from the surface of the monuments and statues, causing irreversible damage.

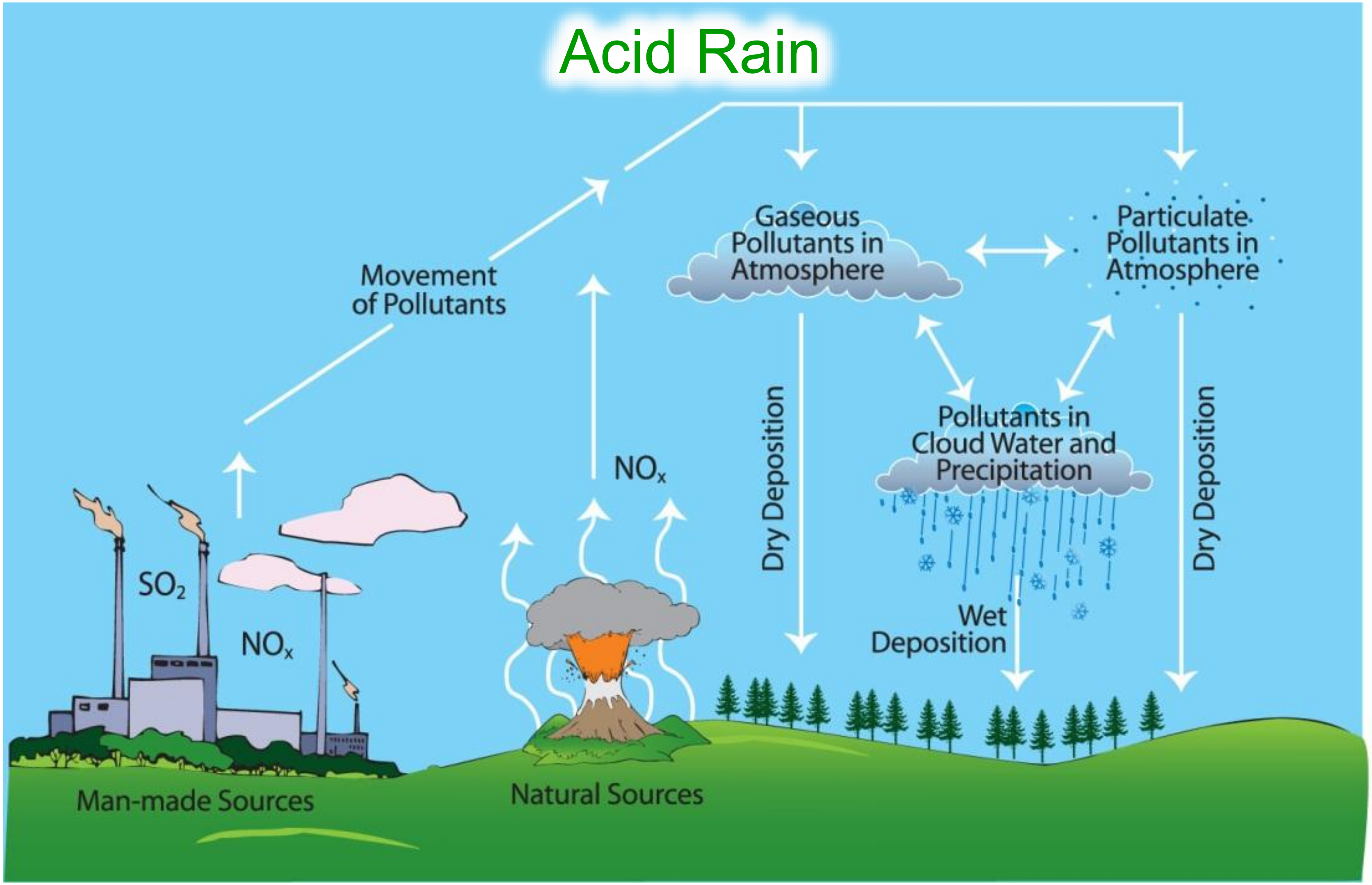
sulfuric acid + calcium carbonate

↓

calcium sulfate + water + carbon dioxide

$$H_2SO_4(g) + CaCO_3(s) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$$

Acids, Bases and Salts



Acids, Bases and Salts

Acids, Bases and Salts

- As pollution causes the Earth's oceans to become gradually more acidic, the growth of corals and other marine creatures with calcium carbonate shells is being adversely affected.

Acids, Bases and Salts

Acids, Bases and Salts

- Trees in northern Europe killed by acid rain, produced by atmospheric pollution from coal fired power stations.

- Coal contains between 0.5 and 3 percent sulfur, which produces sulfur dioxide when burnt. Sulfur dioxide is an acidic oxide that dissolves in rainwater to form acid rain.

- Acid rain lowers the pH of soil, and dissolves essential minerals, removing them from the soil. This has led to the widespread destruction of forests across Europe.

Acids, Bases and Salts

Acids, Bases and Salts

- Acid rain can leach nutrients from the soil, adversely affecting the growth of crops.
- Crops tend to grow well over narrow ranges of pH. Some examples are given below:

→ Corn: pH range 5.8 – 6.2

→ Soybean: pH range 6.6 – 7.0

→ Rice: pH range 5.5 – 6.5

→ Wheat: pH range 6.3 – 6.5

Acids, Bases and Salts

- Farmers should test the pH of their soil regularly.
- The pH of soil that is too acidic can be increased by adding chemicals such as calcium oxide, CaO, calcium hydroxide, $Ca(OH)_2$, and calcium carbonate, $CaCO_3$.
- The pH of soil that is too alkaline can be reduced by adding ammonium sulfate, $(NH_4)_2SO_4$.

Acids, Bases and Salts

- Calcium hydroxide is used by farmers to increase the pH of soil that has been made acidic by acid rain.

calcium hydroxide + sulfurous acid

↓

calcium sulfite + water

$$Ca(OH)_2(s) + H_2SO_3(aq) \rightarrow CaSO_3(s) + 2H_2O(l)$$

- Note: Calcium hydroxide is *slightly soluble* in water. Adding *excess* calcium hydroxide to the soil will make the soil *alkaline* (pH > 7).

Acids, Bases and Salts

- Why do farmers use calcium hydroxide and not sodium hydroxide to increase the pH of the soil?

- Calcium hydroxide is only slightly soluble in water. Solid calcium hydroxide will remain mixed with the soil, slowly dissolving in rain water and slowly raising the pH of the soil over a long period of time.

- By comparison, sodium hydroxide is very soluble in water. It will readily dissolve in rain water and raise the pH of the soil very quickly, which may be harmful to the food crop. In addition, because it is very soluble in water, rain will wash the sodium hydroxide out of the soil and into streams and rivers. This may be harmful to plants and animals that live in the streams and rivers.

Acids, Bases and Salts

- Calcium carbonate can also be used by farmers to increase the pH of soil that has been made acidic by acid rain.

calcium carbonate + sulfurous acid

↓

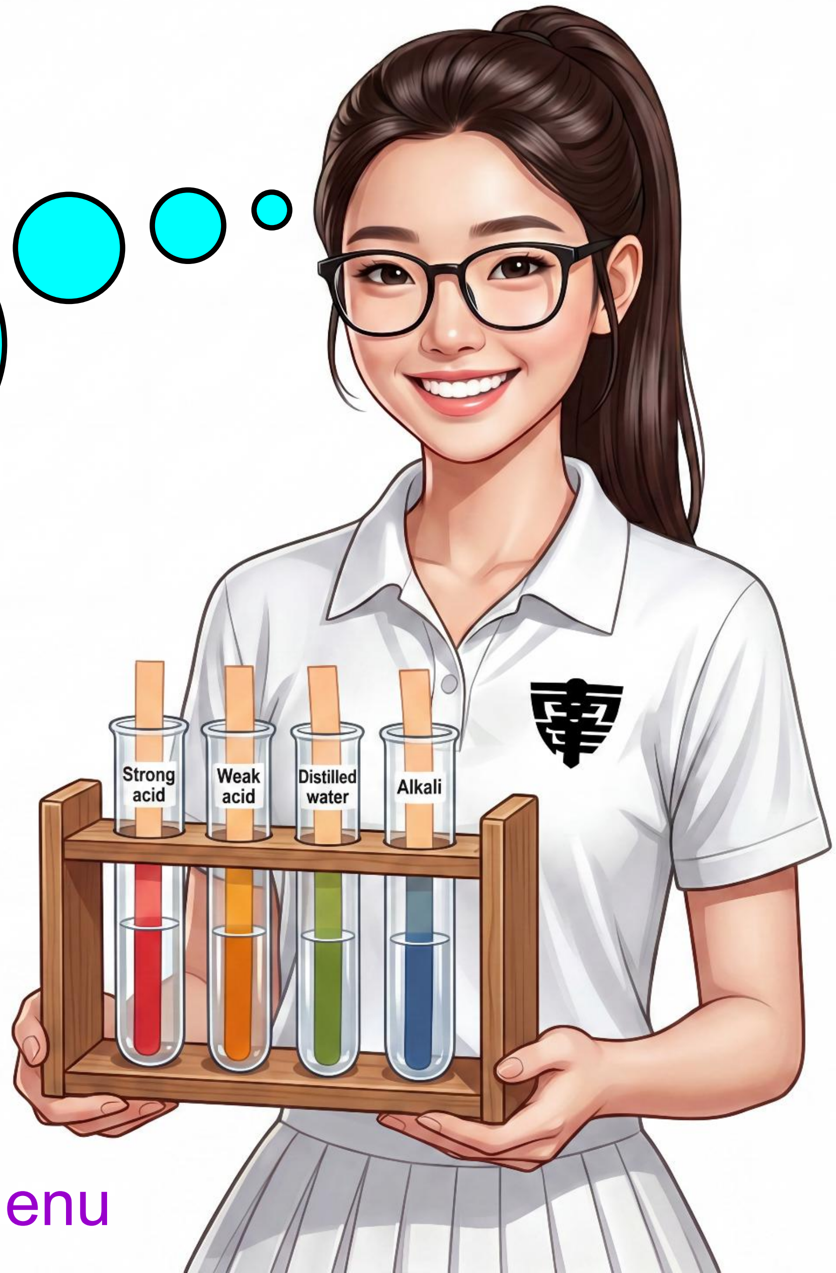
calcium sulfite + water + carbon dioxide

$$CaCO_3(s) + H_2SO_3(aq) \rightarrow CaSO_3(s) + H_2O(l) + CO_2(g)$$

- Note: Calcium carbonate is *insoluble* in water. Adding *excess* calcium carbonate to the soil will only neutralise the acid (pH = 7) and will *not* result in the soil becoming alkaline.

Acids, Bases and Salts

11. How are the *oxides* of the chemical elements *classified* as acids and bases?



Main Menu

Acids, Bases and Salts

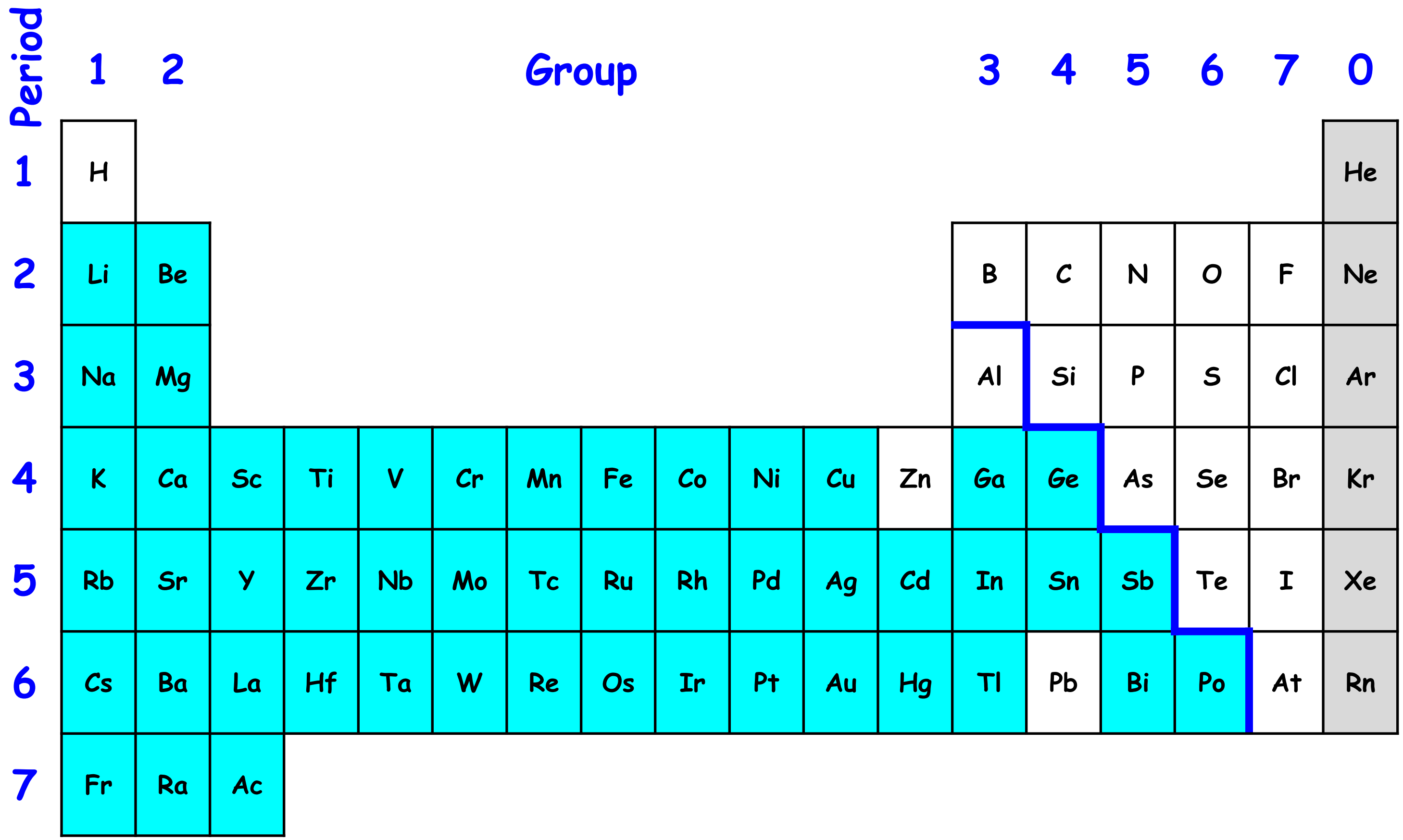
Classification of Oxides

The dividing line between metals (left) and non-metals (right).

Period	1	2						Group					3	4	5	6	7	0
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Acids, Bases and Salts

Classification of Oxides – Metallic Oxides – Basic



Acids, Bases and Salts

Classification of Oxides – Non-metallic Oxides – Acidic

Period	1	2	Group										3	4	5	6	7	0
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

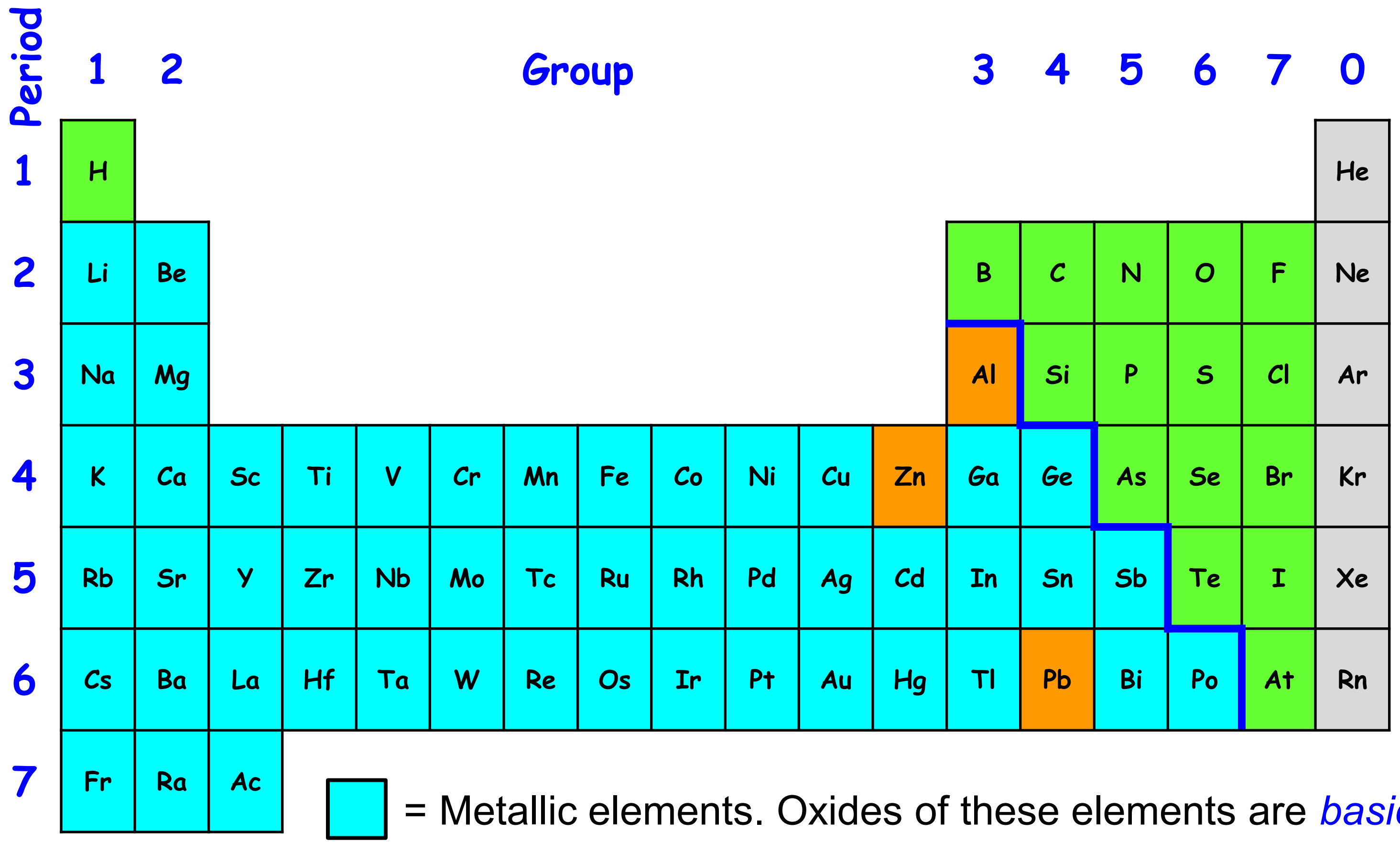
Acids, Bases and Salts

Classification of Oxides – Amphoteric Oxides

Period	1	2				Group							3	4	5	6	7	0
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											**Al**	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	**Zn**	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	**Pb**	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Acids, Bases and Salts

Classification of Oxides – Summary



= Metallic elements. Oxides of these elements are *basic*.

= Non-metallic elements. Oxides of these elements are *acidic*.

= Oxides of these elements are *amphoteric*.

Acids, Bases and Salts

Classification of Oxides – Acidic

- Acidic Oxides: Oxides of *non-metallic elements*, such as carbon dioxide (CO_2), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) dissolve in water to form acidic solutions.

carbon dioxide + water → carbonic acid

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

nitrogen dioxide + water → nitric acid + nitrogen monoxide

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$

sulfur dioxide + water → sulfurous acid

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

- Fizzy drinks, such as Coca-Cola, have a sharp, sour taste due to the carbonic acid that they contain.

Acids, Bases and Salts

Classification of Oxides – Basic

- Basic Oxides: Oxides of *metallic elements*, such as sodium oxide (Na_2O) and copper(II) oxide (CuO) will neutralise acids to form a salt and water.

sodium oxide + sulfuric acid → sodium sulfate + water

$$Na_2O(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

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

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

Acids, Bases and Salts

Classification of Oxides – Neutral

- Neutral Oxides: Oxides of some chemical elements dissolve in water to form neutral solutions. Examples of neutral oxides include carbon monoxide (CO), nitrogen monoxide (NO), dinitrogen monoxide (N_2O) and water (H_2O).

Acids, Bases and Salts

Classification of Oxides – Amphoteric

- Amphoteric Oxides: Oxides of some chemical elements can exhibit both acidic and basic properties, depending upon the conditions that they are subjected to. Examples of amphoteric oxides include aluminium oxide (Al_2O_3), lead(II) oxide (PbO) and zinc oxide (ZnO).

zinc oxide + nitric acid → zinc nitrate + water

$$ZnO(s) + 2HNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + H_2O(l)$$

zinc oxide + sodium hydroxide + water → sodium zincate

$$ZnO(s) + 2NaOH(aq) + H_2O(l) \rightarrow Na_2Zn(OH)_4(aq)$$

Acids, Bases and Salts

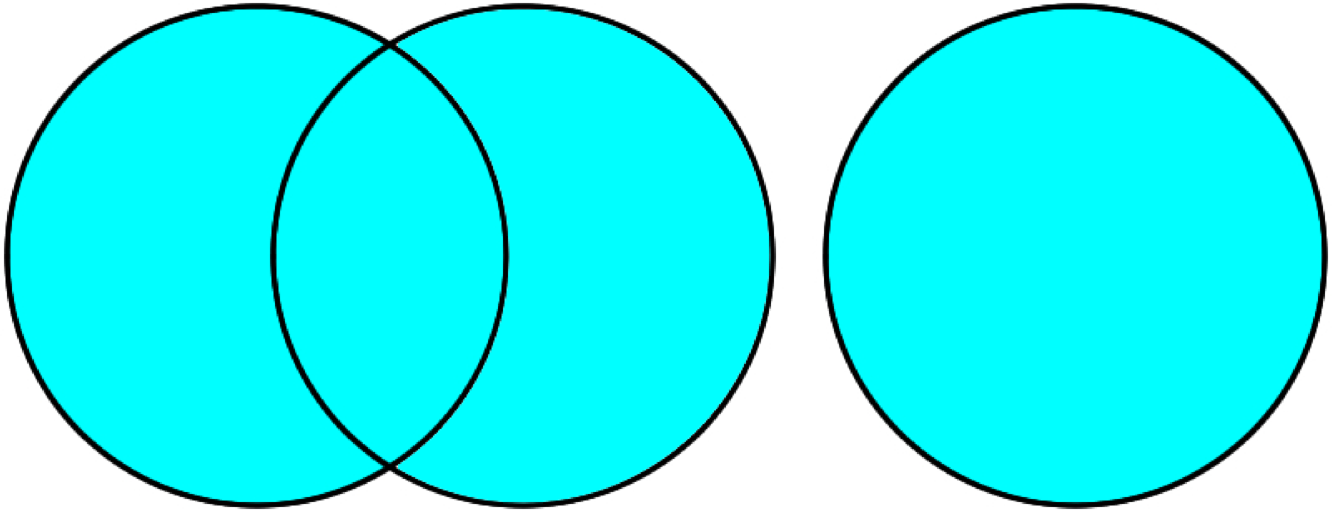
Classification of Oxides – Amphoteric

- Amphoteric Oxides: Oxides of some chemical elements can exhibit both acidic and basic properties, depending upon the conditions that they are subjected to. Examples of amphoteric oxides include aluminium oxide (Al_2O_3), lead(II) oxide (PbO) and zinc oxide (ZnO).

- Note: For qualitative analysis, $Al^{3+}(aq)$, $Pb^{2+}(aq)$ and $Zn^{2+}(aq)$ are the same three cations that form a white precipitate with aqueous sodium hydroxide. The white precipitate dissolves in excess reagent to form a colourless solution.

