Acids and Bases

Curriculum

- define acids and bases in terms of proton donors and proton acceptors

- differentiate among acids, bases, neutral ionic compounds, neutral molecular compounds and strong and weak acids, based on appropriate diagnostic tests

Empirical Properties

- An **empirical property** are made from observations after experiments
  - Ex. A lemon is an acid because it turns litmus red

PROPERTIES OF ACIDS, BASES, AND NEUTRAL SOLUTIONS

Solution	Properties
acid	• electrolytic (conducts a current) • corrosive • turns blue litmus red • reacts with active metals (e.g., Mg, Zn, and Fe) to produce hydrogen gas • neutralized by bases and basic solutions • tastes sour
base	• electrolytic (conducts a current) • corrosive • turns red litmus blue • feels slippery (when diluted) • neutralized by acids and acidic solutions • tastes bitter
neutral	• can be electrolytic (if solute is an ionic compound) • does not change red or blue litmus

Molecular vs. Ionic

- When a substance is dissolved in water is it is called a **solute**
- There are two types of solutes:
  - **Ionic compound** – which is made from a metal and a non metal (positive and negative charges)
  - **Molecular compound** – made of two non metals and share electrons between atoms
- Ionic compounds will make an **electrolytic solution** while molecular will not

Svante August Arrhenius

- Arrhenius proposed that acids contained hydrogen atoms that formed hydrogen ions ($H^+(aq)$) in solution

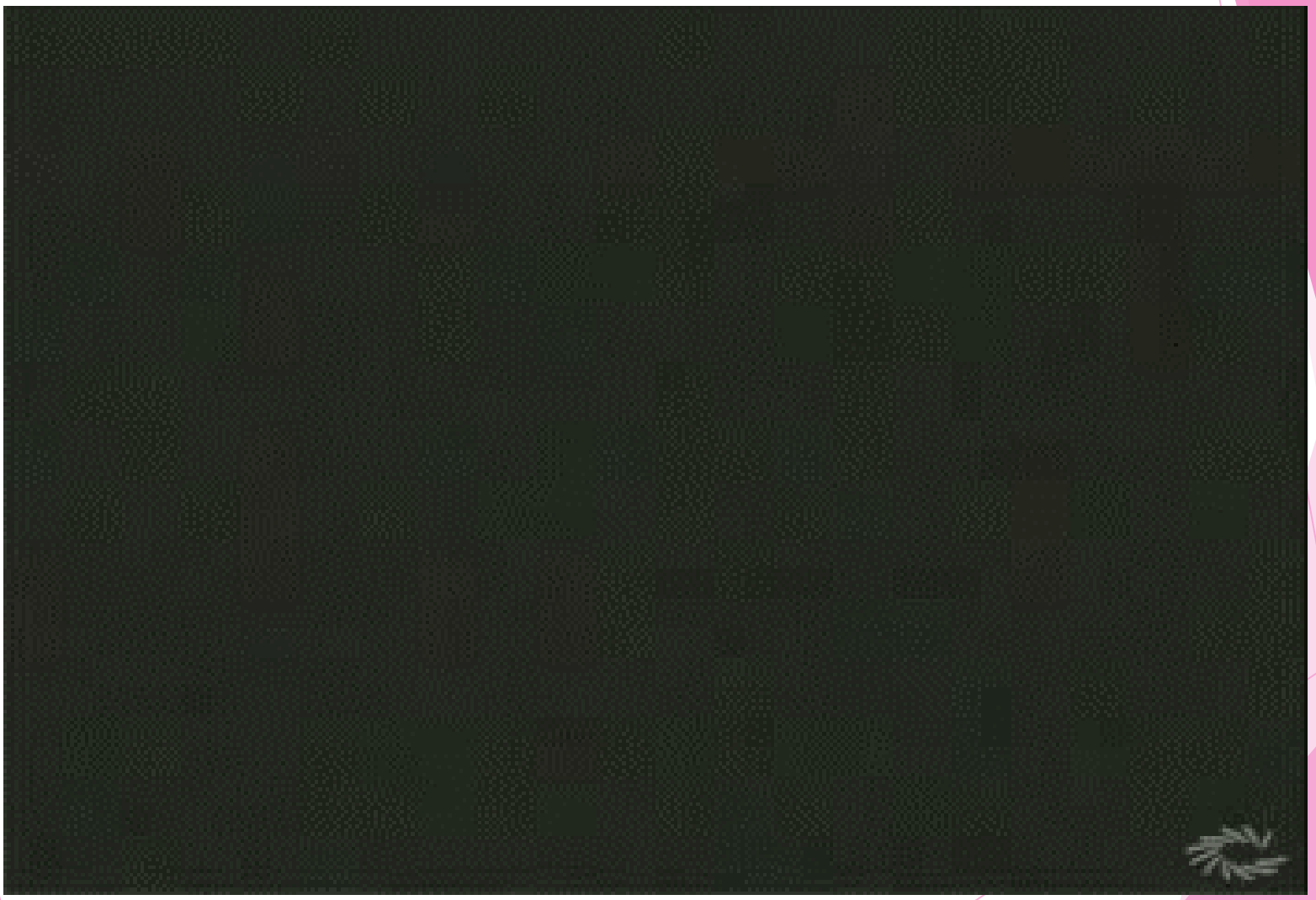
$$HCl(g) \xrightarrow{\text{in water}} H^+(aq) + Cl^-(aq)$$