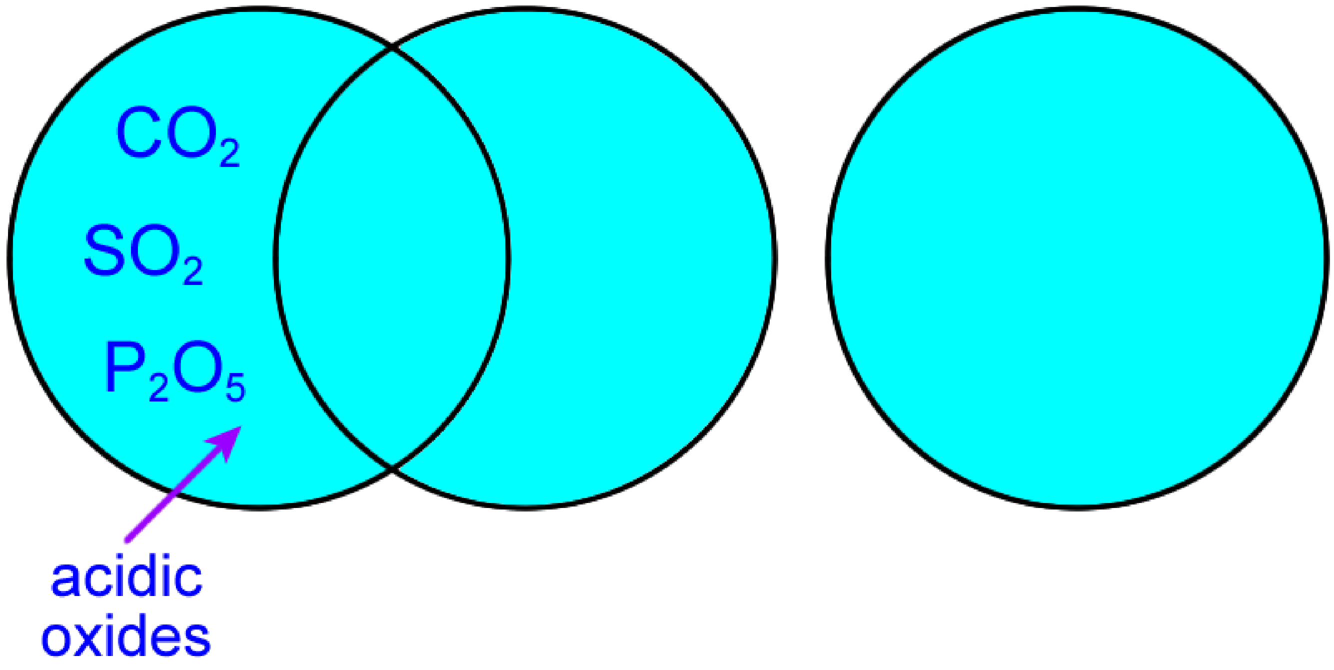
Acids, Bases and Salts

Classification of Oxides
Venn Diagram



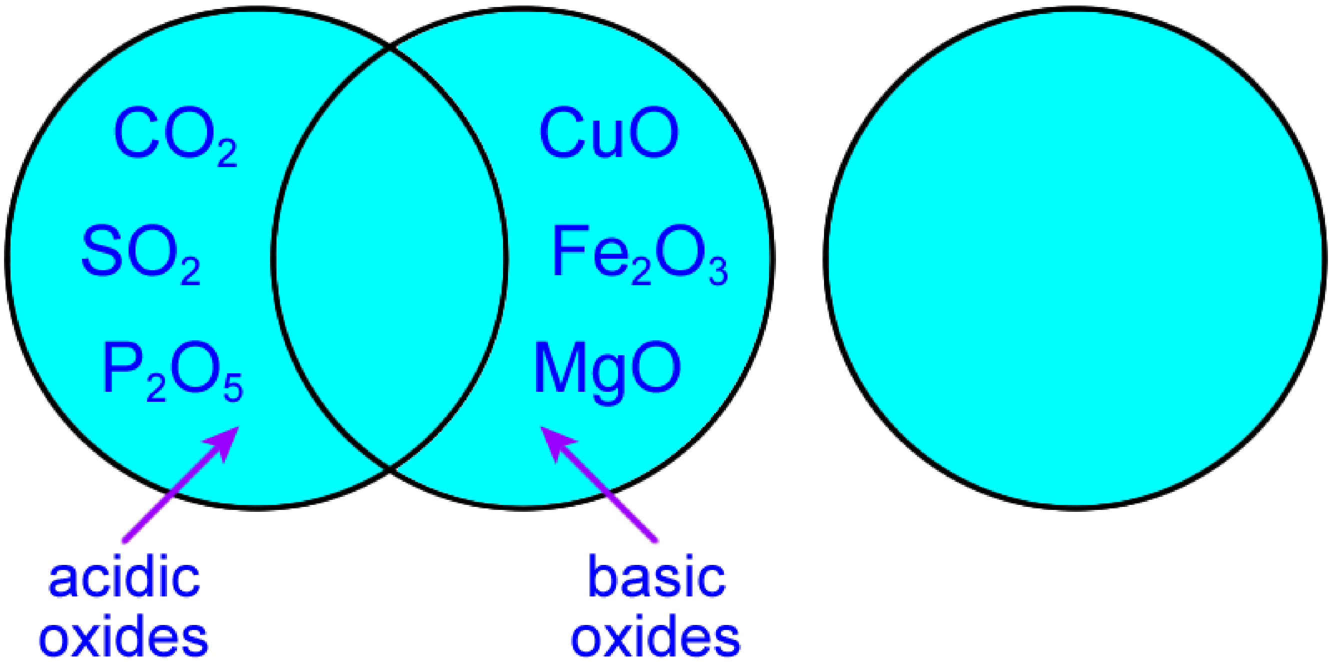
Acids, Bases and Salts

Classification of Oxides
Venn Diagram



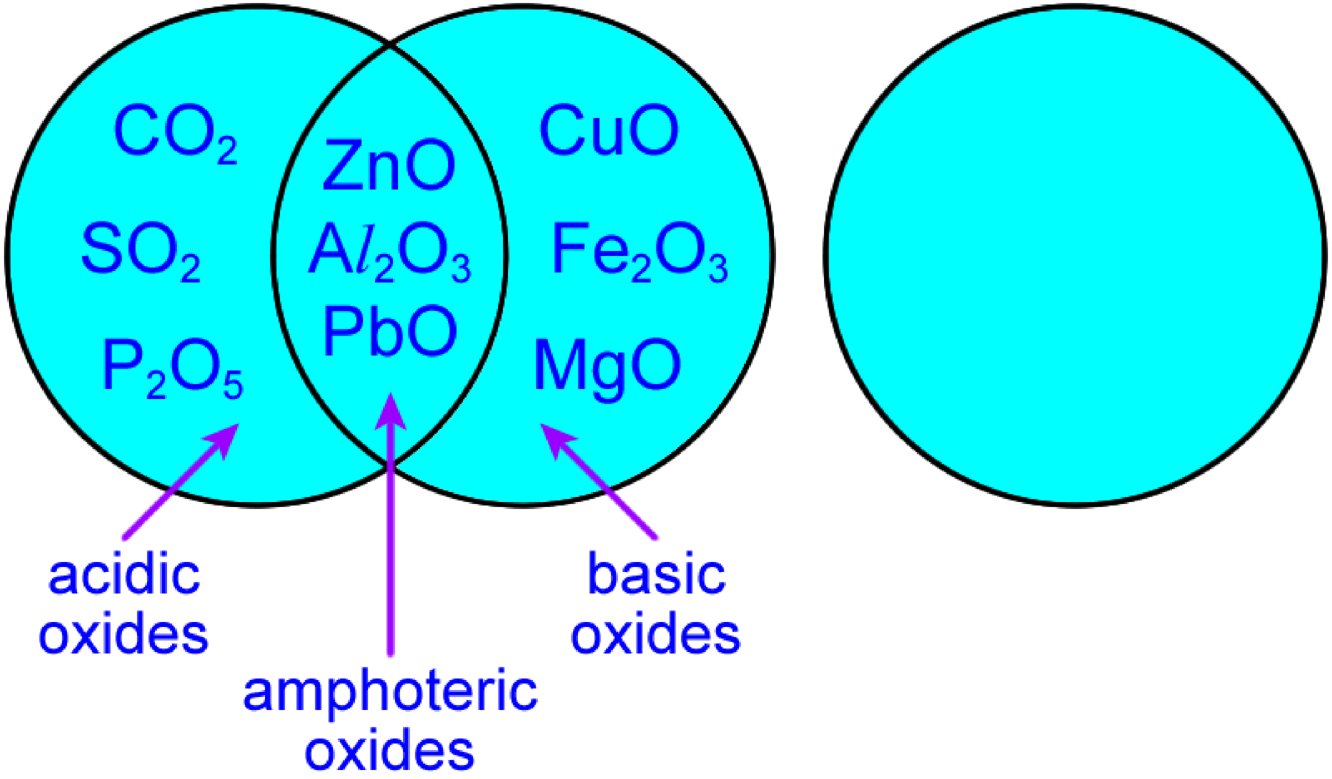
Acids, Bases and Salts

Classification of Oxides
Venn Diagram



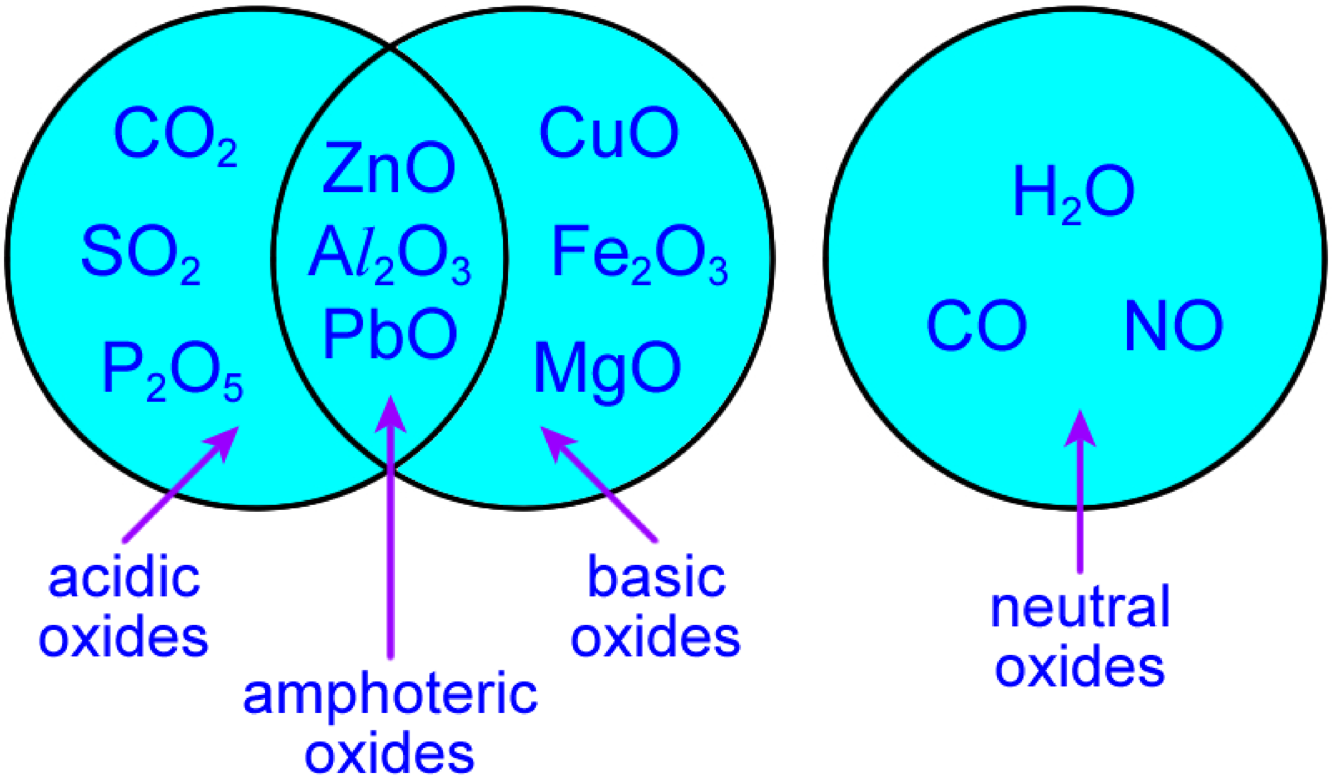
Acids, Bases and Salts

Classification of Oxides
Venn Diagram



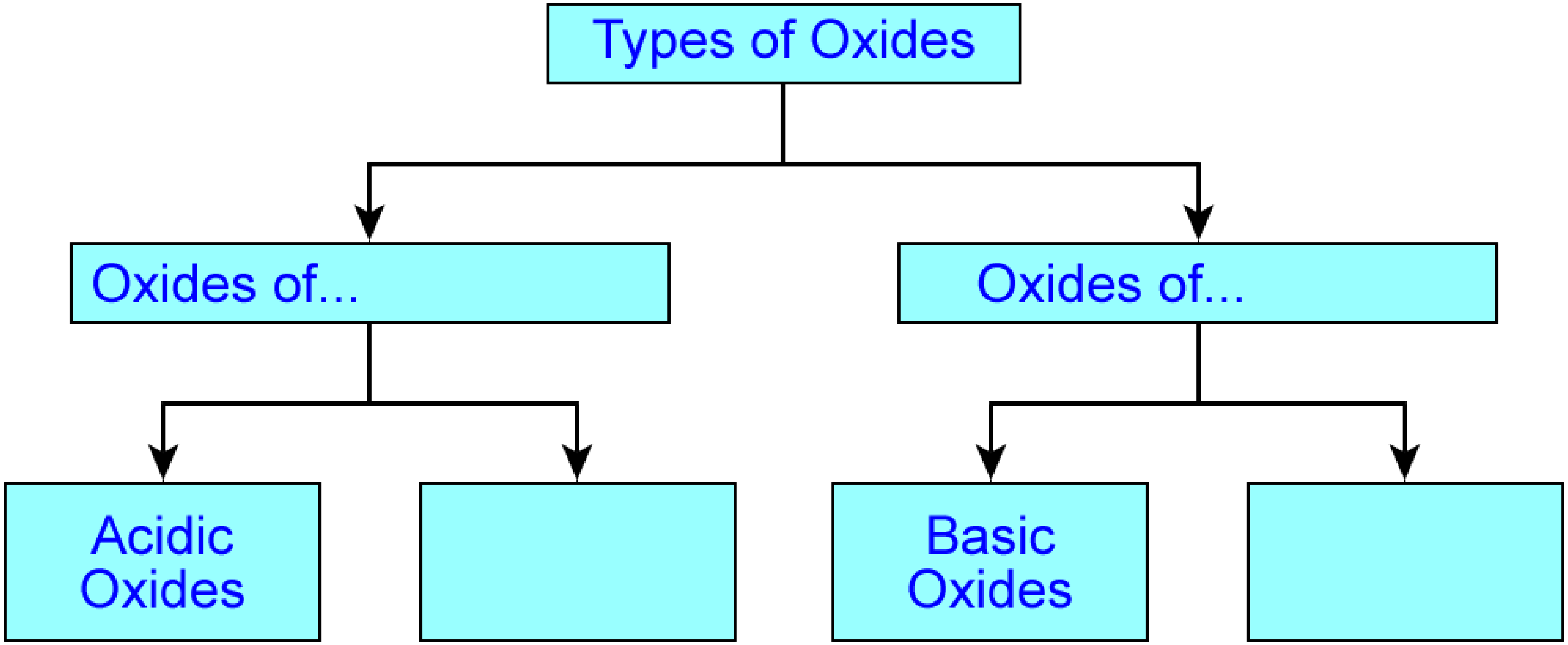
Acids, Bases and Salts

Classification of Oxides
Venn Diagram



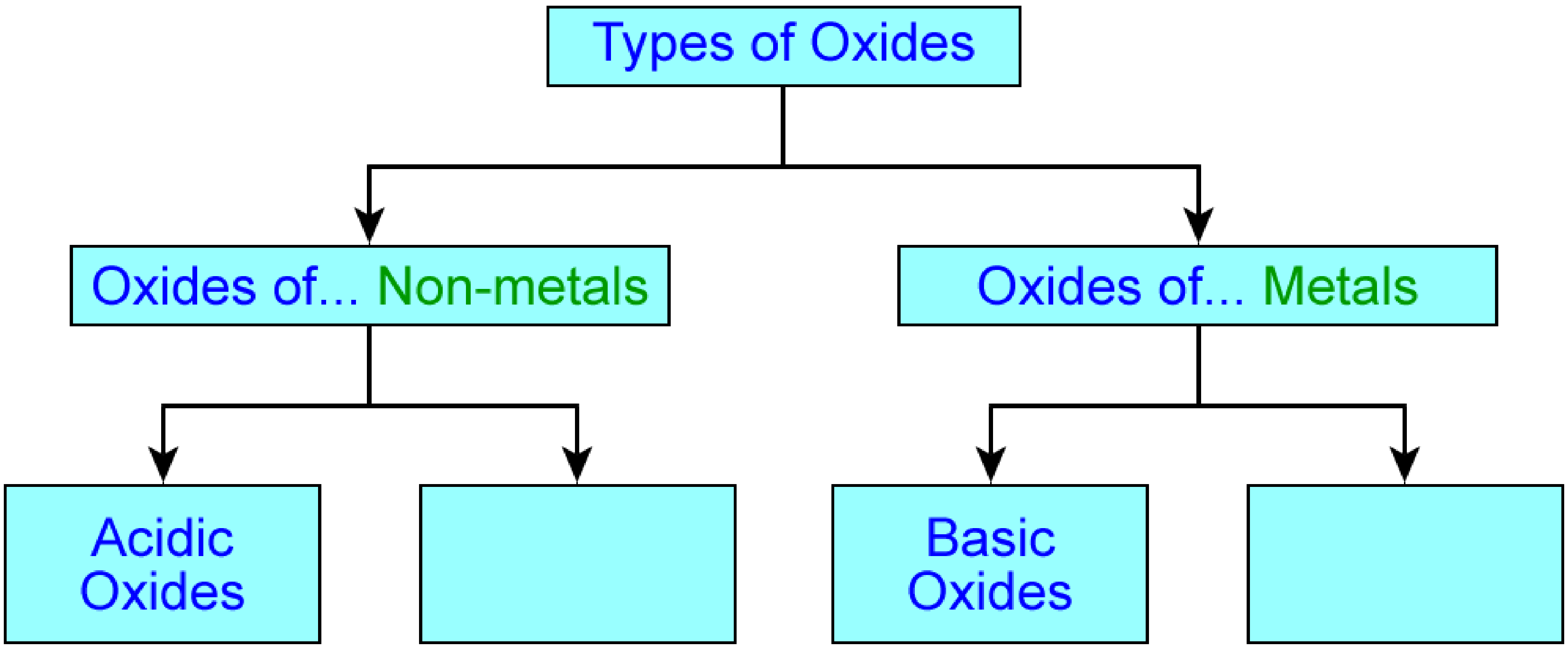
Acids, Bases and Salts

Classification of Oxides
Flow Diagram



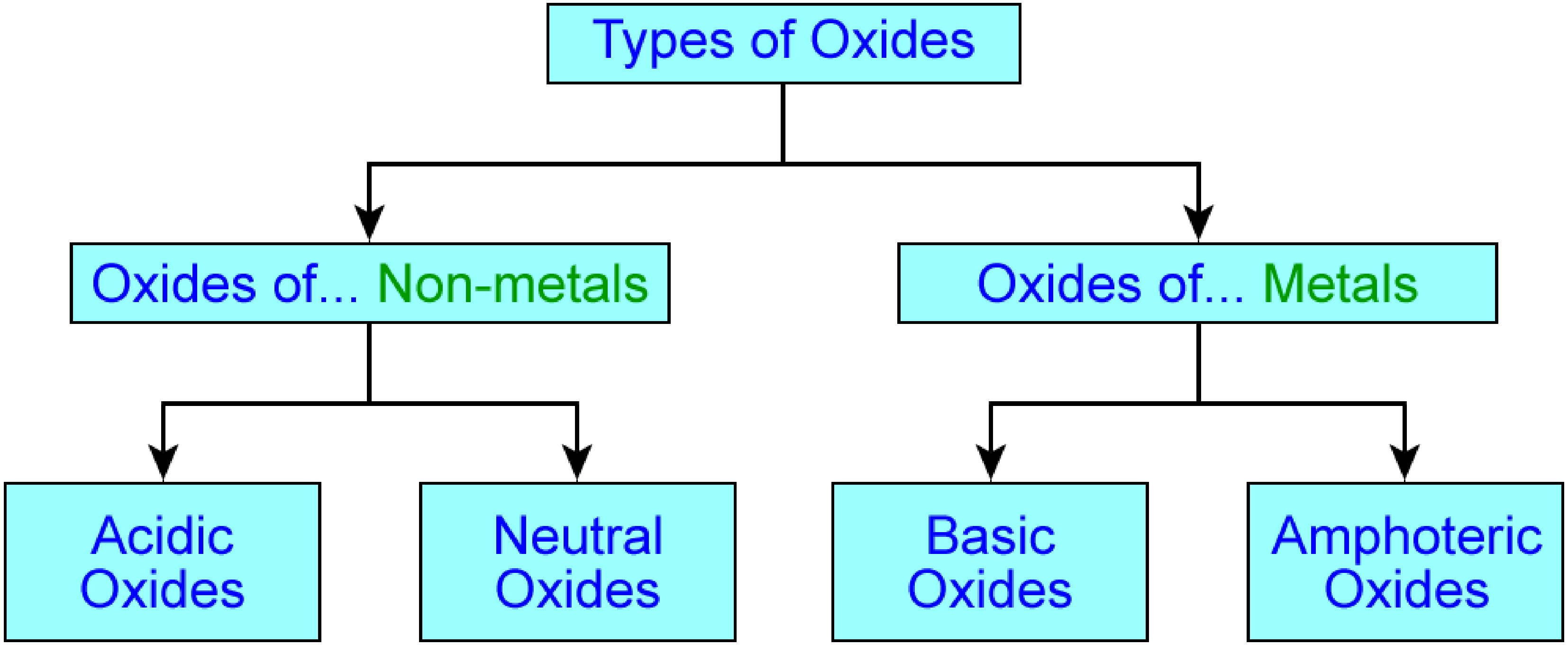
Acids, Bases and Salts

Classification of Oxides
Flow Diagram



Acids, Bases and Salts

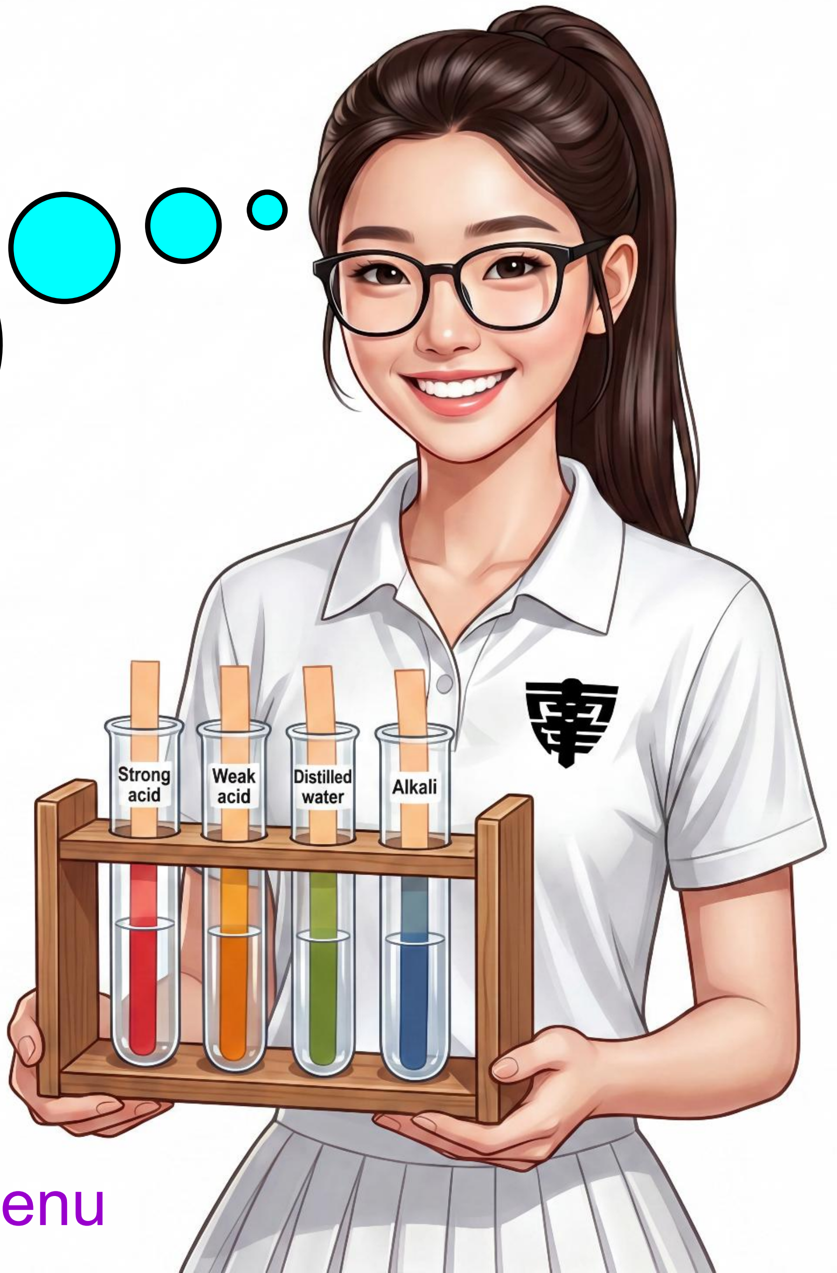
Classification of Oxides
Flow Diagram



CO_2	CO	CuO	ZnO
SO_2	NO	Fe_2O_3	Al_2O_3
P_2O_5	H_2O	MgO	PbO

Acids, Bases and Salts

12. What are *bases* and *alkalis*?



Main Menu

Acids, Bases and Salts

Bases and Alkalis

- Bases are typically the *oxides* and *hydroxides* of *metallic elements*, for example:
  - Sodium hydroxide, NaOH
  - Calcium oxide, CaO
  - Iron(III) hydroxide, $Fe(OH)_3$
  - Copper(II) oxide, CuO
- Two exceptions include the compounds *ammonia*, NH_3, and *ammonium hydroxide*, NH_4OH.

Acids, Bases and Salts

Bases and Alkalis

- A base that *dissolves in water* is known as an *alkali*, for example:
  - Sodium hydroxide, $NaOH$

    $NaOH(s) \rightarrow Na^{+}(aq) + OH^{-}(aq)$
  - Potassium hydroxide, KOH

    $KOH(s) \rightarrow K^{+}(aq) + OH^{-}(aq)$
  - Ammonium hydroxide, NH_4OH

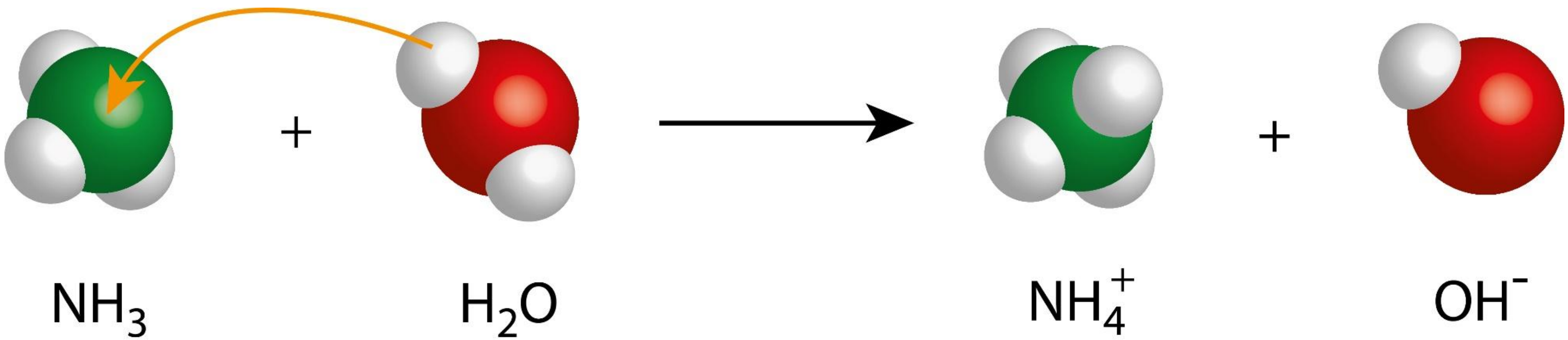
    $NH_4OH(s) \rightarrow NH_4^{+}(aq) + OH^{-}(aq)$
- It can be seen that alkaline solutions typically contain *hydroxide ions* dissolved in water – *$OH^{-}(aq)$*

Acids, Bases and Salts

- Soap tends to be slightly alkaline due to the sodium hydroxide that is used during its manufacture.

Acids, Bases and Salts

- Ammonia gas is very soluble in water. Approximately 500 g of ammonia will dissolve in 1000g of water at 25 °C.



- When ammonia gas dissolves in water, some of the ammonia molecules and water molecules react to form an alkaline solution of ammonium hydroxide.

$$\text{ammonia} + \text{water} \rightleftharpoons \text{ammonium hydroxide}$$

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq)$$

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Acids, Bases and Salts

- Just as acids dissolve in water to *produce $H^+(aq)$* ions, bases and alkalis react by *accepting $H^+(aq)$* to form water, for example:

$$NaOH(aq) + H^+(aq) \rightarrow Na^+(aq) + H_2O(l)$$

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

- A *strong alkali* is an alkali that *fully ionises* in water to produce hydroxide ions, for example:

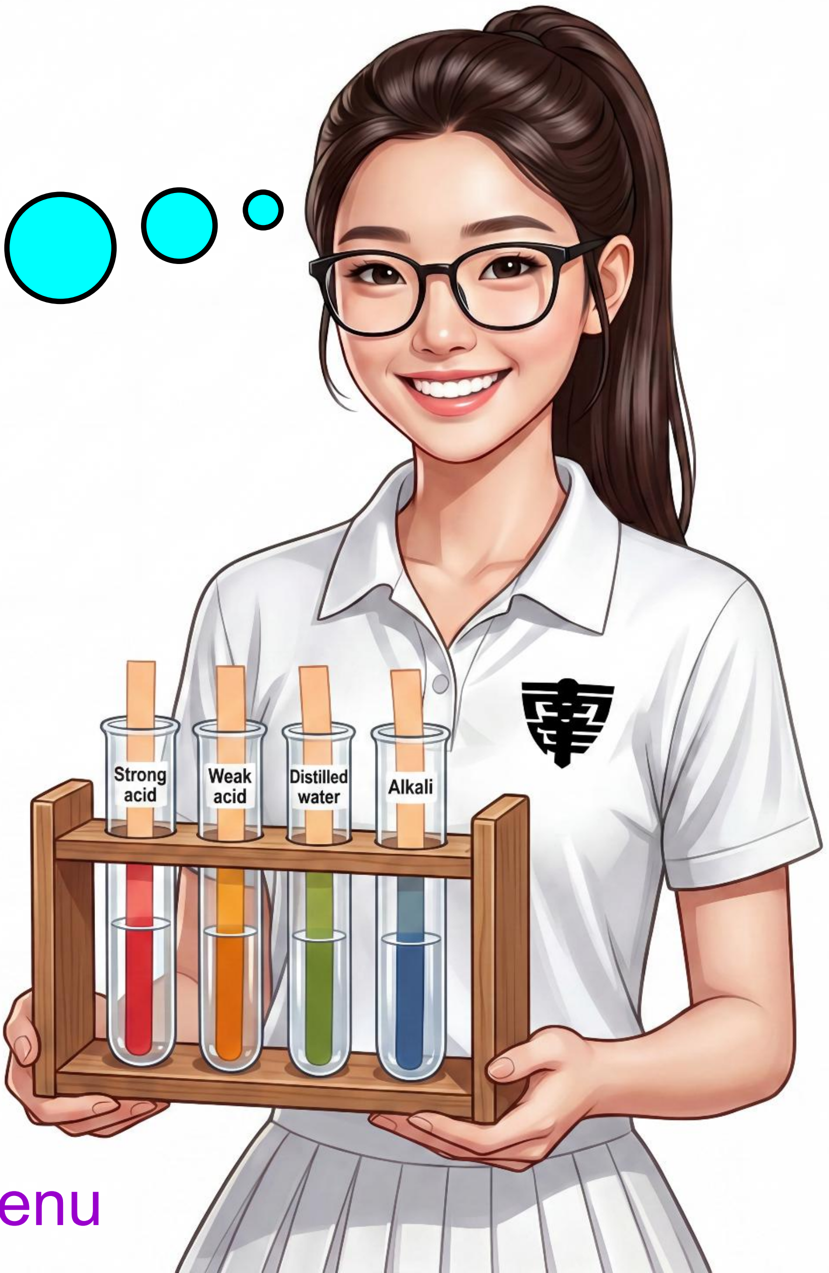
$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

- A *weak alkali* is an alkali that *partially ionises* in water to produce hydroxide ions, for example:

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Acids, Bases and Salts

13. What are the *typical reactions* of *bases* and *alkalis*?



Main Menu

Acids, Bases and Salts

acid + base (alkali) $\rightarrow$ salt + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide →

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide →

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

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

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

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

sulfuric acid + ammonium hydroxide →

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

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

sulfuric acid + ammonium hydroxide → ammonium sulfate + water

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

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

sulfuric acid + ammonium hydroxide → ammonium sulfate + water

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

Acids, Bases and Salts

acid + base (alkali) → salt + water

nitric acid + sodium hydroxide → sodium nitrate + water

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

hydrochloric acid + potassium hydroxide → potassium chloride + water

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

sulfuric acid + ammonium hydroxide → ammonium sulfate + water

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

These are all classified as *neutralisation reactions*:

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

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

calcium chloride + water + ammonia

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

calcium chloride + water + ammonia

$$2NH_4Cl(aq) + Ca(OH)_2(s) \rightarrow CaCl_2(aq) + 2H_2O(l) + 2NH_3(g)$$

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

calcium chloride + water + ammonia

$$2NH_4Cl(aq) + Ca(OH)_2(s) \rightarrow CaCl_2(aq) + 2H_2O(l) + 2NH_3(g)$$

ammonium sulfate + sodium hydroxide

↓

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

calcium chloride + water + ammonia

$$2NH_4Cl(aq) + Ca(OH)_2(s) \rightarrow CaCl_2(aq) + 2H_2O(l) + 2NH_3(g)$$

ammonium sulfate + sodium hydroxide

↓

sodium sulfate + water + ammonia

Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia

ammonium chloride + calcium hydroxide

↓

calcium chloride + water + ammonia

$$2\mathrm{NH_4C}l\mathrm{(aq)} + \mathrm{Ca(OH)_2(s)} \rightarrow \mathrm{CaC}l_2\mathrm{(aq)} + 2\mathrm{H_2O}(l) + 2\mathrm{NH_3(g)}$$

ammonium sulfate + sodium hydroxide

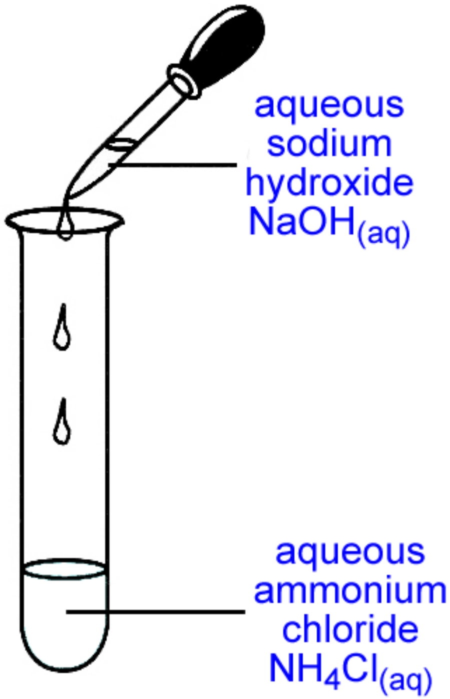
↓

sodium sulfate + water + ammonia

$$\mathrm{(NH_4)_2SO_4(aq)} + 2\mathrm{NaOH(s)} \rightarrow \mathrm{Na_2SO_4(aq)} + 2\mathrm{H_2O}(l) + 2\mathrm{NH_3(g)}$$

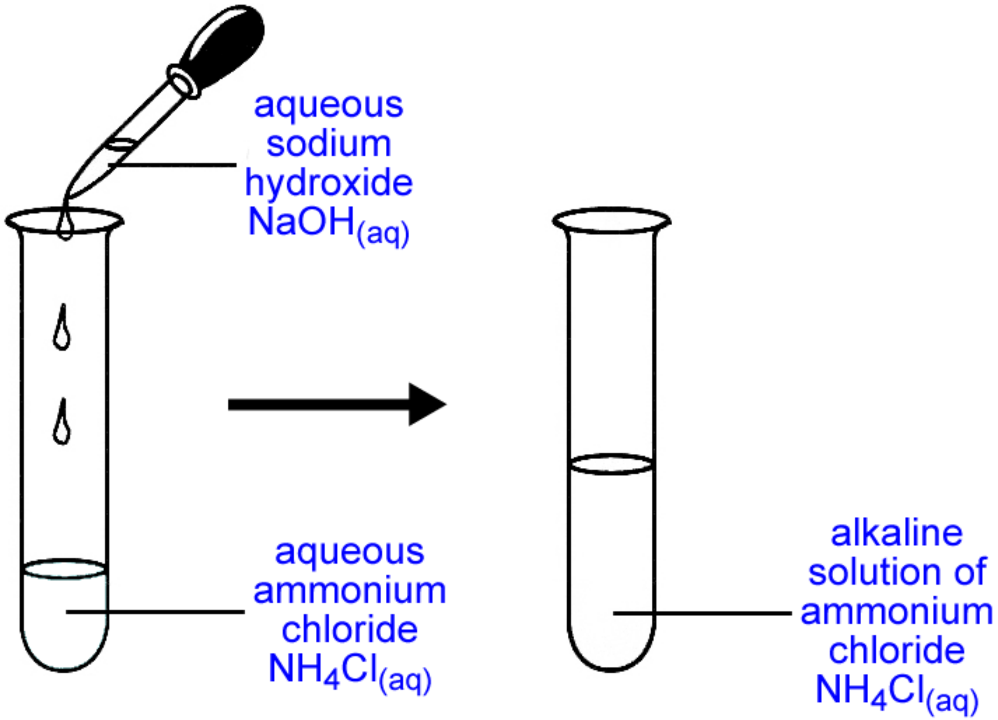
Acids, Bases and Salts

ammonium salt + alkali $\rightarrow$ salt + water + ammonia



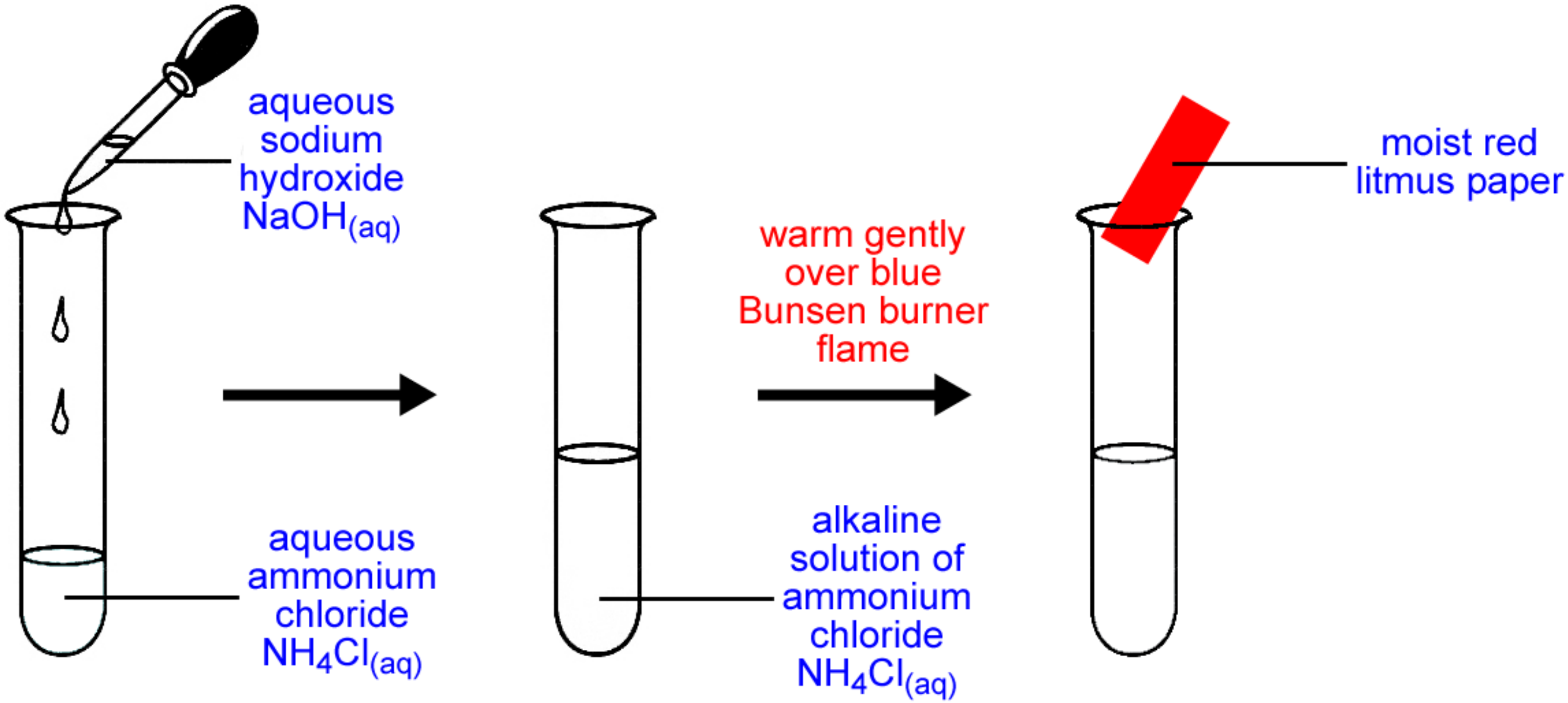
Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia



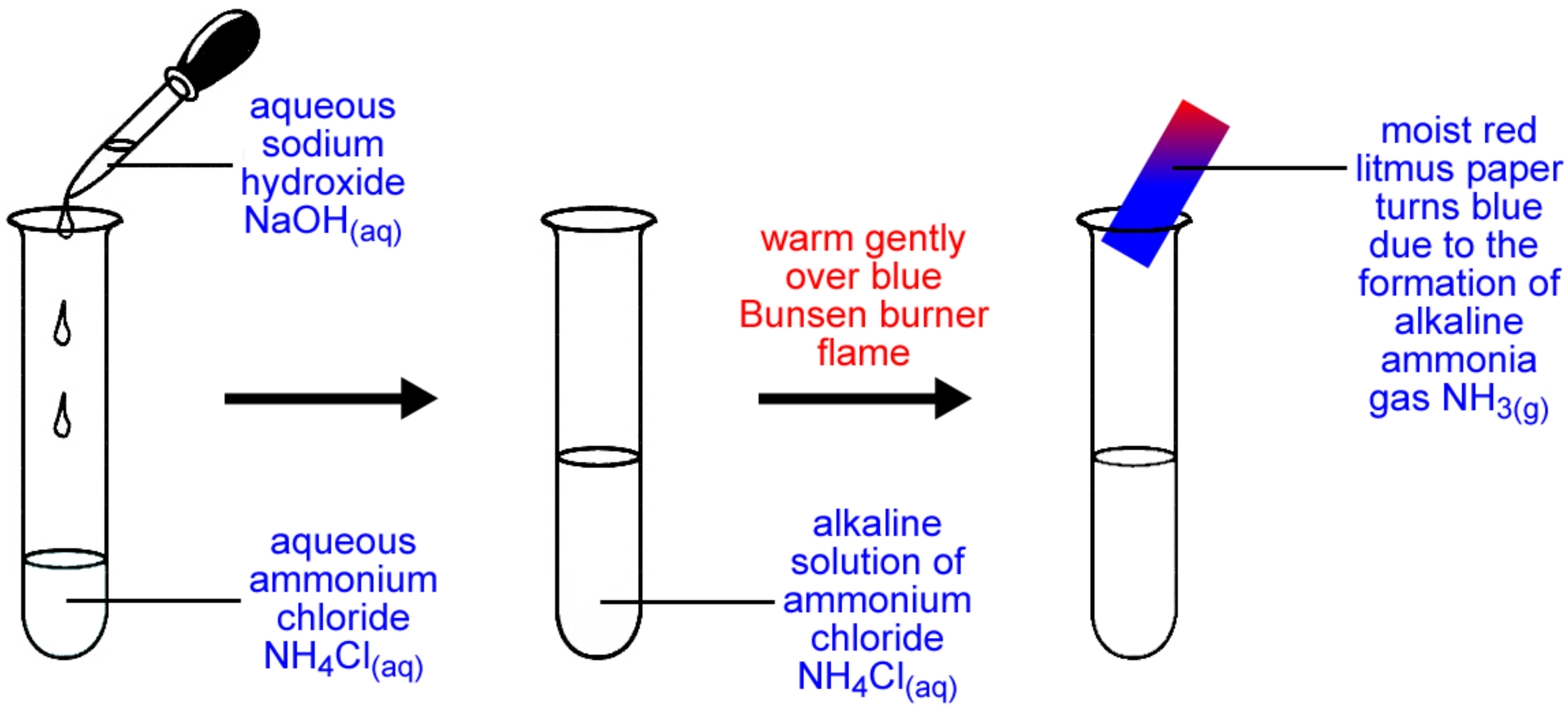
Acids, Bases and Salts

ammonium salt + alkali $\rightarrow$ salt + water + ammonia



Acids, Bases and Salts

ammonium salt + alkali → salt + water + ammonia



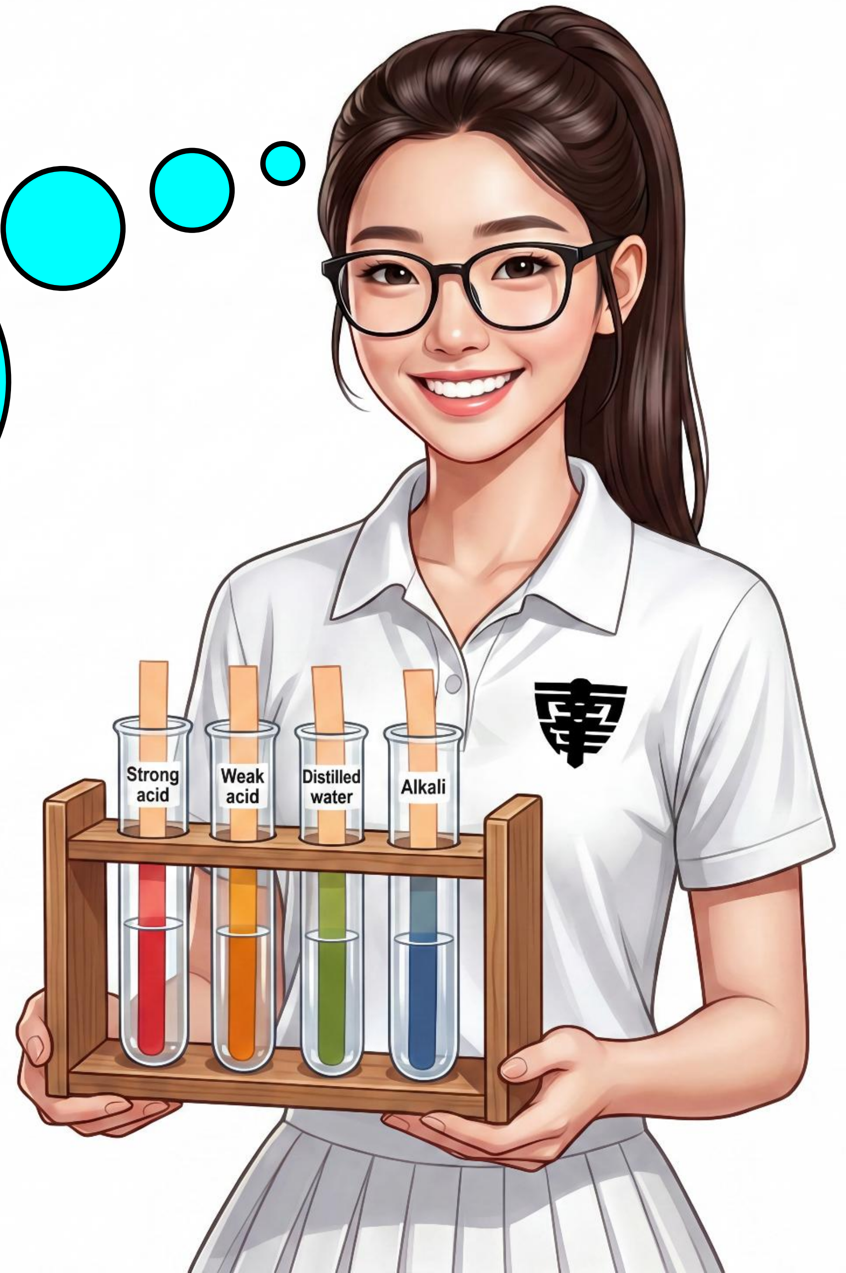
Ammonium Chloride + Sodium Hydroxide → Sodium Chloride + Water + Ammonia

$$NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) + NH_3(g)$$

$$NH_4^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_3(g)$$

Acids, Bases and Salts

13. Why is it important that farmers *do not* add a base and an ammonium salt fertiliser to the same field?



Acids, Bases and Salts

- The base (which has been added to neutralise acid in the soil) and the ammonium salt fertiliser would react to form a salt, water and ammonia. For example:

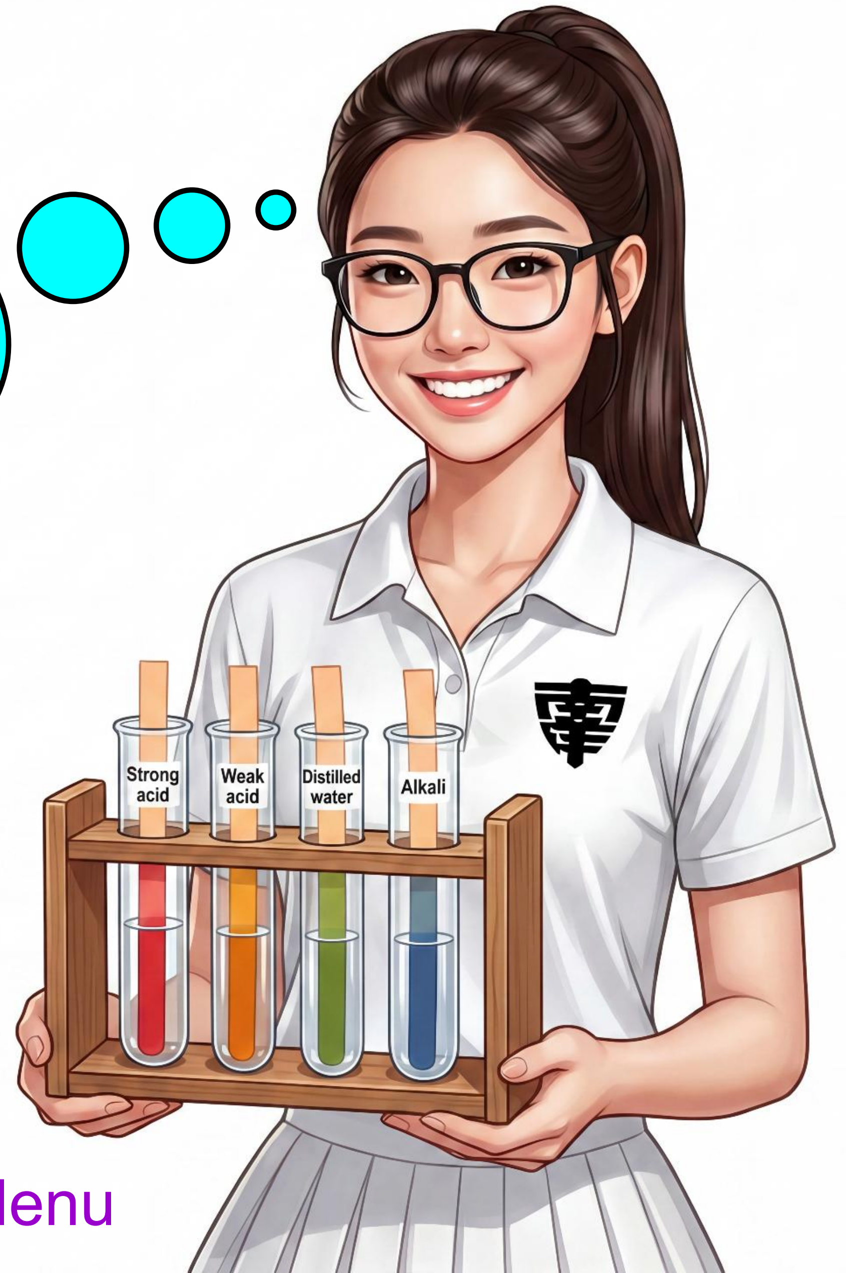
$$2NH_4NO_3(aq) + Ca(OH)_2(s) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l) + 2NH_3(g)$$

$$(NH_4)_2SO_4(aq) + CaO(s) \rightarrow CaSO_4(s) + H_2O(l) + 2NH_3(g)$$

- Because the base and the ammonium salt fertiliser react with each other, the acid in the soil would not be neutralised and the nitrogen in the fertiliser (which should be absorbed by the plants to support their growth) will be removed from the soil.