- He also proposed that bases contained hydroxide ions ($OH^-(aq)$) that could dissociate in solution

$$NaOH(s) \xrightarrow{\text{in water}} Na^+(aq) + OH^-(aq)$$

- These are what you would call Arrhenius acids and bases

3 minutes

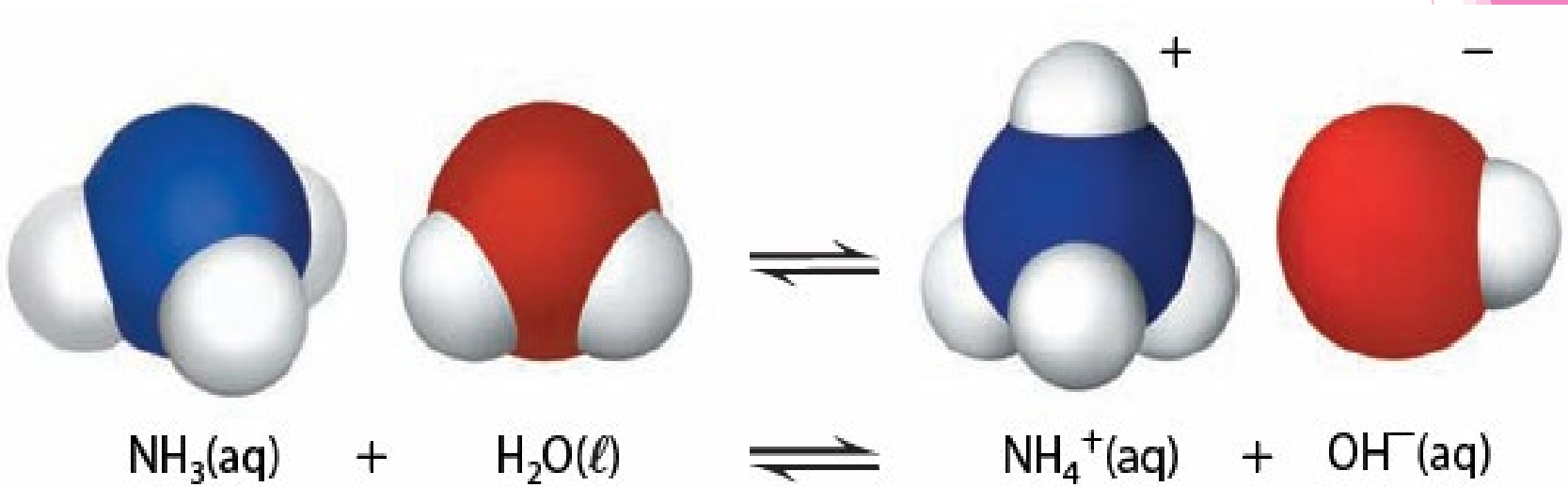


Limitations of Arrhenius Theory

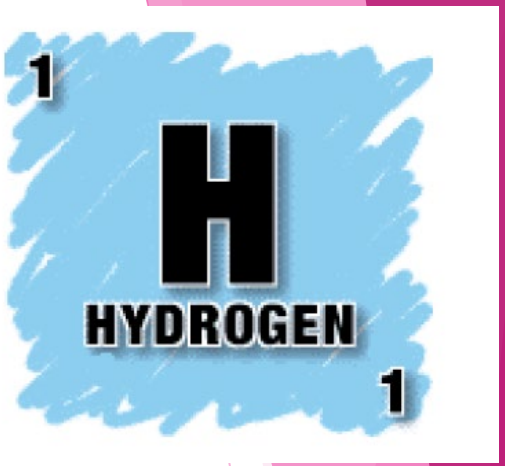
- Ammonia NH_3 and $NaHCO_3$ (aq) (baking soda) have properties of a base
- Because of this the theory must be modified
- It also couldn't explain why some acids lit the lightbulb only to a small extent