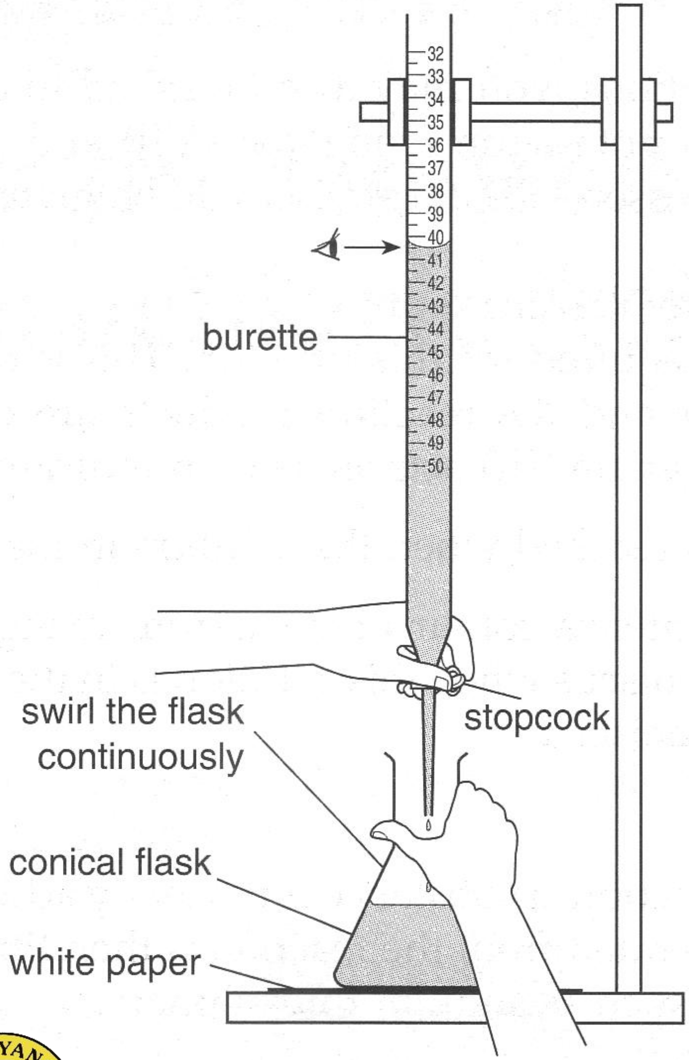
Acids, Bases and Salts

14. What is an acid / alkali *titration*?



Main Menu

Acids, Bases and Salts



- *Titration*, also known a *volumetric analysis*, is often used to determine the concentration of an acid or an alkali.
- One of the reagents is contained in a burette while a known volume of the other reagent is contained in a conical flask.
- The reagent in the burette is slowly added to the reagent in the conical flask. An indicator is used to tell when the two reagents have exactly neutralised each other.
- Once the volume of reagent added from the burette is known, the unknown concentration is calculated from:

$$c_{acid} \times v_{acid} = c_{alkali} \times v_{alkali}$$

c = concentration in mol/dm^3

v = volume in cm^3

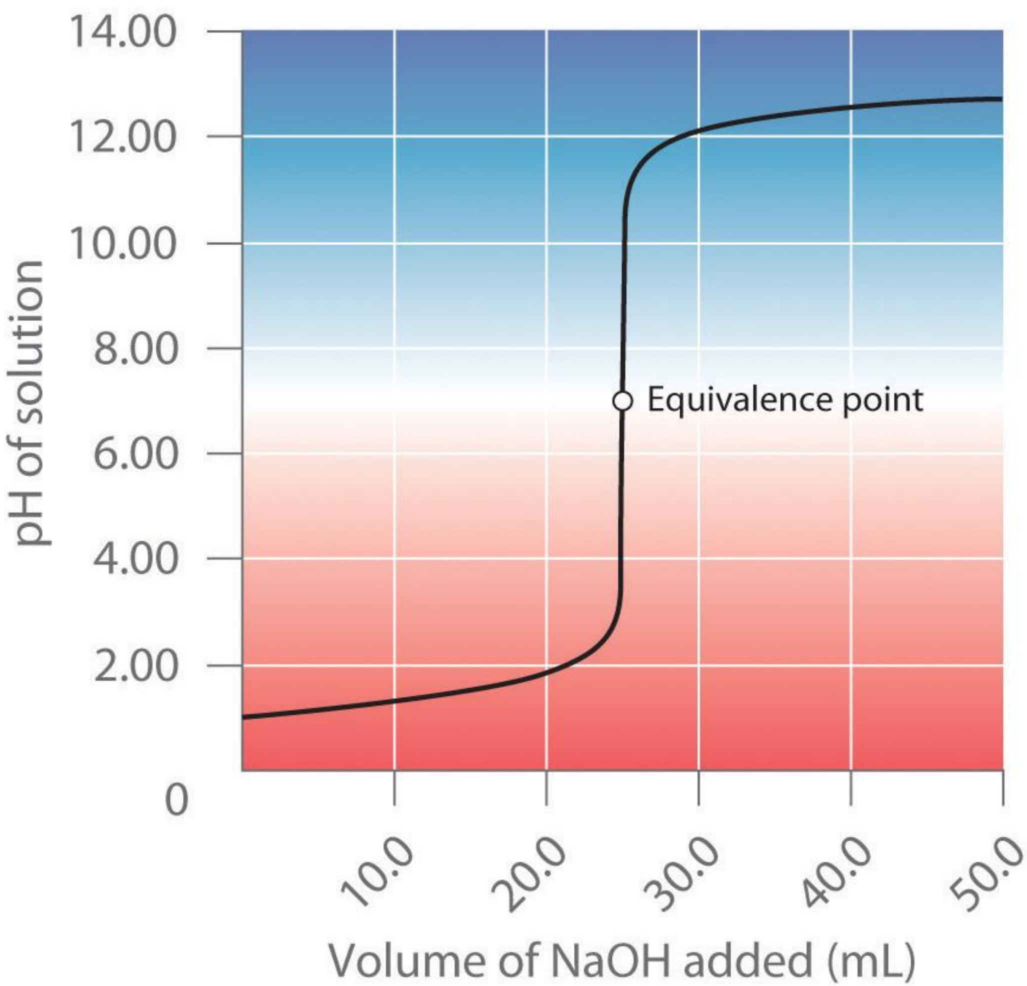
Note: Assumes 1 mol of acid reacts with 1 mol of alkali.

Acids, Bases and Salts

- A pH probe connected to a digital pH meter can be used to follow the change in pH of the reaction mixture as the acid and alkali neutralise each other:

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

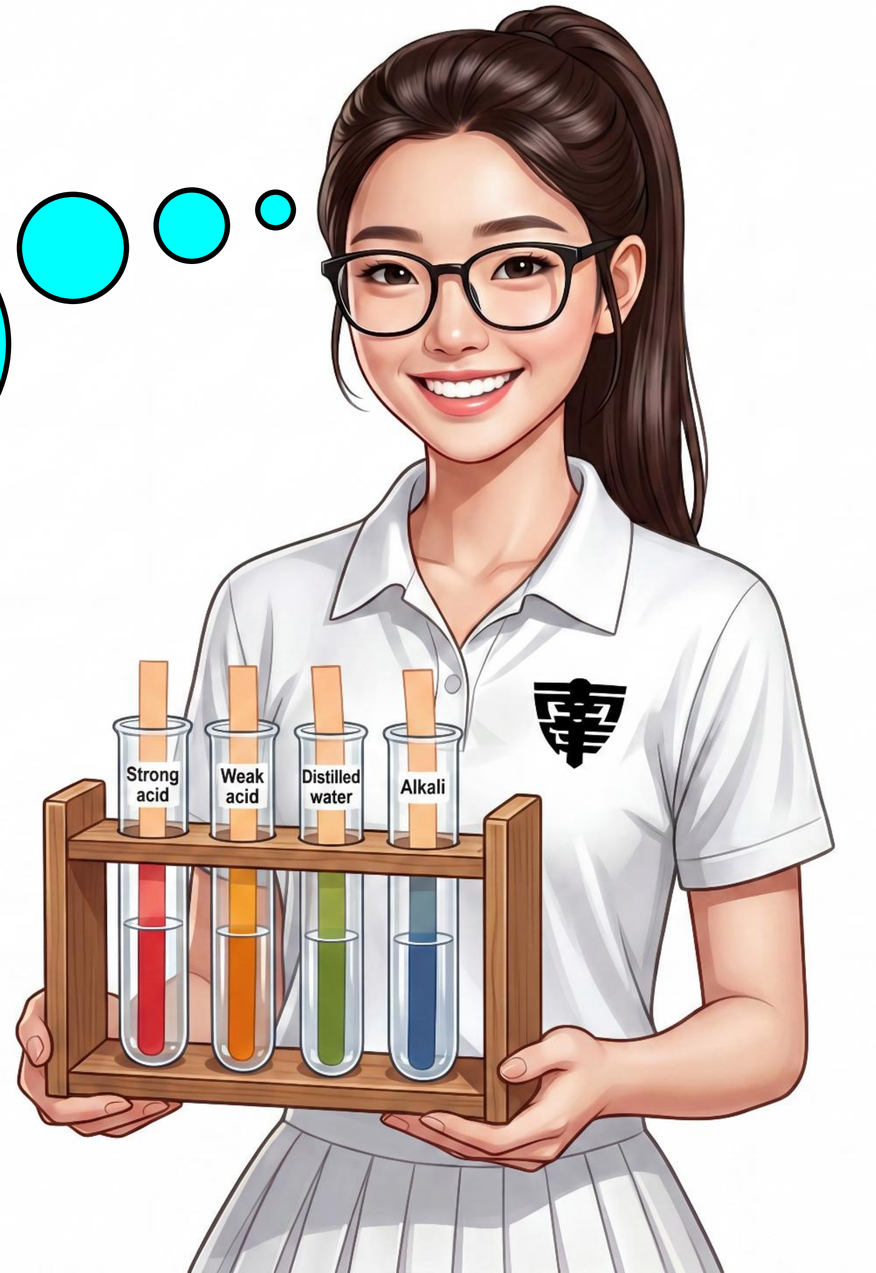
Acids, Bases and Salts



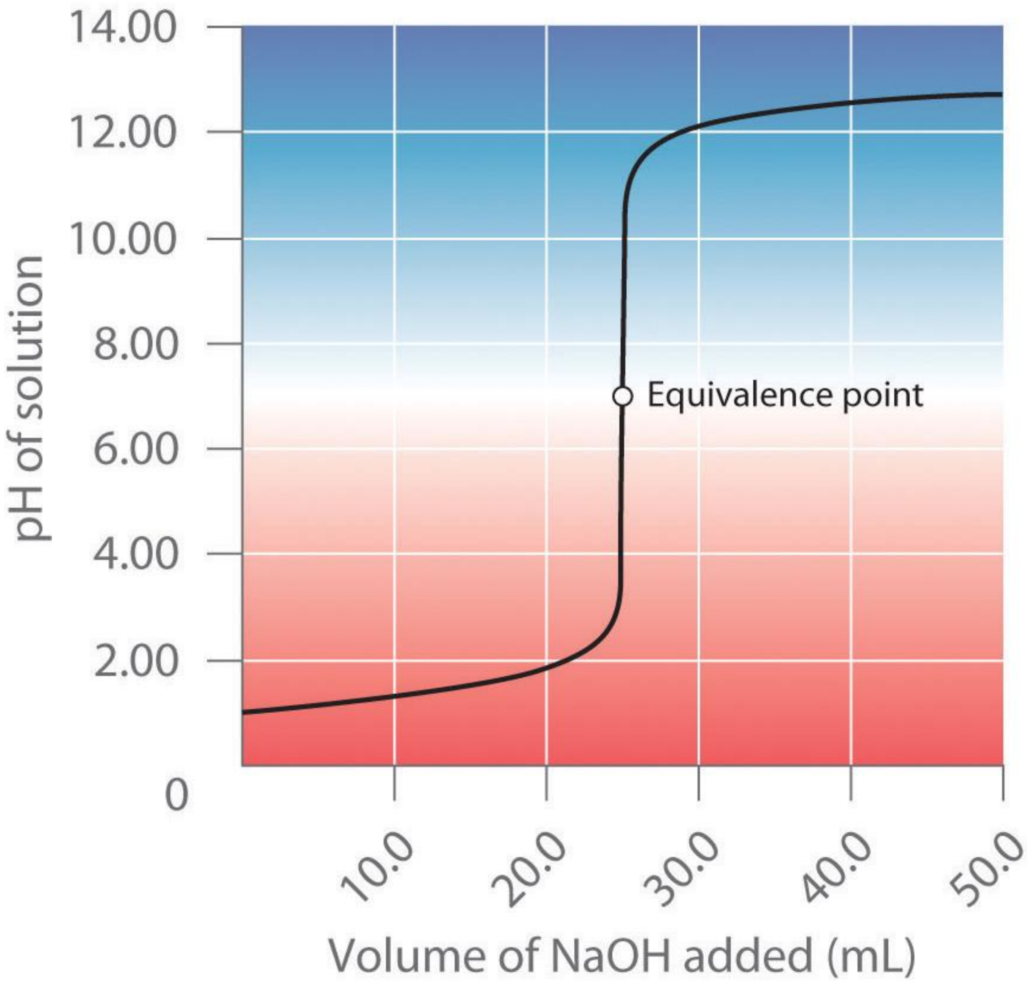
- Example of a pH curve that would be obtained when the solution of a strong alkali, *e.g.* NaOH(aq) is added to the solution of a strong acid, *e.g.* HC*l*(aq).
- The *equivalence point* is the point in the reaction at which the amount (*moles*) of acid and amount (*moles*) of alkali are in the same ratio as the one given by the balanced chemical equation.

Acids, Bases and Salts

14. What do the *pH titration curves* for different acid and alkali reactions look like?

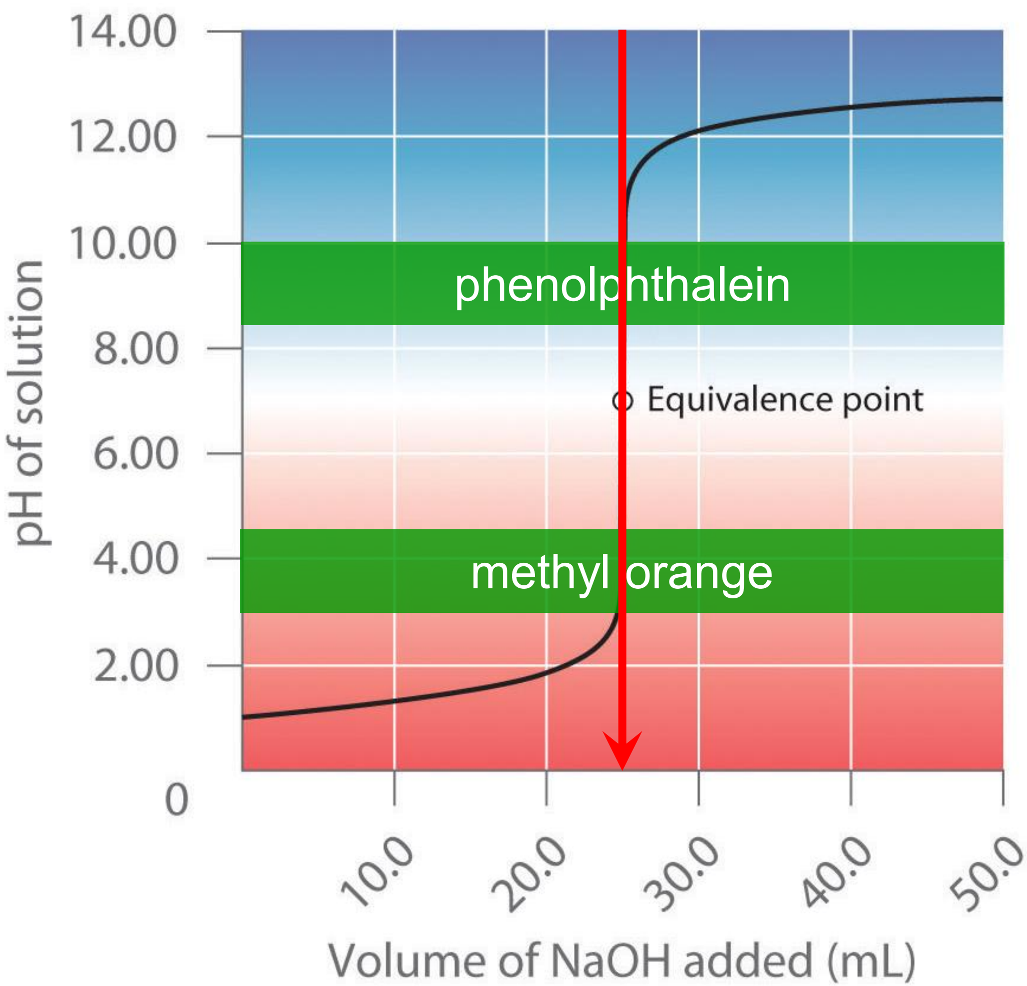


Acids, Bases and Salts



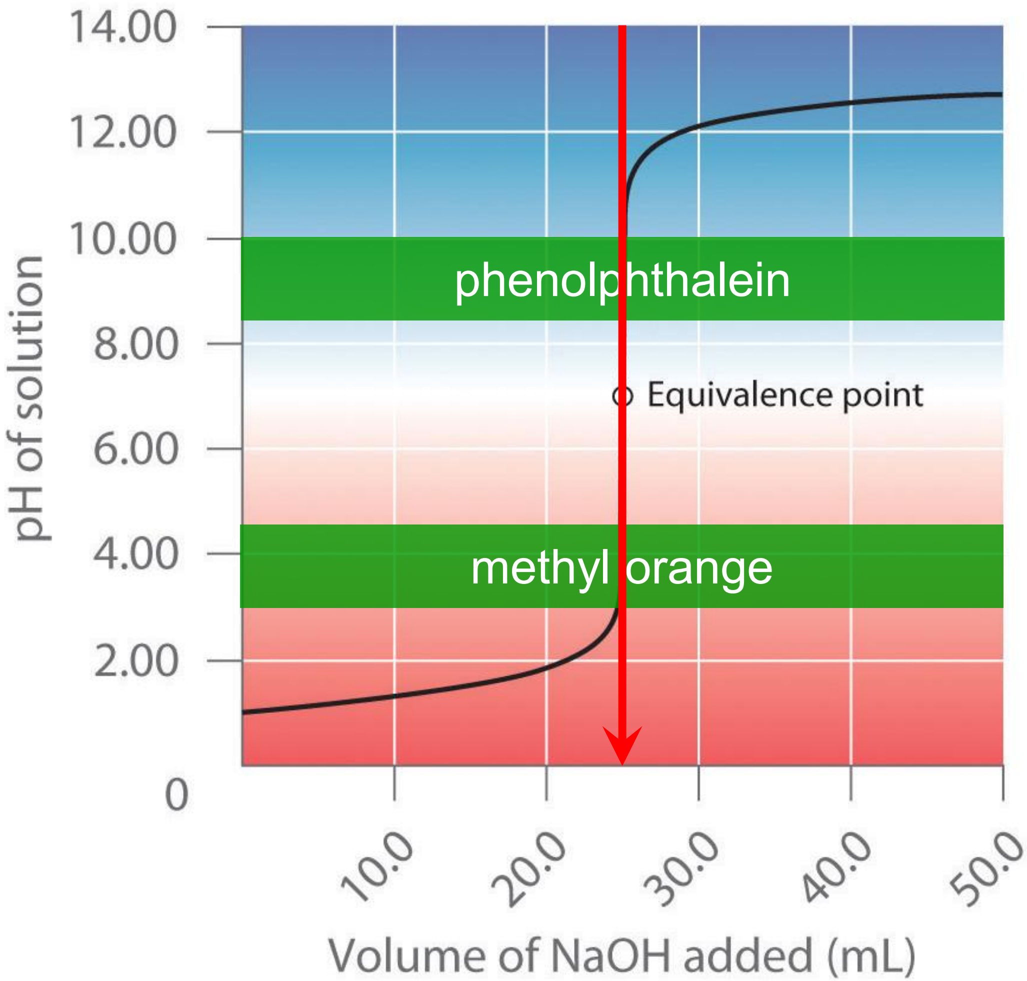
- The equivalence point for the addition of a strong alkali to a strong acid is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.

Acids, Bases and Salts



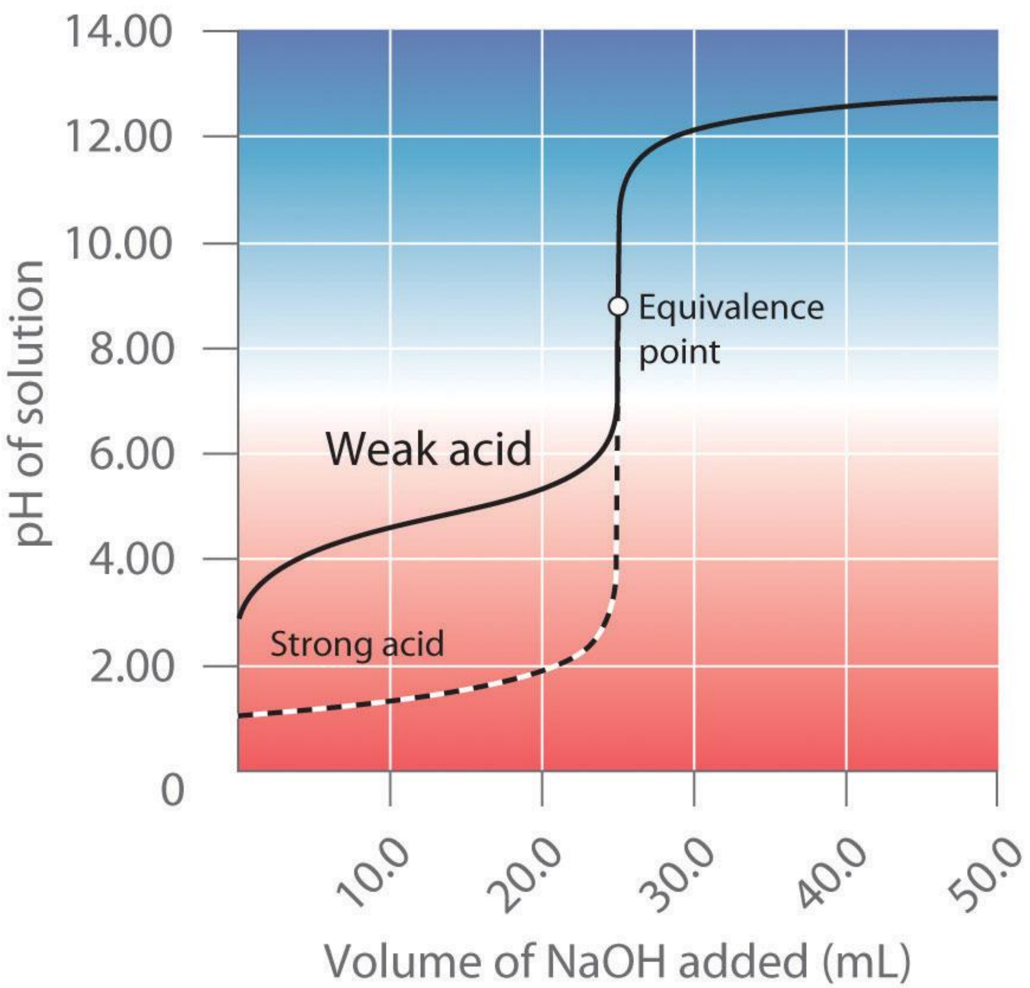
- The equivalence point for the addition of a strong alkali to a strong acid is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.
- Methyl orange = 3.1 – 4.4
- Phenolphthalein = 8.3 – 10.0