Reacting with water

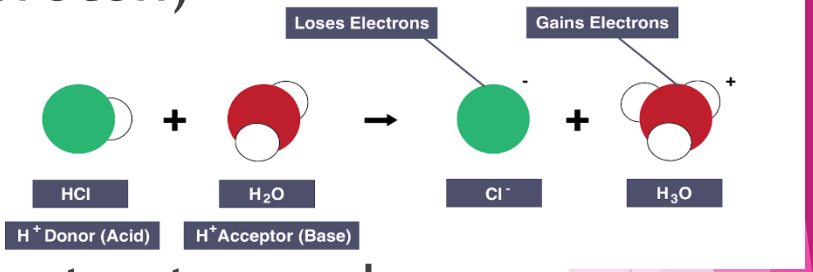
- A modified theory recognizes that substances like ammonia react with water to produce the OH^- ion



Hydronium ion

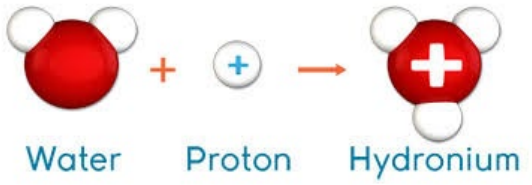


- Hydrogen as an ion is just a proton
- A proton by itself is very unstable
- The hydrogen ion will be very attracted to a water molecule (and will donate its proton)



- An Arrhenius acid reacts with water to produce $H_3O^+(aq)$ (hydronium) in aqueous solution

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



Acids

- The concentration of an acid changes the acidic properties of a solution
- The type of acid also changes the acidic properties of a solution

Acids

- What would you be more worried about, spilling 1 mol/L hydrochloric acid or spilling 1 mol/L acetic acid (vinegar) all over you face?
- Look on page 12 on your data book!

Acids

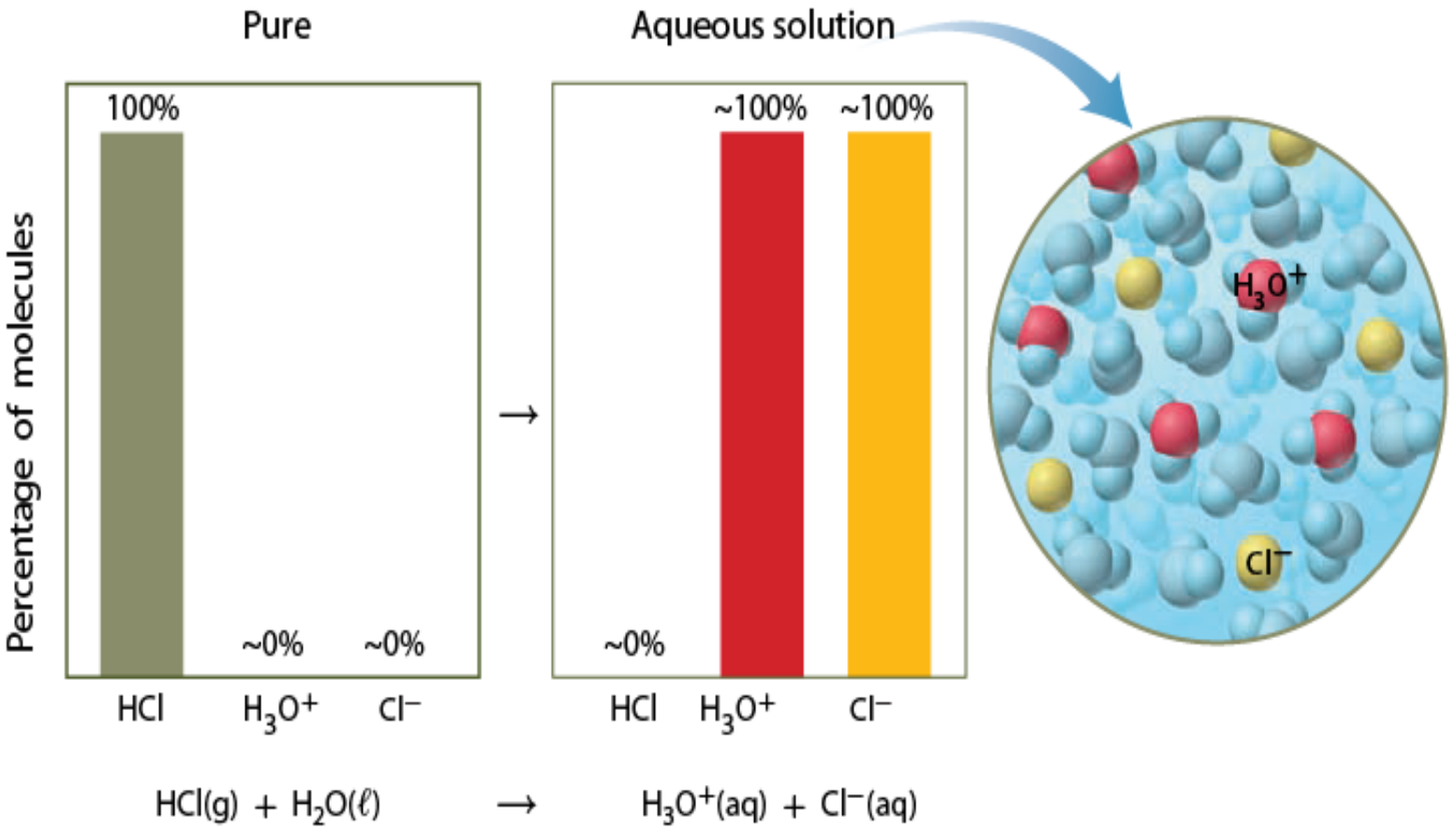
- The concentration of an acid changes the acidic properties of a solution
- The type of acid also changes the acidic properties of a solution

Strong Acids

- Why does one acid make the bulb glow brighter than the other acid?
- Not all acids ionize to the same degree
- An acid that ionizes to nearly 100% would be considered a **strong acid**
- For example HCl is a strong acid. Nearly 100% of the molecules in HCl react with water to form ions

$$HCl(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq) \qquad (\sim 100\% \text{ reaction})$$

Strong Acids



Strong Acids

- There are only 3 strong acids we use and they are the first 3 found on our acid base chart on page 12