Acids, Bases and Salts



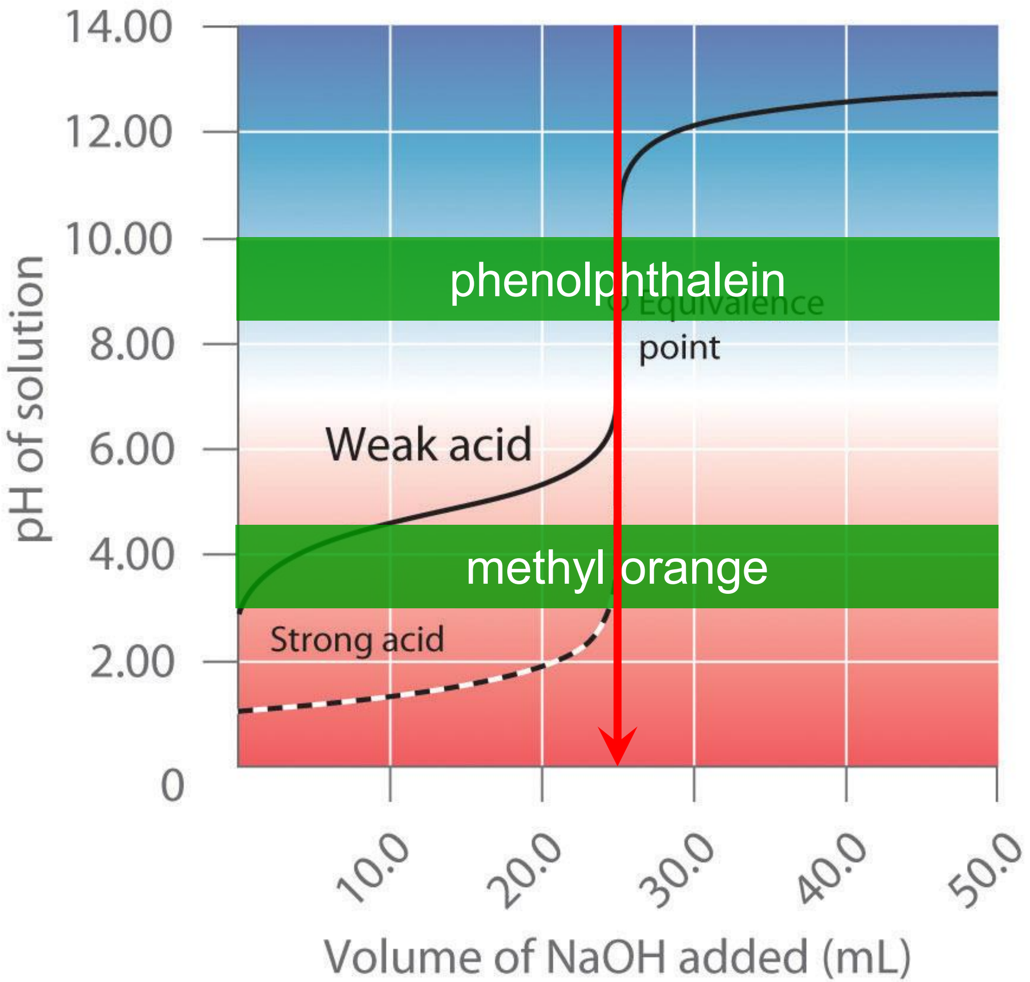
- The equivalence point for the addition of a strong alkali to a strong acid is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.
  - Methyl orange = 3.1 – 4.4 ✓
  - Phenolphthalein = 8.3 – 10.0 ✓

Acids, Bases and Salts



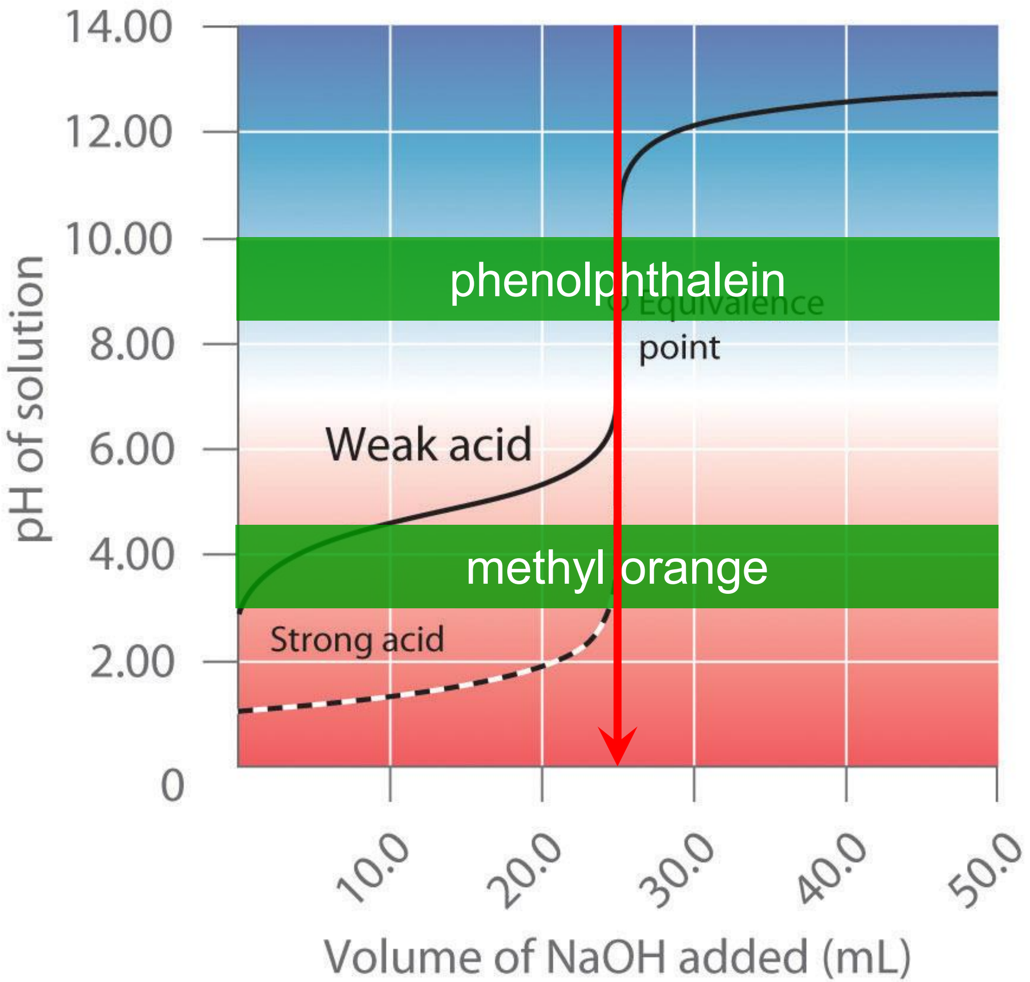
- The equivalence point for the addition of a strong alkali to a weak acid is at pH 9.00.
- A suitable indicator would change colour completely over the pH range 7.0 – 11.0.

Acids, Bases and Salts



- The equivalence point for the addition of a strong alkali to a weak acid is at pH 9.00.
- A suitable indicator would change colour completely over the pH range 7.0 – 11.0.
- Methyl orange = 3.1 – 4.4
- Phenolphthalein = 8.3 – 10.0

Acids, Bases and Salts



- The equivalence point for the addition of a strong alkali to a weak acid is at pH 9.00.
- A suitable indicator would change colour completely over the pH range 7.0 – 11.0.
  - Methyl orange = ✗ 3.1 – 4.4
  - Phenolphthalein = ✓ 8.3 – 10.0

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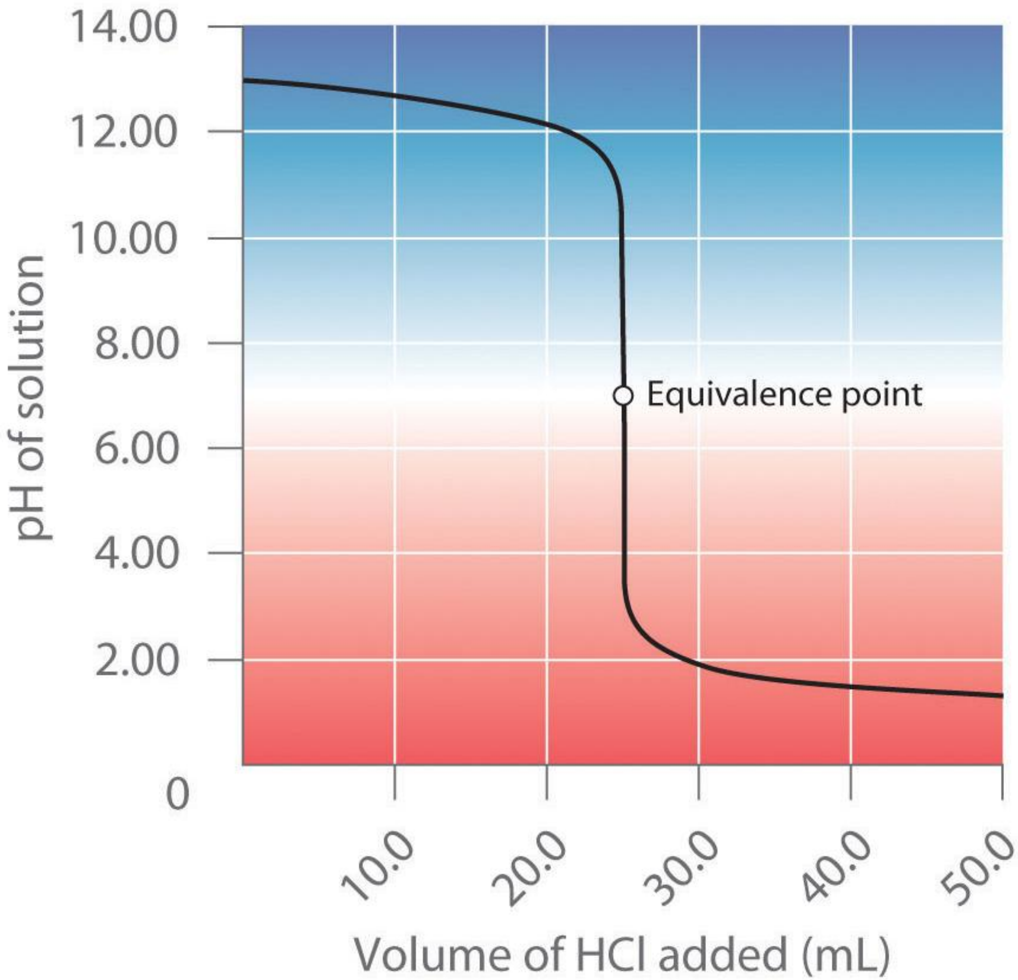
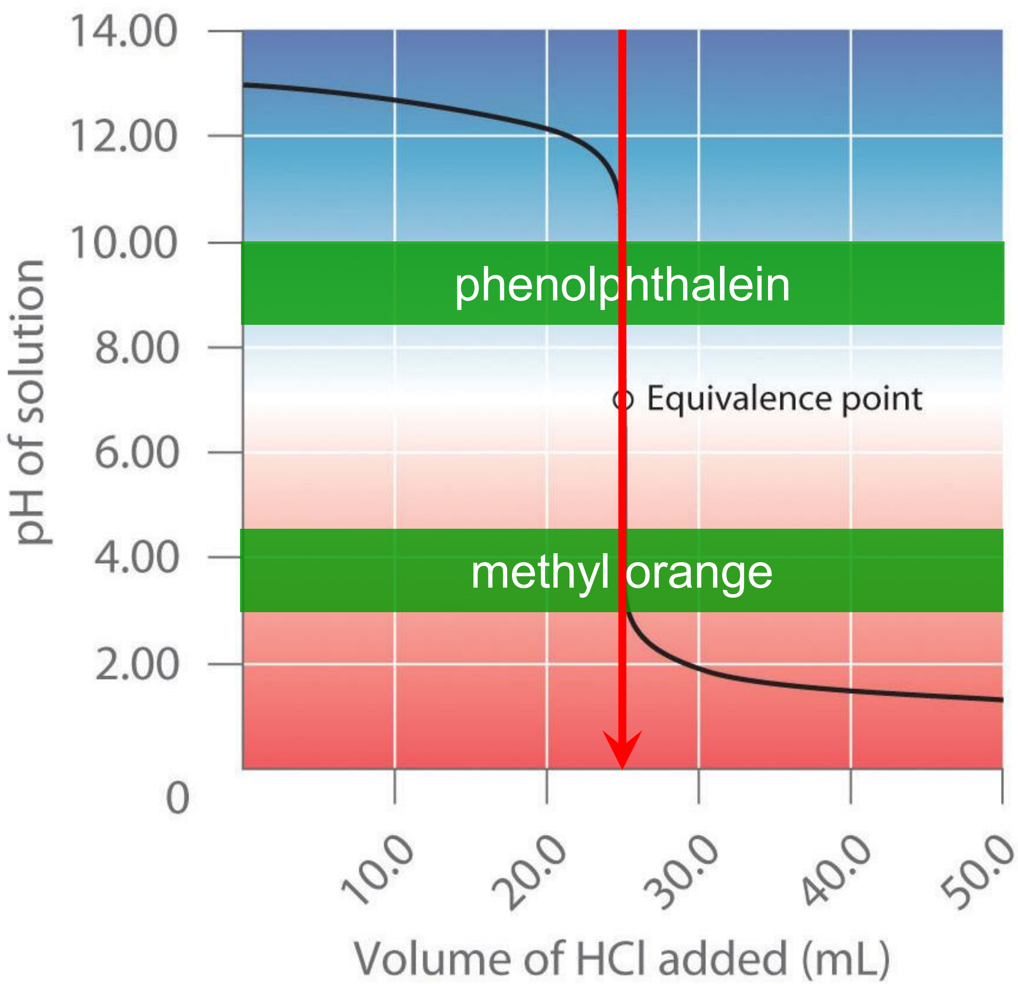
Acids, Bases and Salts



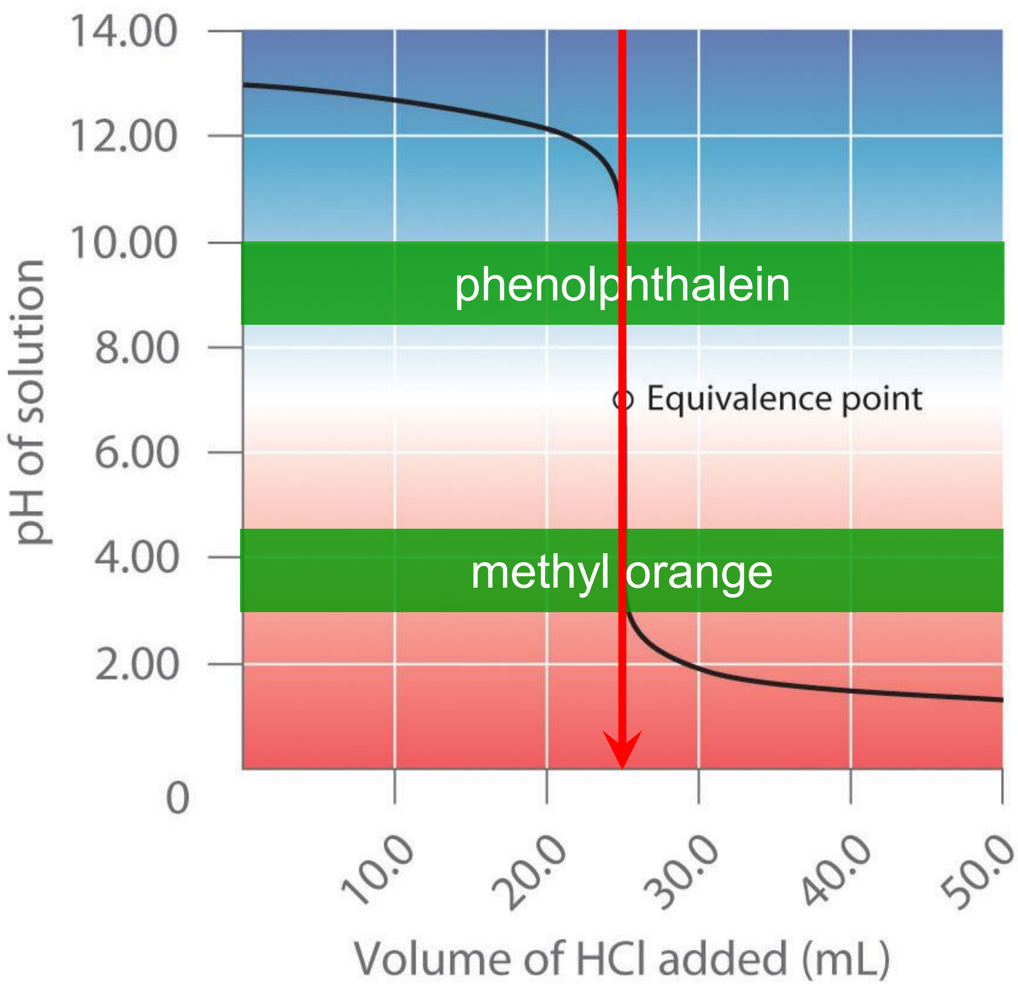
- The equivalence point for the addition of a strong acid to a strong alkali is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.

Acids, Bases and Salts



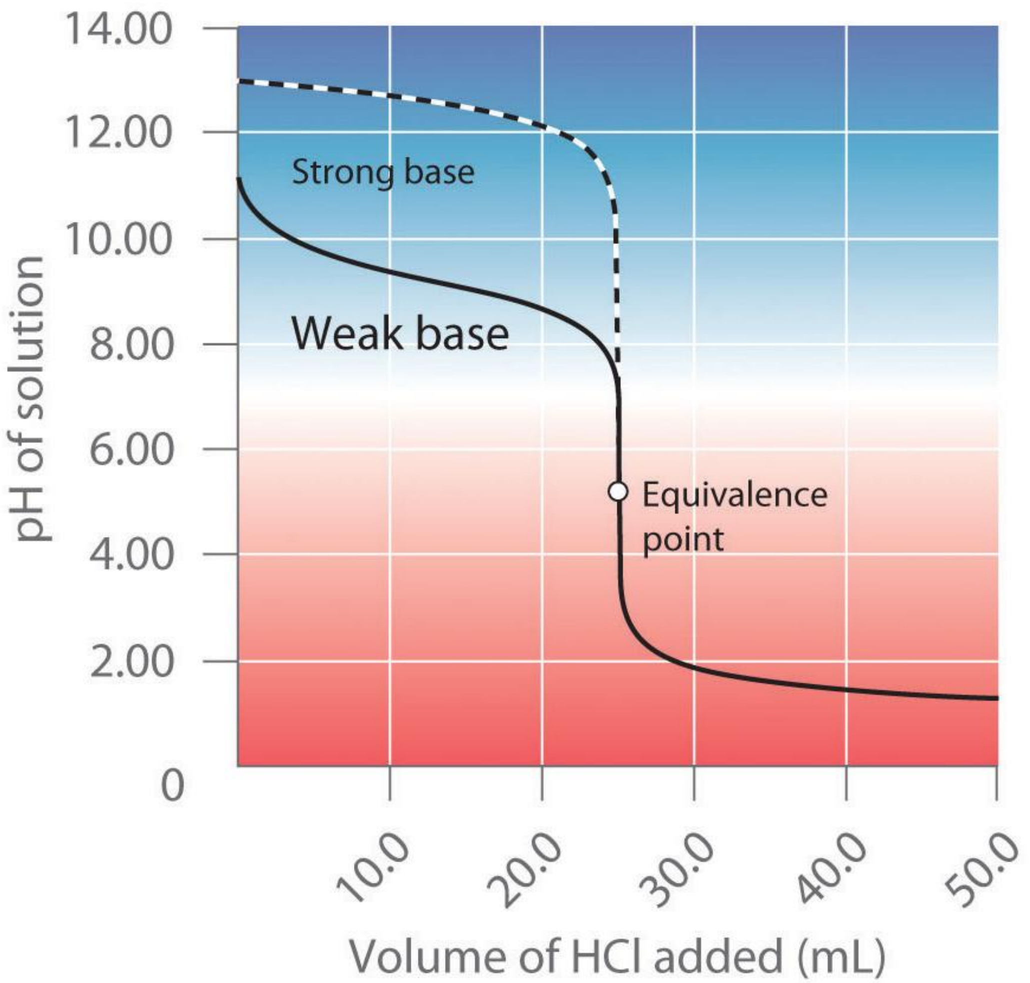
- The equivalence point for the addition of a strong acid to a strong alkali is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.
- Methyl orange = 3.1 – 4.4
- Phenolphthalein = 8.3 – 10.0

Acids, Bases and Salts



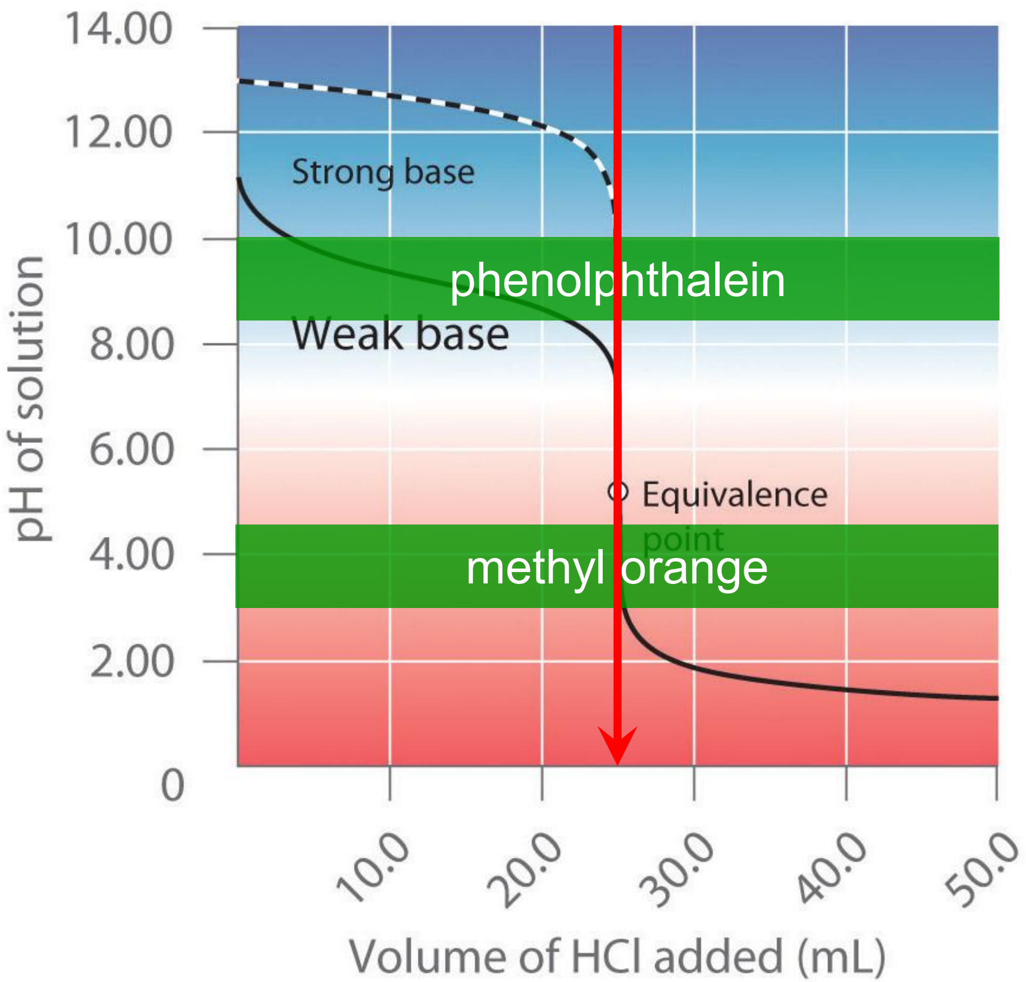
- The equivalence point for the addition of a strong acid to a strong alkali is at pH 7.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 11.0.
  - Methyl orange = 3.1 – 4.4 ✓
  - Phenolphthalein = 8.3 – 10.0 ✓

Acids, Bases and Salts



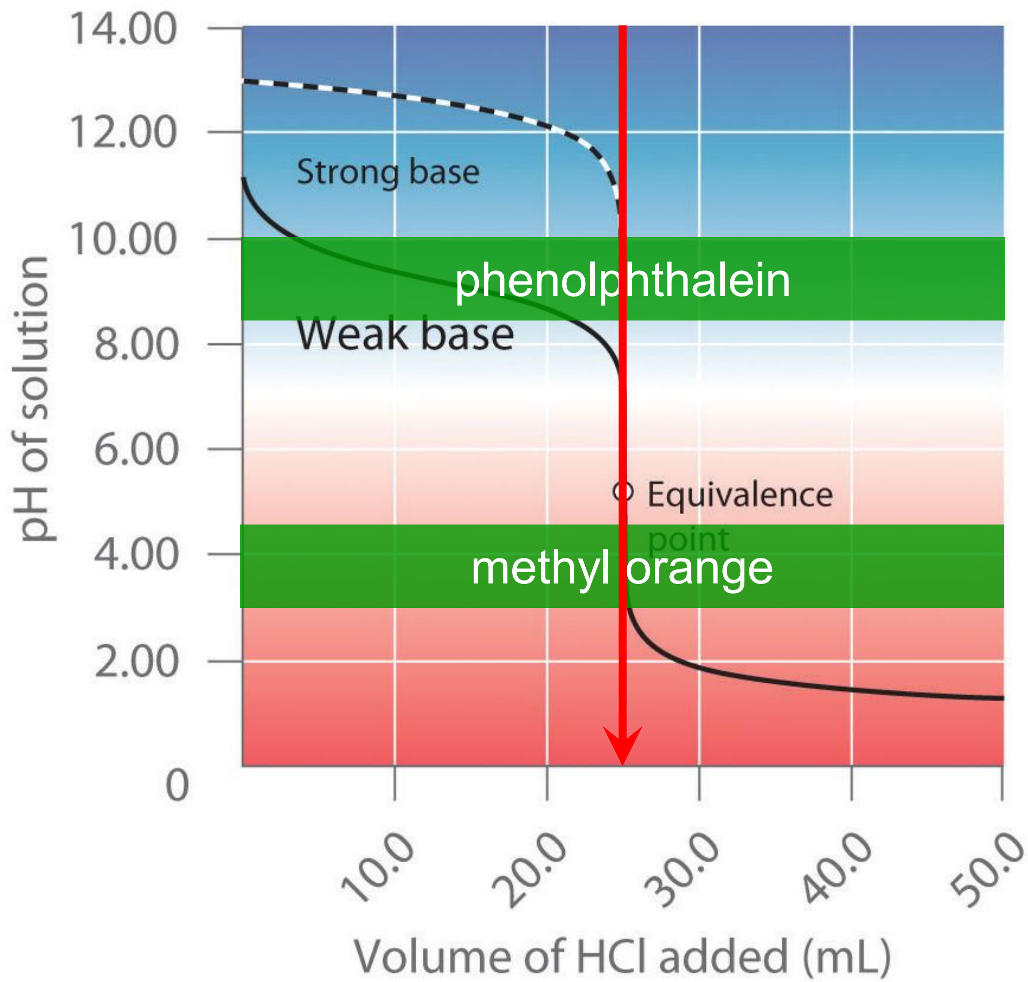
- The equivalence point for the addition of a strong acid to a weak alkali is at pH 5.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 7.0.