Relative Strengths of Selected Acids and Bases for 0.10 mol/L Solution at 25°C

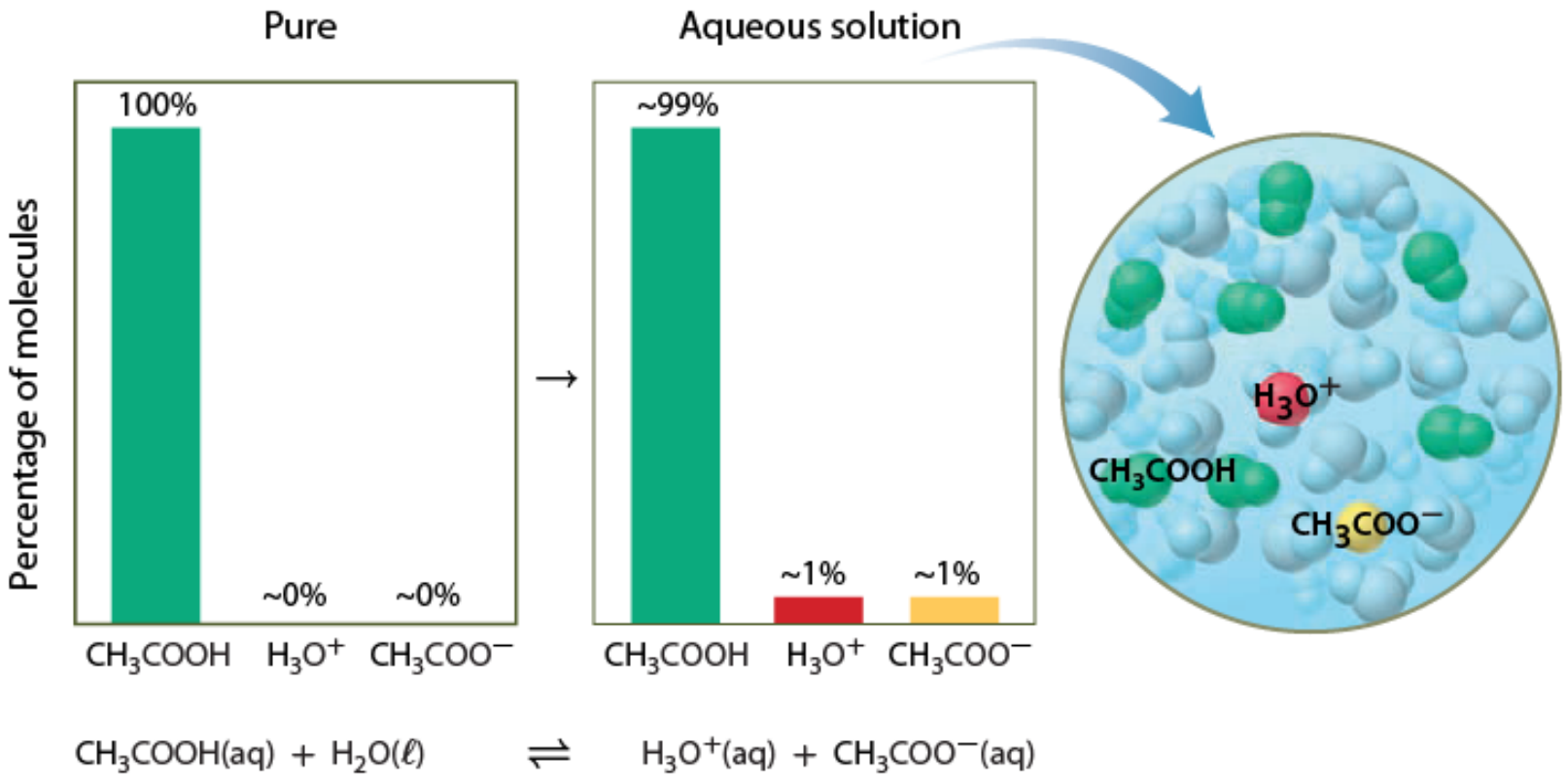
Acid Name	Acid Formula	Conjugate Base Formula
hydrochloric acid	$HCl(aq)$	$Cl^-(aq)$
sulfuric acid	$H_2SO_4(aq)$	$HSO_4^-(aq)$
nitric acid	$HNO_3(aq)$	$NO_3^-(aq)$
hydronium ion	$H_3O^+(aq)$	$H_2O(l)$
oxalic acid	$HOOCCOOH(aq)$	$HOOCCOO^-(aq)$
sulfurous acid	$H_2SO_3(aq)$	$HSO_3^-(aq)$
hydrogen sulfate ion	$HSO_4^-(aq)$	$SO_4^{2-}(aq)$
phosphoric acid	$H_3PO_4(aq)$	$H_2PO_4^-(aq)$
orange IV	$HOr(aq)$	$Or^-(aq)$

Weak Acids

- A weak acid will react very little in water
- Only a small percentage will form ions in water
- Most of the acid molecule remains intact
- Acetic acid is a weak acid and only about 1% of the molecules will react with water to form ions

$$CH_3COOH(aq) + H_2O(\ell) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq) \qquad (\sim 1\%\ \text{reaction})$$

Weak Acid


Pure
Aqueous solution
Percentage of molecules
100%
~0%
~0%
~99%
~1%
~1%
CH3COOH
H3O+
CH3COO−
CH3COOH
H3O+
CH3COO−
CH3COOH(aq) + H2O(ℓ)
H3O+(aq) + CH3COO−(aq)

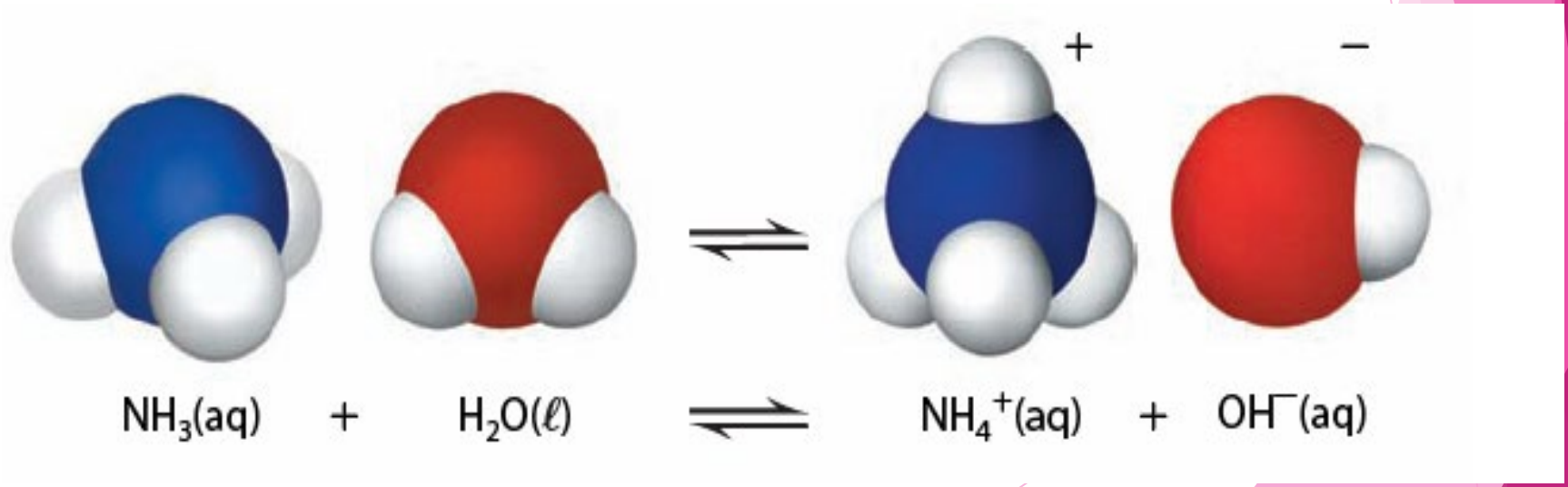
Strong Bases

- Most bases are ionic compounds so they will *dissociate* completely in water

- All hydroxides (OH-) that are bonded to metals from group 1 and group 2 will be strong bases

Weak Bases

- **Weak bases** are substances where a low percentage of molecules react with water to produce OH^-
- A common weak base is ammonia $NH_3(aq)$
- Only about 1% of ammonia molecules will react with water to form hydroxide ions



Strong Acid/weak acid / base/ionic molecular? Board Question

- $Ca(OH)_2$ — Base (OH)
- HNO_3 — Acid (H in front) SA
- C_6H_5COOH — Acid COOH WA
- KF — Neutral / ionic
- HF — Acid H in front

Exchange of hydrogen atoms

- Acids and bases can be looked as reactions where acids and bases change exchange protons (hydrogen ions)

- Johannes Bronsted and Thomas Lowry discovered this and used this as the principle for their new acid base theory

Bronsted-Lowry Model of Acids and Bases

- Acids - compounds which are able to **donate protons** in a reaction (Bronsted acids must contain at least one ionizable hydrogen atom)

- Bases - compounds which are able to **accept protons** in a reaction (Bronsted bases must contain at least one lone pair of electrons with which to form a bond with the ionized hydrogen atom)

- A Bronsted-Lowry neutralization is a competition for protons that results in a proton transfer from the strongest acid to the strongest base.

3 things can be a bases

- Nitrogen with a one pair ……
  ex: NH3
- Water
- Something with a –’ve charge
  ex: CO_3^{-2}