Acids, Bases and Salts



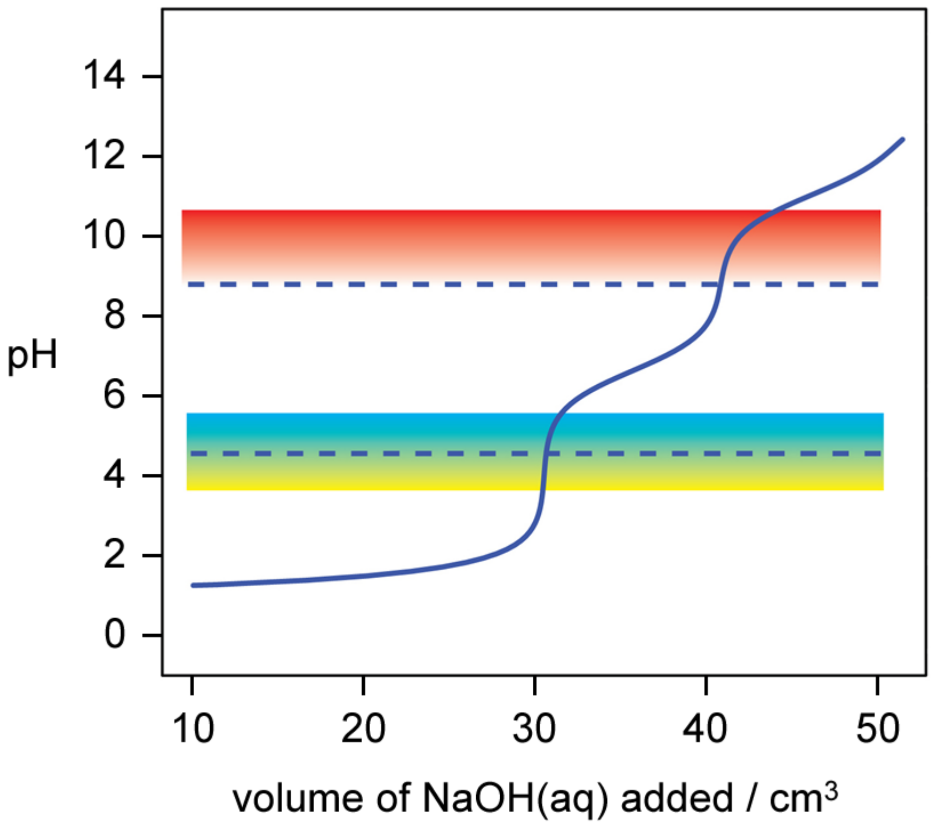
- The equivalence point for the addition of a strong acid to a weak alkali is at pH 5.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 7.0.
- Methyl orange = 3.1 – 4.4
- Phenolphthalein = 8.3 – 10.0

Acids, Bases and Salts



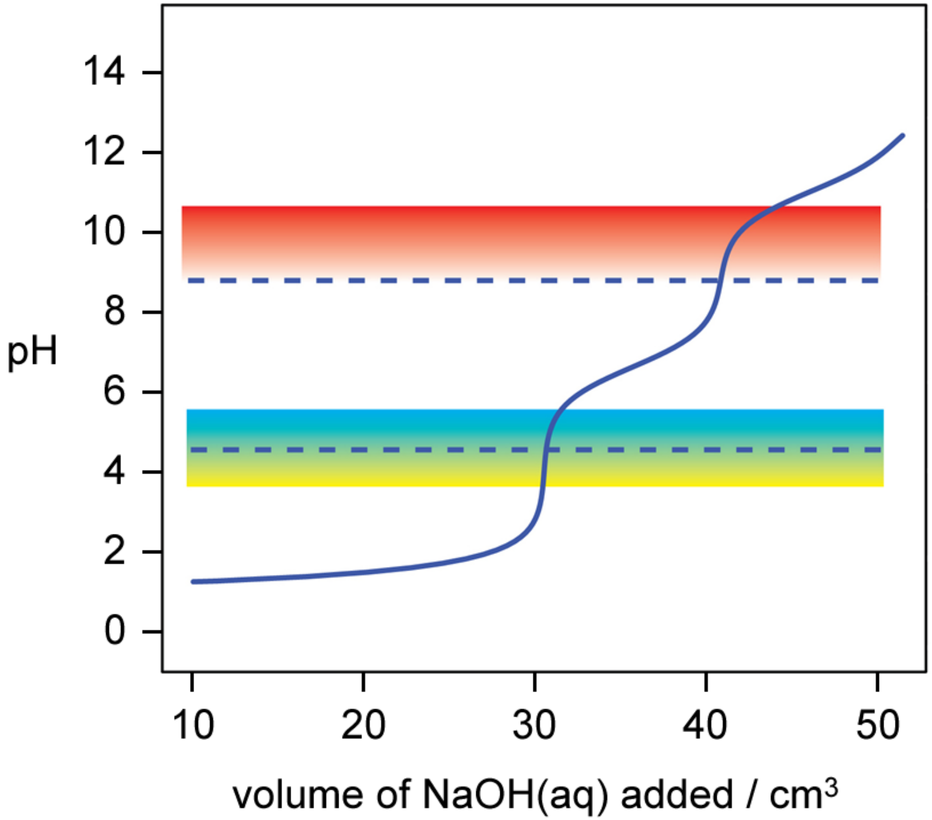
- The equivalence point for the addition of a strong acid to a weak alkali is at pH 5.00.
- A suitable indicator would change colour completely over the pH range 3.0 – 7.0.
  - Methyl orange = ✓ 3.1 – 4.4
  - Phenolphthalein = ✗ 8.3 – 10.0

Acids, Bases and Salts



- The pH curve shown on the left is obtained during a *double end point* titration.
- An example of a double end point titration would be the addition of aqueous sodium hydroxide to a *dibasic acid*, such as sulfuric acid.
- A double end point titration requires *two different* indicators.

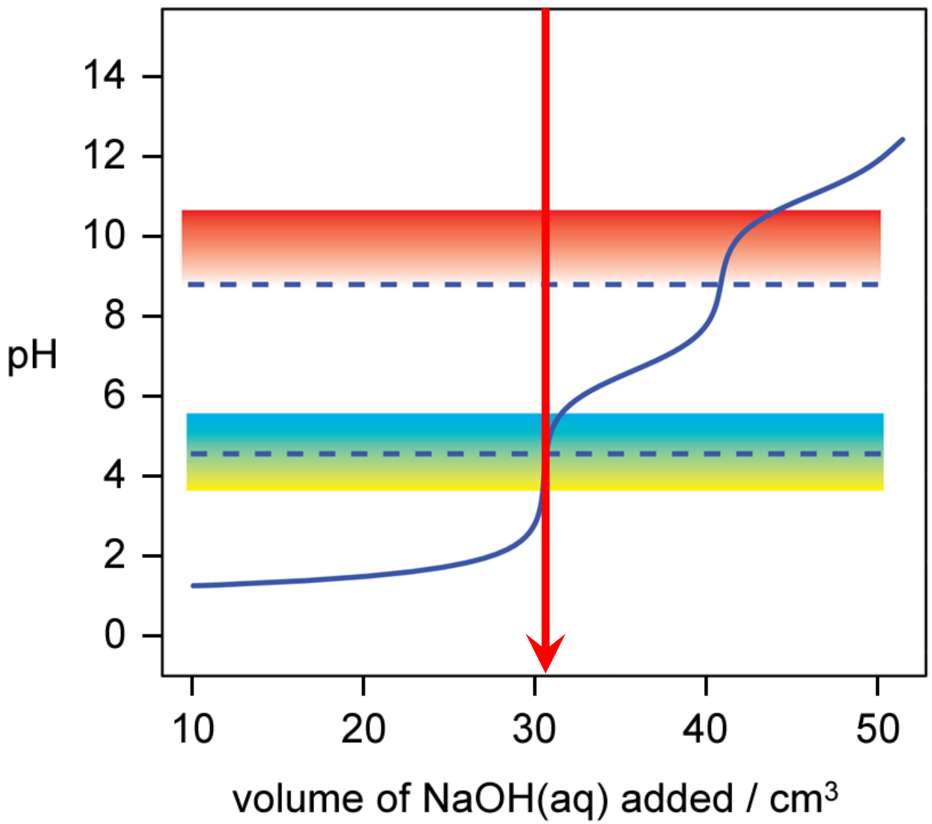
Acids, Bases and Salts



- Initially, the first hydrogen ion of the sulfuric acid is replaced by a sodium ion to form sodium hydrogen sulfate:

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

Acids, Bases and Salts

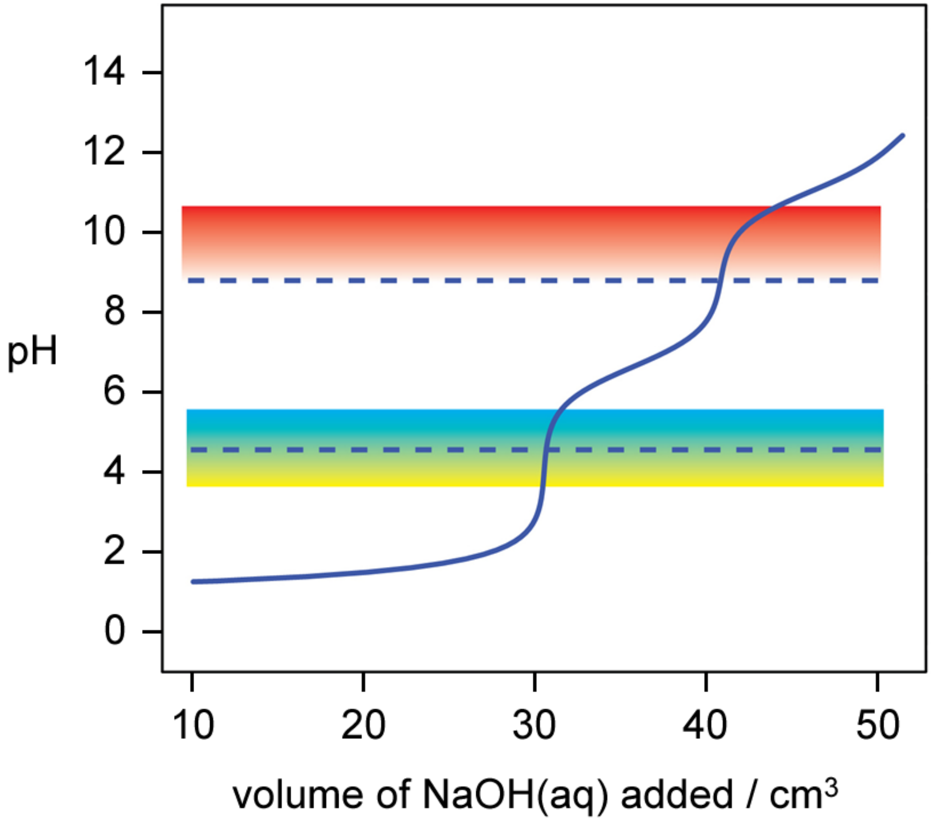


- Initially, the first hydrogen ion of the sulfuric acid is replaced by a sodium ion to form sodium hydrogen sulfate:

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

- The pH at the equivalence point of this reaction is 4.3, and a suitable indicator is bromocresol green (yellow → green → blue).

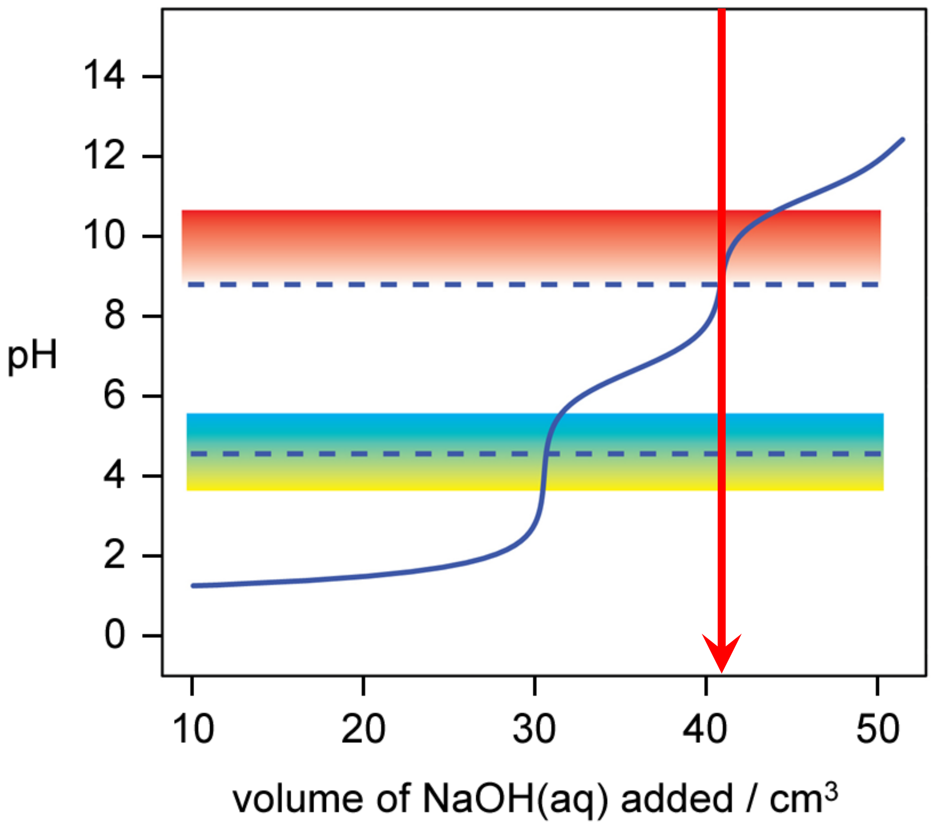
Acids, Bases and Salts



- Next, the second hydrogen ion of the sulfuric acid is replaced by a sodium ion to form sodium sulfate:

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

Acids, Bases and Salts



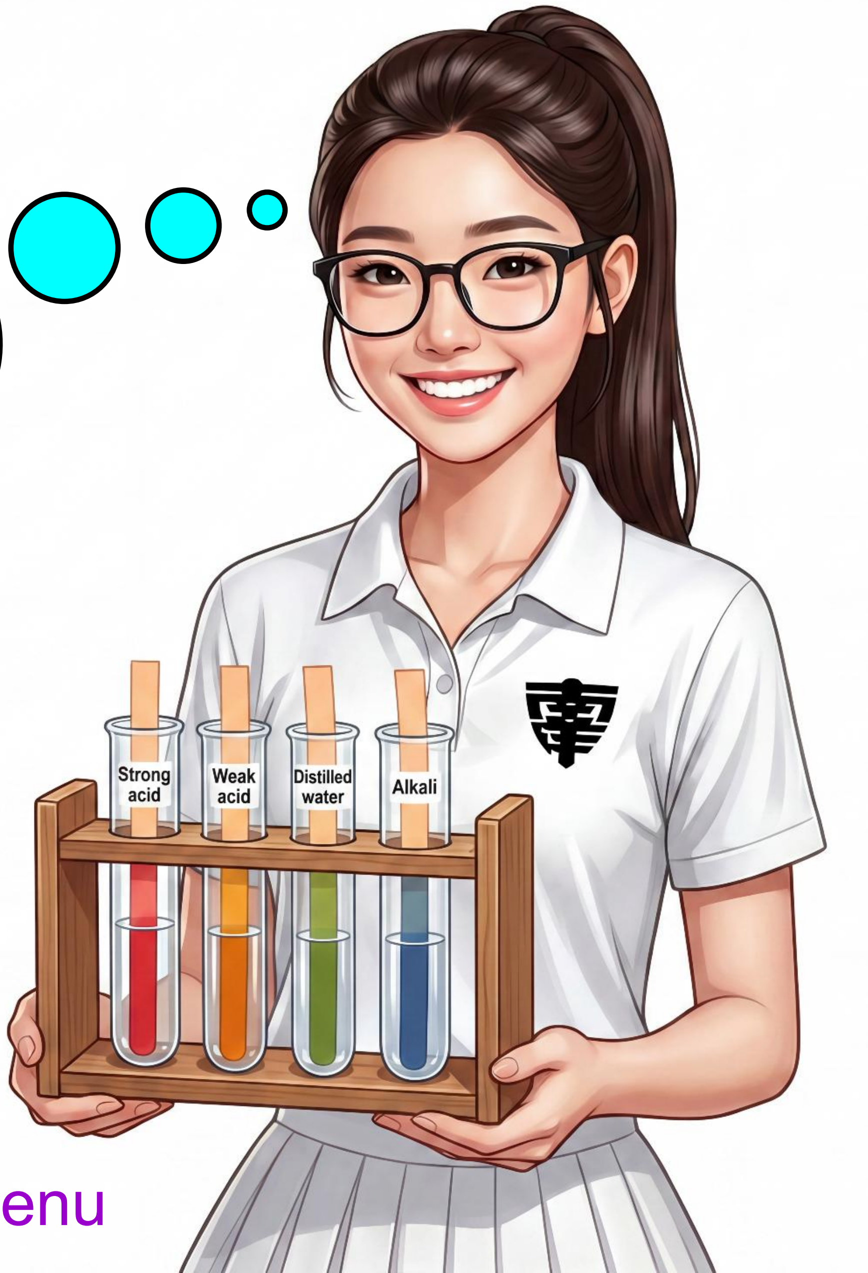
- Next, the second hydrogen ion of the sulfuric acid is replaced by a sodium ion to form sodium sulfate:

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

- The pH at the equivalence point of this reaction is 8.5, and a suitable indicator is phenolphthalein (colourless → pink).

Acids, Bases and Salts

15. How are the *solubilities* of metal hydroxides used in *qualitative analysis*?



Main Menu

Acids, Bases and Salts

- The identification of an unknown chemical, *e.g.* the identification of which anions and cations are present in a salt, is known as *qualitative analysis*.

- The solubility rules state that hydroxides are generally *insoluble* in water.

- So when the aqueous solution of an alkali is added to the aqueous solution of a salt, an *insoluble metal hydroxide may precipitate* from the solution. The colour and nature of the precipitate may give enough information to identify the metal hydroxide, and hence the salt.

Acids, Bases and Salts

- Example #1

Adding an aqueous solution of sodium hydroxide to an unknown salt solution produces a *blue* precipitate.

$$CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$$

The *blue* precipitate is probably copper(II) hydroxide, indicating that the unknown salt solution contains copper(II) ions – $Cu^{2+}(aq)$.

Acids, Bases and Salts

- Example #2

Adding an aqueous solution of sodium hydroxide to an unknown salt solution produces a *green* precipitate.

$$Fe(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + 2NaNO_3(aq)$$

The *green* precipitate is probably iron(II) hydroxide, indicating that the unknown salt solution contains iron(II) ions – $Fe^{2+}(aq)$.

Acids, Bases and Salts

- Example #3

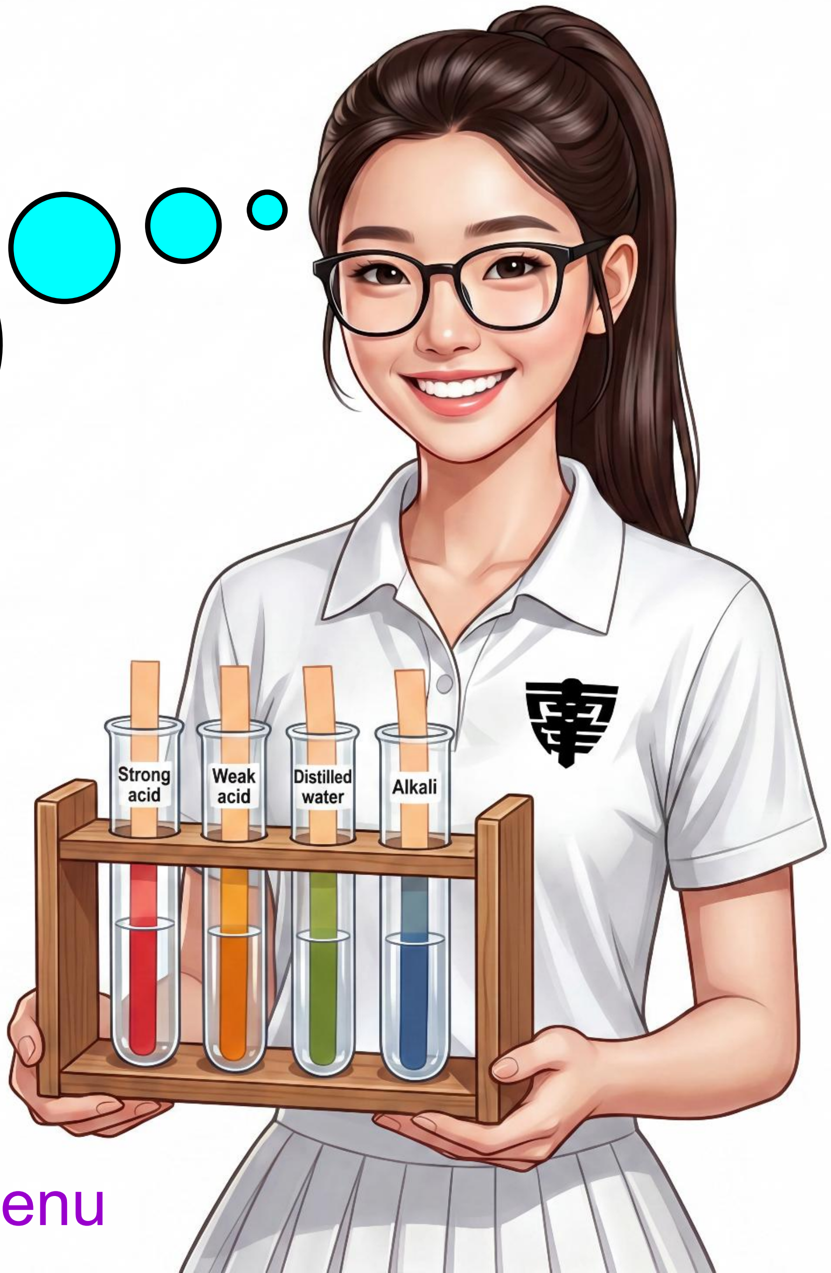
Adding an aqueous solution of sodium hydroxide to an unknown salt solution produces a *reddish-brown* precipitate.

$$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$$

The *reddish-brown* precipitate is probably iron(III) hydroxide, indicating that the unknown salt solution contains iron(III) ions – $Fe^{3+}(aq)$.

Acids, Bases and Salts

16. Could I please have a *summary* of the *essential reactions* that we have studied?



Main Menu

Acids, Bases and Salts

Reactions of Acids:

acid + metal

acid + base

acid + carbonate

Reactions of Bases:

base + ammonium salt

alkali + aqueous metal salt

Acids, Bases and Salts

Reactions of Acids:

- acid + metal → salt + H_2
- acid + base → salt + H_2O
- acid + carbonate → salt + H_2O + CO_2

Reactions of Bases:

- base + ammonium salt → salt + H_2O + NH_3
- alkali + aqueous metal salt → precipitate of metal hydroxide

Acids, Bases and Salts

1. acid + metal → salt + hydrogen

2. acid + carbonate → salt + water + carbon dioxide

3. acid + base / alkali → salt + water

4. ammonium salt + base / alkali → salt + water + ammonia

5. aqueous metal salt + alkali → metal hydroxide ppt. + salt

Acids, Bases and Salts

[a]**1.** acid + metal → salt + hydrogen

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

2. acid + carbonate → salt + water + carbon dioxide

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

3. acid + base / alkali → salt + water

$$2HNO_3(aq) + Ca(OH)_2(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l)$$

4. ammonium salt + base / alkali → salt + water + ammonia

$$NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) + NH_3(g)$$

5. aqueous metal salt + alkali → metal hydroxide ppt. + salt

$$Pb(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Pb(OH)_2(s) + 2NaNO_3(aq)$$

[a]**Note**: Copper, silver and gold do *not* react with acids.

Acids, Bases and Salts

1. acid + metal → salt + hydrogen

2. acid + carbonate → salt + water + carbon dioxide

3. acid + base / alkali → salt + water

4. ammonium salt + base / alkali → salt + water + ammonia

5. aqueous metal salt + alkali → metal hydroxide ppt. + salt

Acids, Bases and Salts

[a] **1.** acid + metal → salt + hydrogen

$$2H^+(aq) + Mg(s) \rightarrow Mg^{2+}(aq) + H_2(g)$$

[b] **2.** acid + carbonate → salt + water + carbon dioxide

$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$$

[c] **3.** acid + base / alkali → salt + water

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

[c] **4.** ammonium salt + base / alkali → salt + water + ammonia

$$NH_4^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_3(g)$$

5. aqueous metal salt + alkali → metal hydroxide ppt. + salt

$$Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$$

[a] **Note**: Copper, silver and gold do *not* react with acids.

[b] **Note**: Ionic equation for carbonates that are *soluble in water*.

[c] **Note**: Ionic equation for bases that are *soluble in water*.

Acids, Bases and Salts

General Ionic Equations

- acid and alkali:

- acid and carbonate:

- acid and metal:

- ammonium salt and alkali:

Acids, Bases and Salts

General Ionic Equations

- acid and alkali:

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

- acid and carbonate:

$$2H^+(aq) + {*}CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$$

- acid and metal:

$$2H^+(aq) + {*}M(s) \rightarrow M^{2+}(aq) + H_2(g)$$

- ammonium salt and alkali:

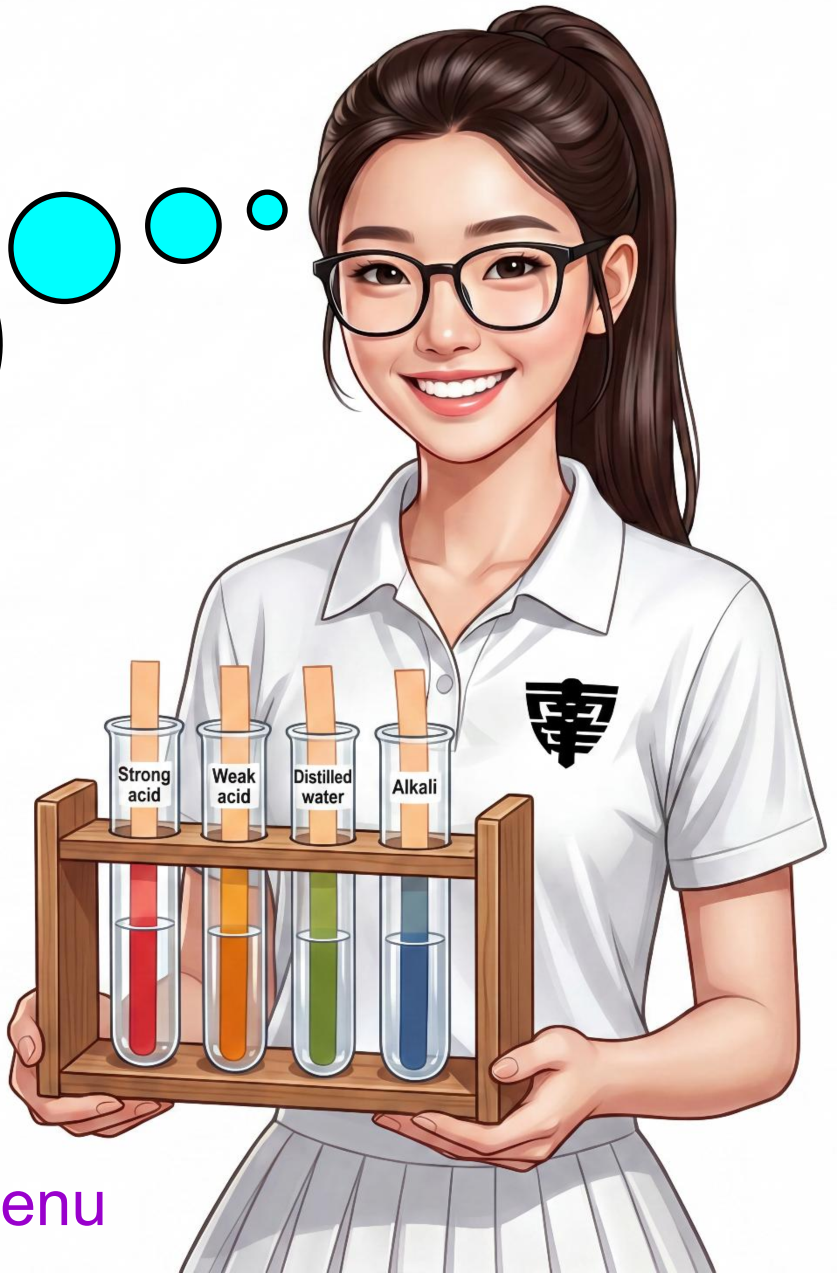
$$NH_4^+(aq) + {*}OH^-(aq) \rightarrow H_2O(l) + NH_3(g)$$

*Ionic equation will vary if the hydroxide or carbonate is insoluble.

*Ionic equation will vary based upon the valency of the metal, M^+, M^{2+}, M^{3+}.

Acids, Bases and Salts

17. What *advanced concepts* are there to define acids and bases?



Acids, Bases and Salts

Lewis Theory

- Different theories have been proposed in order to define and explain what acids and bases are. Each theory has its own advantages and disadvantages.

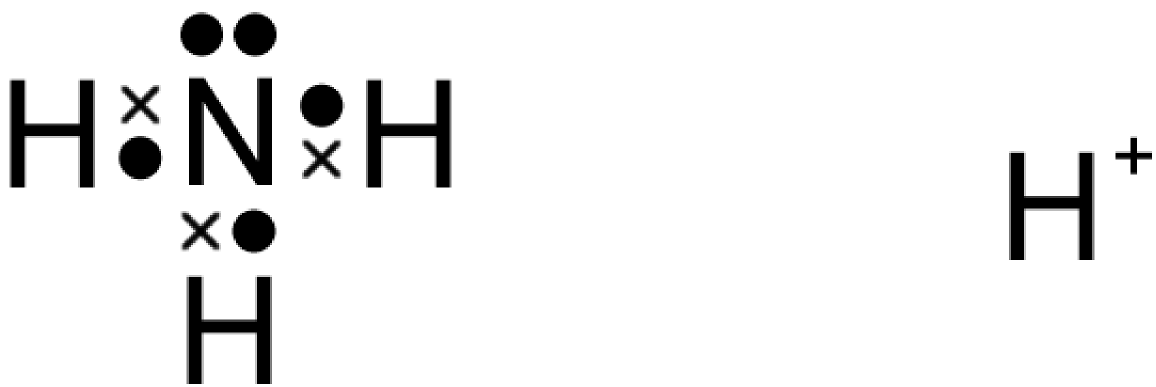
- The *Arrhenius* theory of acids and bases defines an *acid* as a chemical that ionizes in water to produce *hydrogen ions* (H^+) and defines a *base* as a substance that ionizes in water to produce *hydroxide ions* ($OH^–$).

- The *Lewis* theory of acids and bases defines an *acid* as an *electron pair acceptor* and defines a *base* as an *electron pair donor*.

Acids, Bases and Salts

Lewis Theory

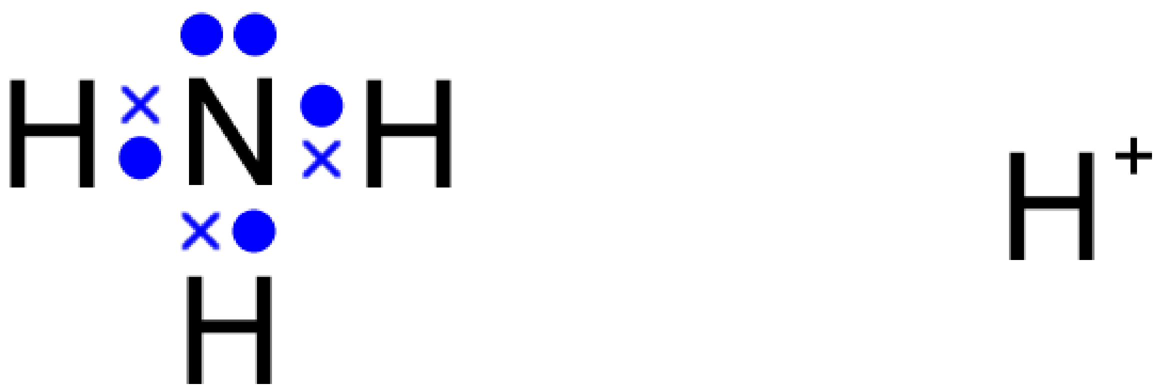
- To understand Lewis theory in more detail, consider an *ammonia molecule* (NH_3) and a *hydrogen ion* (H^+).



Acids, Bases and Salts

Lewis Theory

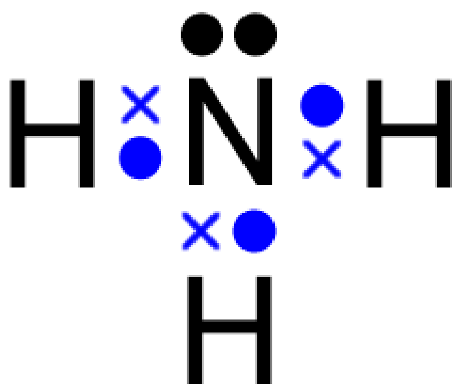
- The nitrogen atom has *four pairs* of electrons in its valence shell.



Acids, Bases and Salts

Lewis Theory

- *Three pairs* of electrons in the valence shell of the nitrogen atom are involved in forming covalent bonds between nitrogen and hydrogen. These are referred to as *bonding pair electrons*.

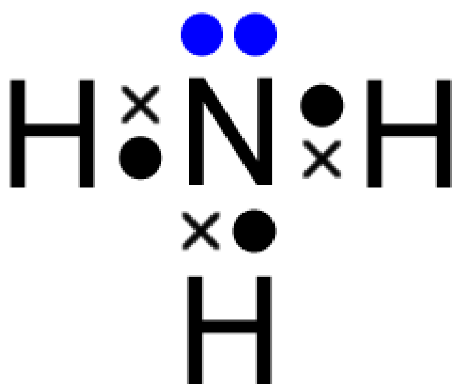


H^+

Acids, Bases and Salts

Lewis Theory

- *One pair* of electrons in the valence shell of the nitrogen atom is not involved in bonding. These are referred to as a *lone-pair* or *non-bonding pair* electrons.

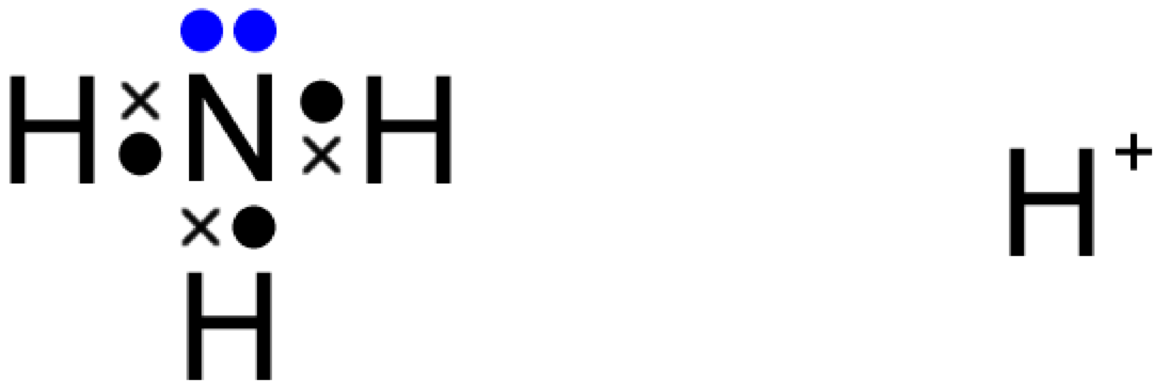


H^+

Acids, Bases and Salts

Lewis Theory

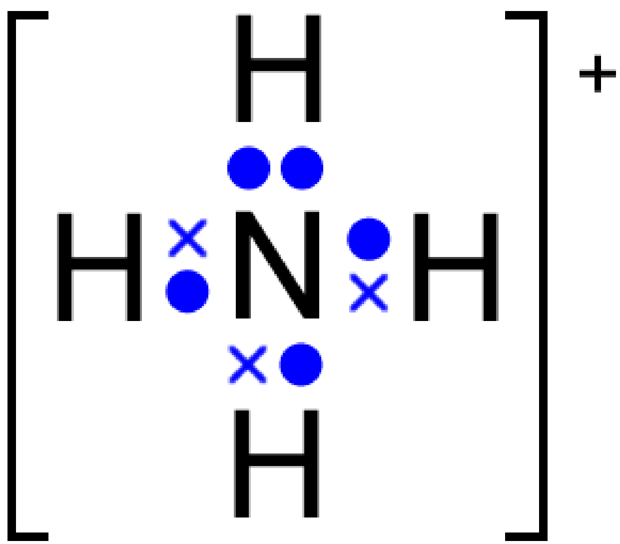
- The *lone-pair electrons* in the valence shell of the nitrogen atom are available to be donated towards and shared with the hydrogen ion.



Acids, Bases and Salts

Lewis Theory

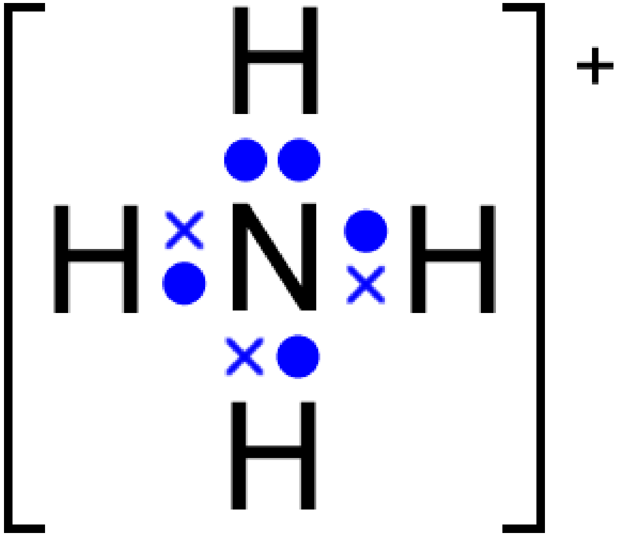
- When the hydrogen ion accepts and shares the lone pair of electrons in the valence shell of nitrogen, the hydrogen obtains the stable electronic configuration of a noble gas.



Acids, Bases and Salts

Lewis Theory

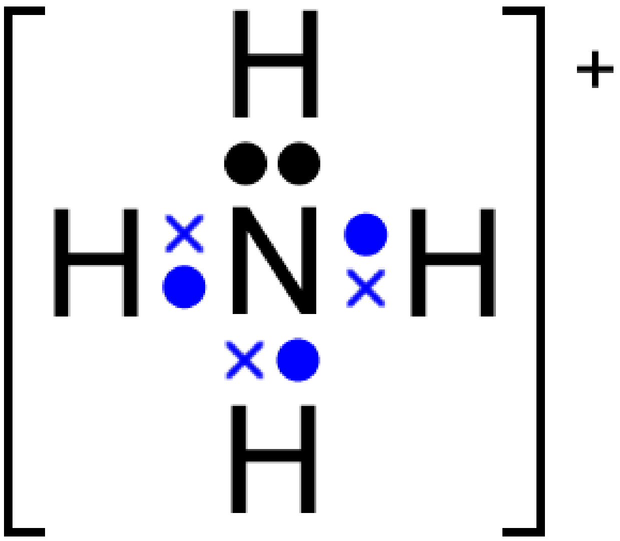
- This results in the formation of the polyatomic *ammonium ion* (NH_4^+). The hydrogen ion is the *Lewis acid* (electron pair acceptor) while the ammonia molecule is the *Lewis base* (electron pair donor).



Acids, Bases and Salts

Lewis Theory

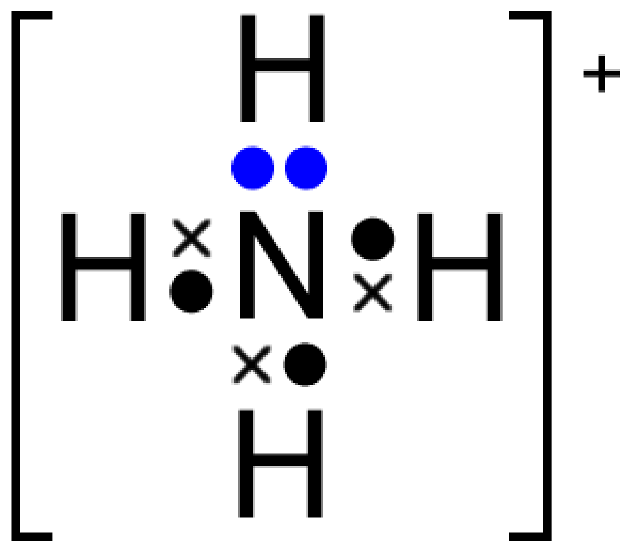
- **Note**: In three of the covalent bonds, one electron is donated by the nitrogen atom (•) while the second electron is donated by a hydrogen atom (×).



Acids, Bases and Salts

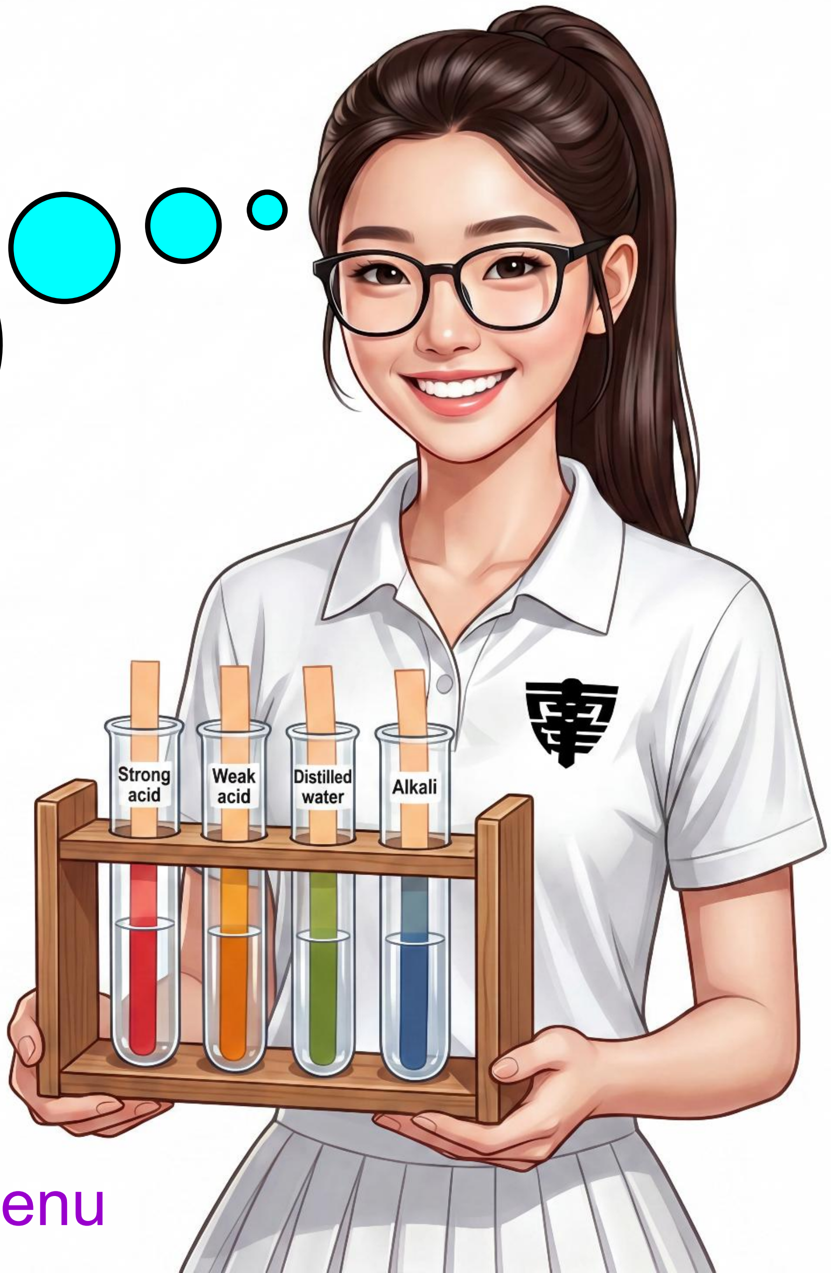
Lewis Theory

- **Note**: But in the fourth covalent bond, *both* electrons are donated by the nitrogen atom (••). This is a special type of covalent bond called a *dative covalent bond*.



Acids, Bases and Salts

18. Could I have some questions to practice my understanding of acids, bases and salts?



Main Menu

Acids, Bases and Salts

Question 1.

Which one of the following solutions is the best conductor of electricity?

A. Concentrated hydrochloric acid

B. Dilute nitric acid

C. Concentrated sulfuric acid

D. Dilute ethanoic acid

Acids, Bases and Salts

Question 1.

Which one of the following solutions is the best conductor of electricity?

A. Concentrated hydrochloric acid

B. Dilute nitric acid

C. Concentrated sulfuric acid ✓

D. Dilute ethanoic acid

- Electricity is the flow of charged particles which, in the case of an acid, are anions (–) and cations (H^+). *Concentrated*, *strong*, *polybasic* acids have a high concentration of ions, and are therefore the best conductors of electricity, *e.g.* $H_2SO_4(l) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$.

Acids, Bases and Salts

Question 2.

Which one of the following reactions produces a colourless solution *only*?

A. $HCl(aq)$ and $Mg(s)$

B. $HNO_3(aq)$ and $CaCO_3(s)$

C. $H_2SO_4(aq)$ and $CuO(s)$

D. $H_2SO_4(aq)$ and $NaOH(aq)$

Acids, Bases and Salts

Question 2.

Which one of the following reactions produces a colourless solution *only*?

A. HCl(aq) and Mg(s)

B. HNO_3(aq) and $CaCO_3$(s)

C. H_2SO_4(aq) and CuO(s)

D. H_2SO_4(aq) and NaOH(aq) ✓

• Option **A** will also produce hydrogen gas. Option **B** will also produce carbon dioxide gas. Option **C** will produce a *blue* solution of copper(II) sulfate – transition metal compounds are often coloured. Only option **D** will produce a colourless salt dissolved in water:

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

The salts of Group 1 and Group 2 metals are *colourless*.

Acids, Bases and Salts

Question 3.

Which one of the following is a list of neutral oxides?

A. Al_2O_3, PbO, ZnO

B. CO, N_2O, H_2O

C. CO_2, P_2O_5, SO_2

D. CaO, CuO, MgO

NANYANG GIRLS' HIGH

Acids, Bases and Salts

Question 3.

Which one of the following is a list of neutral oxides?

A. Al_2O_3, PbO, ZnO

B. CO, N_2O, H_2O ✓

C. CO_2, P_2O_5, SO_2

D. CaO, CuO, MgO

- Option **A** is a list of *amphoteric* oxides. Option **B** is a list of *neutral* oxides. Option **C** is a list of *acidic* oxides. Option **D** is a list of *basic* oxides. In general, metal oxides are basic – with some exceptions that are amphoteric – and non-metal oxides are acidic – with some exceptions that are neutral.

Acids, Bases and Salts

Question 4.

Which one of the following reactions *cannot* be used to prepare a sample of copper(II) sulfate in the lab?

A. Cu(s) and $H_2SO_4(aq)$

B. $CuCO_3(s)$ and $H_2SO_4(aq)$

C. $Cu(OH)_2(s)$ and $H_2SO_4(aq)$

D. CuO(s) and $H_2SO_4(aq)$

Acids, Bases and Salts

Question 4.

Which one of the following reactions *cannot* be used to prepare a sample of copper(II) sulfate in the lab?

A. Cu(s) and H_2SO_4(aq) ✓

B. $CuCO_3$(s) and H_2SO_4(aq)

C. $Cu(OH)_2$(s) and H_2SO_4(aq)

D. CuO(s) and H_2SO_4(aq)

- Pure metallic elements, such as *copper*, *gold*, *platinum* and *silver*, are not reactive enough to displace the hydrogen of an acid to form a salt.

NANYANG GIRLS' HIGH

Acids, Bases and Salts

Question 5.

In which one of the following pairs of acids can both acids react with an alkali to form an *acid salt*?

A. HCl(aq) and H_2SO_4(aq)

B. H_2SO_4(aq) and H_3PO_4(aq)

C. H_3PO_4(aq) and HNO_3(aq)

D. HNO_3(aq) and CH_3COOH(aq)

Acids, Bases and Salts

Question 5.

In which one of the following pairs of acids can both acids react with an alkali to form an *acid salt*?

A. $HCl(aq)$ and $H_2SO_4(aq)$

B. $H_2SO_4(aq)$ and $H_3PO_4(aq)$ ✓

C. $H_3PO_4(aq)$ and $HNO_3(aq)$

D. $HNO_3(aq)$ and $CH_3COOH(aq)$

- Only *polybasic* acids – one that contain two or more replaceable hydrogens – can form acid salts, *e.g.*

$$H_2SO_4(aq) + NaOH(aq) \rightarrow NaHSO_4(aq) + H_2O(l)$$
$$H_3PO_4(aq) + NaOH(aq) \rightarrow NaH_2PO_4(aq) + H_2O(l)$$

Acids, Bases and Salts

Question 6.

Which one of the following oxides reacts with sodium hydroxide to form a salt?

A. Calcium oxide

B. Copper(II) oxide

C. Iron(III) oxide

D. Zinc oxide

Acids, Bases and Salts

Question 6.

Which one of the following oxides reacts with sodium hydroxide to form a salt?

A. Calcium oxide

B. Copper(II) oxide

C. Iron(III) oxide

D. Zinc oxide ✓

- Zinc oxide is *amphoteric*. It can react with both acids and alkalis. The other oxides that are listed are all *basic* oxides which will *not* react with alkalis.

Acids, Bases and Salts

Question 7.

Which one of the following statements is true for all strong acids in aqueous solution?

A. They liberate carbon dioxide from carbonates.

B. They liberate ammonia from ammonium salts.

C. They produce hydrogen gas when added to any metal.

D. They have a pH value greater than 7.

Acids, Bases and Salts

Question 7.

Which one of the following statements is true for all strong acids in aqueous solution?

A. They liberate carbon dioxide from carbonates. ✓

B. They liberate ammonia from ammonium salts.

C. They produce hydrogen gas when added to any metal.

D. They have a pH value greater than 7.

- (**A**) All strong acids will react with metal carbonates to form a salt, water and carbon dioxide. (**B**) Ammonium salts react with *bases* to liberate ammonia. (**C**) Not all metals react with acids, *e.g.* Ag, Au, Cu and Pt do not react directly with acids. (**D**) Acids have pH values *below* 7.

Acids, Bases and Salts

Question 8.

Which one of the following elements burns in air to form an oxide which, when shaken with water, produces a solution with a pH value greater than 7?

A. Carbon

B. Copper

C. Hydrogen

D. Magnesium

Acids, Bases and Salts

Question 8.

Which one of the following elements burns in air to form an oxide which, when shaken with water, produces a solution with a pH value greater than 7?

A. Carbon

B. Copper

C. Hydrogen

D. Magnesium ✓

- (**A**) Carbon burns in air to form carbon dioxide, which is acidic. (**B**) Copper burns in air to form copper(II) oxide, which is basic, but *insoluble* in water. (**C**) Hydrogen burns in air to form water, which is neutral. (**D**) Magnesium burns in air to form magnesium oxide – a small amount of which will react with and dissolve in water to form alkaline magnesium hydroxide – $Mg(OH)_2(aq)$.

Acids, Bases and Salts

Question 9.

Which one of the following salts *cannot* be prepared by reacting a metal directly with an acid?

A. Calcium chloride

B. Iron(II) chloride

C. Magnesium sulfate

D. Silver nitrate

Acids, Bases and Salts

Question 9.

Which one of the following salts *cannot* be prepared by reacting a metal directly with an acid?

A. Calcium chloride

B. Iron(II) chloride

C. Magnesium sulfate

D. Silver nitrate ✓

- Metallic silver is *not* reactive enough to displace the hydrogen from an acid, hence silver nitrate *cannot* be prepared by reacting metallic silver with nitric acid – silver oxide or silver carbonate would have to be used instead.

NANYANG GIRLS' HIGH

Acids, Bases and Salts

Question 10.

In an accident at a factory, some nitric acid was spilt. Which one of the following substances, when added in excess, would neutralise the acid without leaving an alkaline solution?

A. Aqueous ammonia

B. Aqueous sodium hydroxide

C. Calcium carbonate

D. Water

Acids, Bases and Salts

Question 10.
In an accident at a factory, some nitric acid was spilt. Which one of the following substances, when added in excess, would neutralise the acid without leaving an alkaline solution?

A. Aqueous ammonia

B. Aqueous sodium hydroxide

C. Calcium carbonate ✓

D. Water

- Aqueous ammonia (**A**) and aqueous sodium hydroxide (**B**) would neutralise the acid and then, when added in *excess*, from an *alkaline* solution. Water (**D**) will only *dilute*, not neutralise, the acid. Calcium carbonate (**C**) is *insoluble* in water. It will react with, and neutralise, the acid, leaving a *neutral* solution.

Acids, Bases and Salts

Question 11.

Which one of the following is the ionic equation for the reaction between dilute sulfuric acid and aqueous sodium hydroxide?

A. $2Na^+ + SO_4^{2-} \rightarrow Na_2SO_4$

B. $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

C. $H^+ + OH^- \rightarrow H_2O$

D. $2NaOH + SO_4^{2-} \rightarrow Na_2SO_4 + 2OH^-$

Acids, Bases and Salts

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C. $H^+ + OH^- \rightarrow H_2O$ ✓

D. $2NaOH + SO_4^{2-} \rightarrow Na_2SO_4 + 2OH^-$

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

$$2H^+ + SO_4^{2-} + 2Na^+ + 2OH^- \rightarrow 2Na^+ + SO_4^{2-} + 2H_2O$$

simplifies to…

$$H^+ + OH^- \rightarrow H_2O$$

Acids, Bases and Salts

Question 12.
How many different chlorides, in total, could be prepared by the reaction of dilute hydrochloric acid with the following substances?

- Copper(II) oxide
- Magnesium
- Silver
- Zinc carbonate

A. 1 **B.** 2 **C.** 3 **D.** 4

Acids, Bases and Salts

Question 12.
How many different chlorides, in total, could be prepared by the reaction of dilute hydrochloric acid with the following substances?

- Copper(II) oxide
- Magnesium
- Silver
- Zinc carbonate

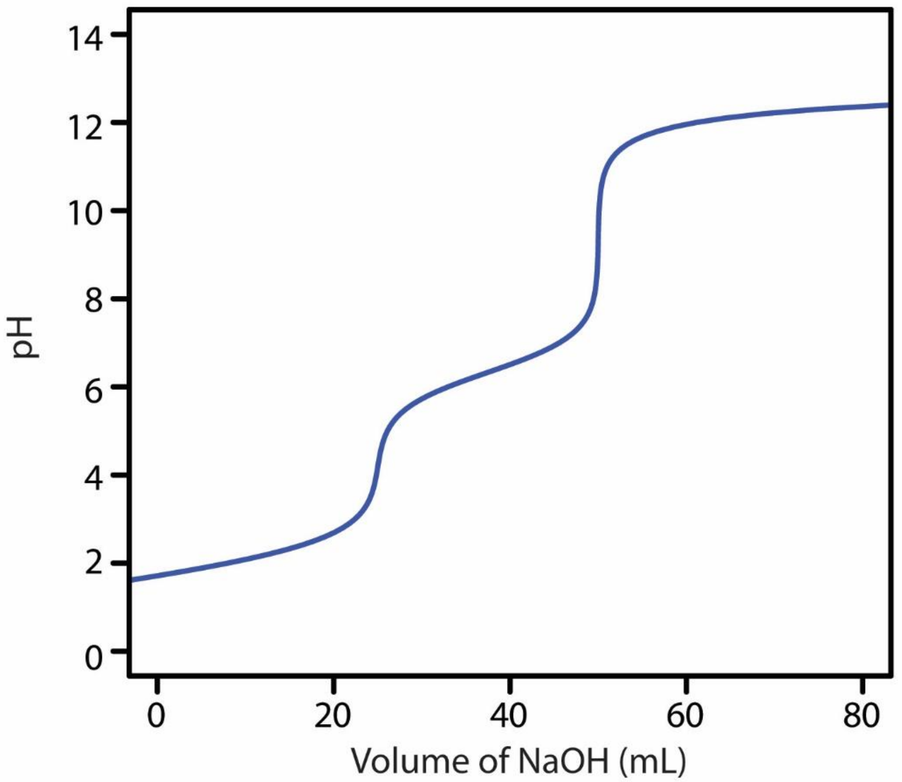
A. 1 **B.** 2 **C.** 3 ✓ **D.** 4

A. $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$ ✓
B. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ ✓
C. $Ag(s) + HCl(aq) \rightarrow$ *no observed reaction* ✗
D. $ZnCO_3(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + CO_2(g) + H_2O(l)$ ✓

Acids, Bases and Salts

Question 13.
Which acid, from the options given below, is most likely to give the pH titration curve given on the right?

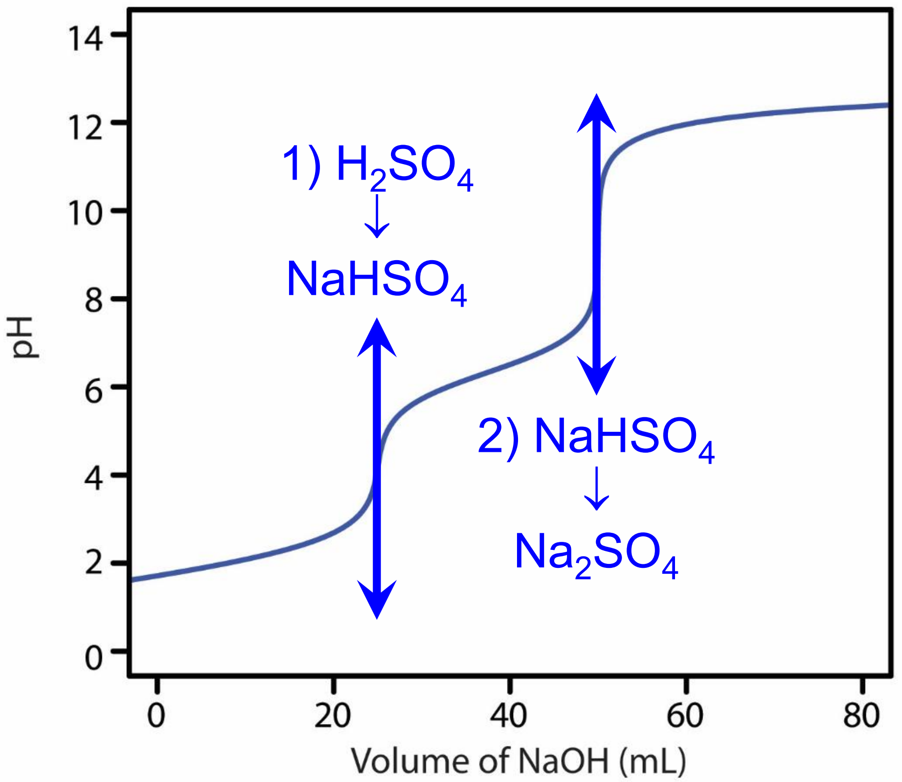
A. CH_3COOH **B.** HCl
C. H_2SO_4 **D.** H_3PO_4



Acids, Bases and Salts

Question 13.
Which acid, from the options given below, is most likely to give the pH titration curve given on the right?

A. CH_3COOH **B.** HCl
C. H_2SO_4 ✓ **D.** H_3PO_4



• The graph shows the results of a *double end-point titration*, obtained when aqueous sodium hydroxide is added to a *dibasic acid* such as sulfuric acid, H_2SO_4.

$$H_2SO_4(aq) + NaOH(aq) \rightarrow NaHSO_4(aq) + H_2O(l)$$
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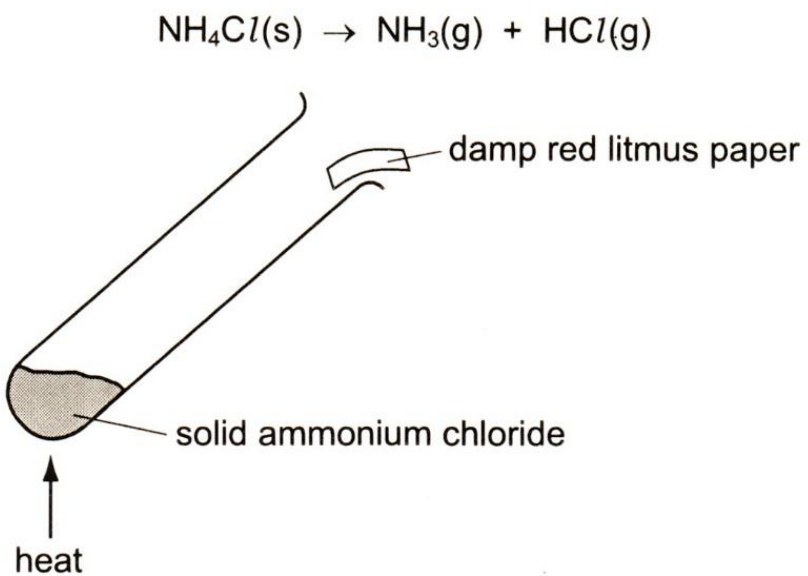
Acids, Bases and Salts

Question 14.
Solid ammonium chloride decomposes on heating according to the following equation:

$$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$$



Which change takes place to the damp red litmus paper in the experiment shown on the right?

A. Remains red.

B. Turns blue and is then bleached.

C. Turns blue and remains blue.

D. Turns blue and then turns red.

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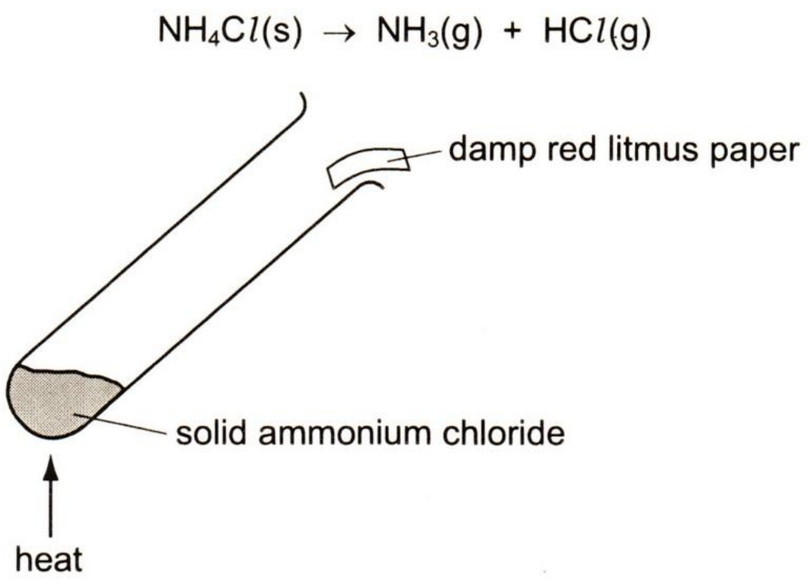

• Ammonia gas (M_r = 17.0) and hydrogen chloride gas (M_r = 36.5) both diffuse out of the test tube. The alkaline ammonia gas diffuses fastest, turning the damp red litmus blue, but then the acidic hydrogen chloride gas – diffusing more slowly – will turn the litmus red once again.

Acids, Bases and Salts

Question 15.

A *dilute* aqueous solution of a *strong* acid, HX, contains molecules of water and the ions H^+ and X^-. Which one of the following statements is *correct*?

A. The pH value of the acid is above 7.

B. The solution also contains a high concentration of HX molecules.

C. The solution also contain OH^- ions.

D. The solution contains more H^+ ions that water molecules.

Acids, Bases and Salts

Question 15.

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B. The solution also contains a high concentration of HX molecules.

C. The solution also contain OH^- ions. ✓

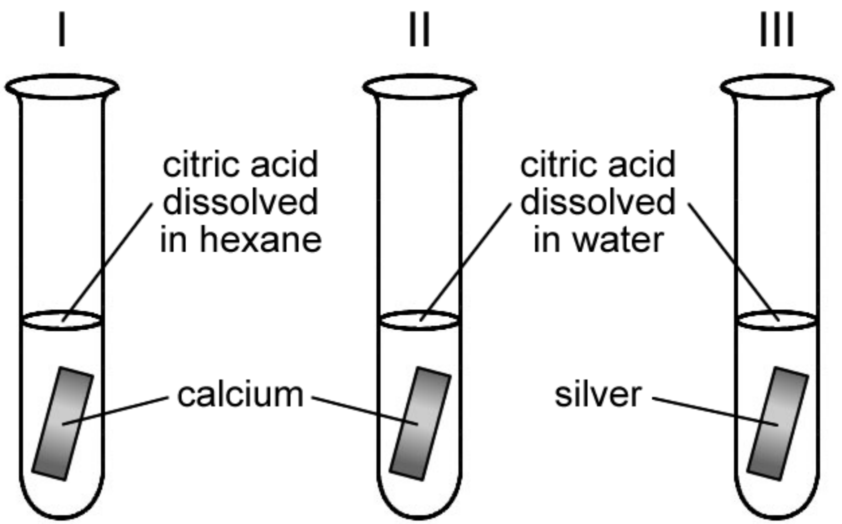
D. The solution contains more H^+ ions that water molecules.

- The solution will contain a very low concentration of hydroxide ions, OH^-, due to the spontaneous ionisation of water molecules, given by the equation, $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$. All acids contain a small amount of $OH^-(aq)$ and all alkalis contain a small amount of $H^+(aq)$.

Acids, Bases and Salts

Question 16.

Study the diagram of the experiment set-up below:



In which test tube(s) will a reaction be seen to take place?

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

Acids, Bases and Salts

Question 16.

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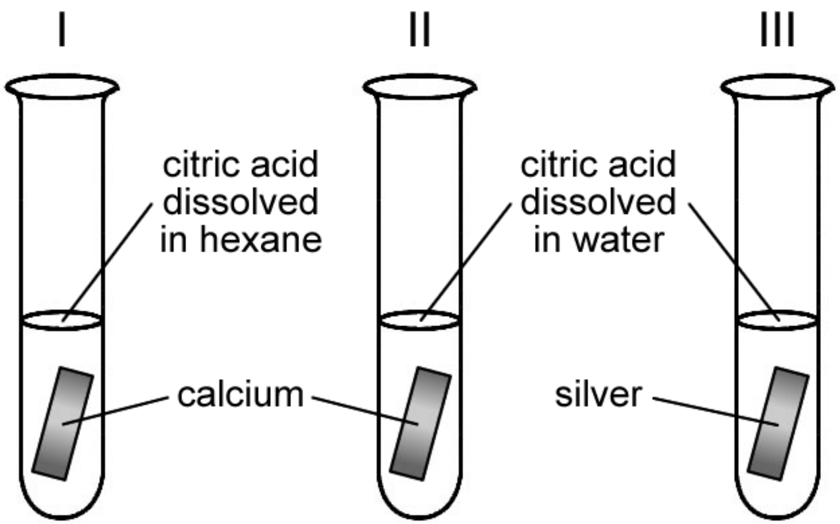

In which test tube(s) will a reaction be seen to take place?

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

- Acids only ionise to produce hydrogen ions, and hence exhibit their acidic properties, when dissolved in *water*. As a consequence, there will be no observed reaction in test tube I. Metallic silver is not sufficiently reactive enough to displace the hydrogen from citric acid, so there will be no observed reaction in test tube III.

Acids, Bases and Salts

Question 17.

In which one of the following reactions is sulfuric acid *not* behaving as an acid?

A. $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

B. $Ba(NO_3)_2 + H_2SO_4 \rightarrow BaSO_4 + 2HNO_3$

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

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Consider the ionic equations for each reaction:

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

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

C. $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

D. $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

Hydrogen ions are *not* required in reaction **B** (ionic precipitation).

Acids, Bases and Salts

Question 18.

A student conducted an experiment to produce a sample of ammonia gas in the laboratory. They tested for the gas by holding a strip of dry red litmus paper in the mouth of the test tube, but the red litmus paper did not turn blue. Why did the litmus paper not change colour?

A. Ammonia gas is acidic.

B. The litmus paper was dry.

C. Ammonia is more dense than air.

D. The student should have used dry universal indicator paper.

Acids, Bases and Salts

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A. Ammonia gas is acidic.

B. The litmus paper was dry. ✓

C. Ammonia is more dense than air.

D. The student should have used dry universal indicator paper.

A. Ammonia gas is *alkaline*.

B. The litmus paper must be *damp* in order for the ammonia gas to *dissolve* and exhibit its alkaline properties.

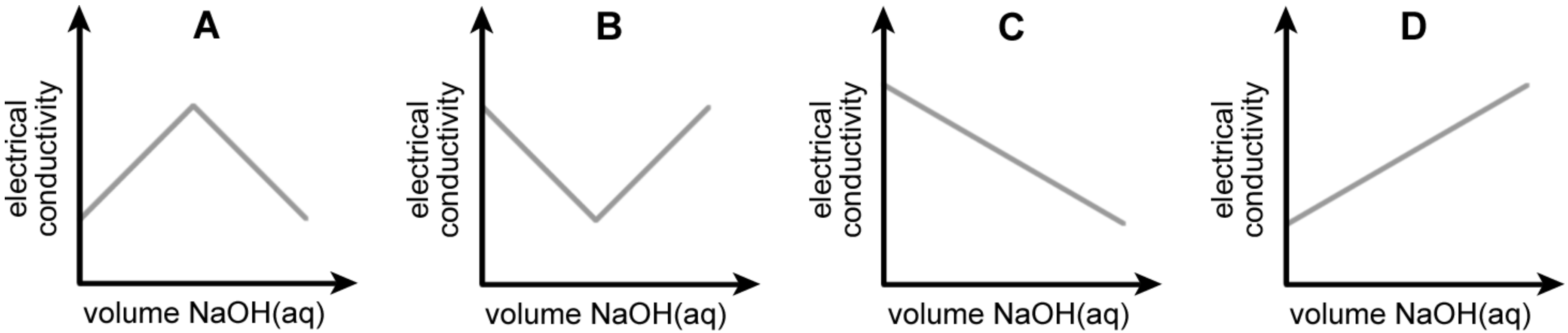
C. Ammonia gas is *less dense* than air.

D. Ammonia would only turn *damp* universal indicator paper blue / violet.

Acids, Bases and Salts

Question 19.

The electrical conductivity of a sample of dilute hydrochloric acid was measured while aqueous sodium hydroxide was slowly added until it was in *excess*. Which one of the following graphs would be obtained?



Acids, Bases and Salts

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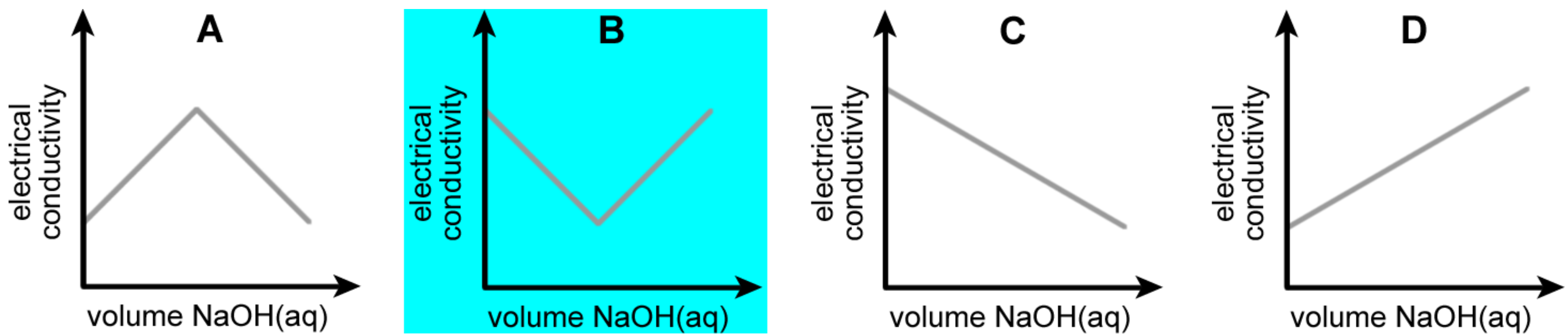

• The addition of aqueous sodium hydroxide to dilute hydrochloric acid will result in the formation of covalent water molecules, reducing the concentration of mobile ions in solution, and hence causing electrical conductivity to decrease.

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

Once the $H^+(aq)$ and $OH^-(aq)$ have completely neutralised each other, any further addition of aqueous sodium hydroxide will increase the concentration of mobile ions and hence increase electrical conductivity of the solution.

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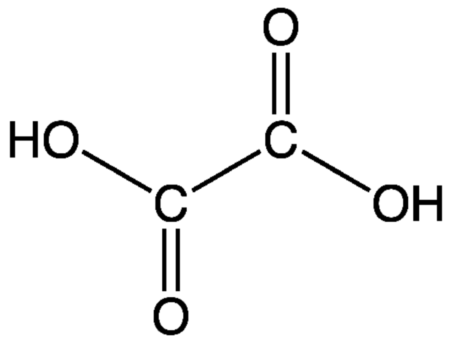
Acids, Bases and Salts

Question 20.

The structural formula of oxalic acid is given below:



Which one of the following statements about oxalic acid is correct?

A. It is a strong, tribasic acid.

B. It is a weak, monobasic acid.

C. The formula of its calcium salt is $Ca(C_2O_4)_2$.

D. The formula of its sodium salt is $Na_2C_2O_4$.

Acids, Bases and Salts

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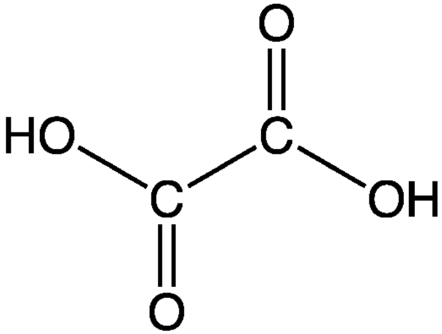

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C. The formula of its calcium salt is $Ca(C_2O_4)_2$.

D. The formula of its sodium salt is $Na_2C_2O_4$. ✓

• Oxalic acid is a *weak*, *dibasic* acid. Being dibasic, the oxalate ion ($C_2O_4^{2-}$) will have a valency of two, so the formula of the calcium salt will be CaC_2O_4, and the formula of the sodium salt will be $Na_2C_2O_4$.

Acids, Bases and Salts

Presentation on
Acids, Bases and Salts
by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

21st January 2016