Example: Hcl + HOH

Anything that donates a H+ is an acid

Anything with a lone pair is a base

Which ever accepts the H is a base

Example HN3 + HOH

Ammonia can act like a base because of the lone pairs

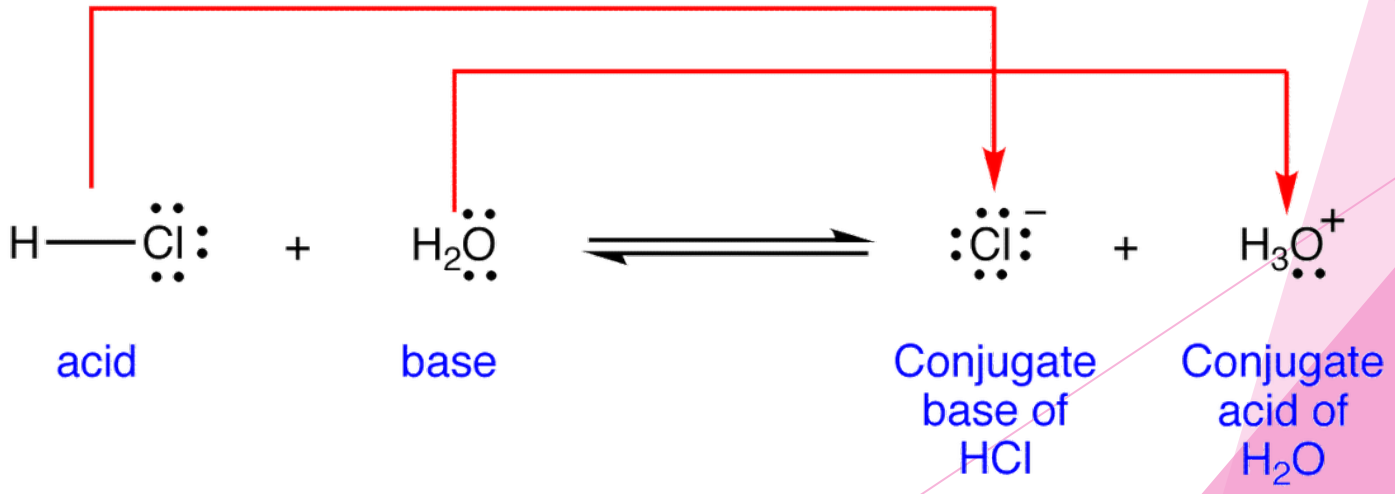
NH3 is the base because it accepts the H

Water is the acid because it donates the H

Conjugate Acids and Bases

- Every acid has a **conjugate base** and every base has a **conjugate acid**
- The original acid and base are called **parents**

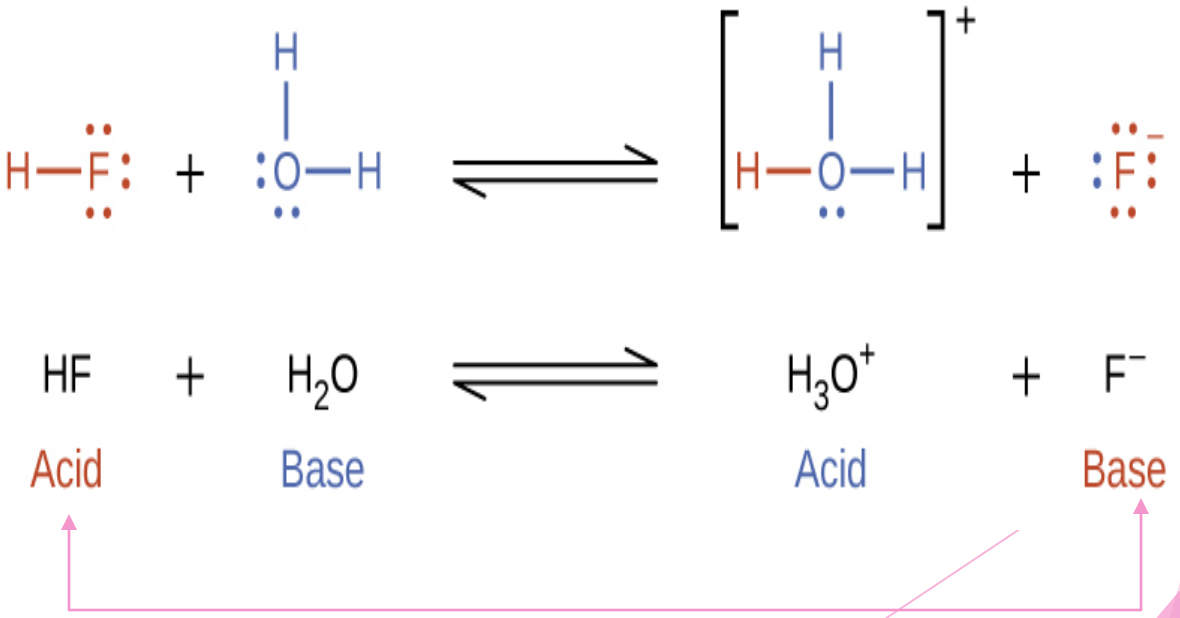
- When an acids gives up its proton it leaves itself with a **lone pair**



- If the reverse reaction happened, our former acid would become our base and our base becomes our acid

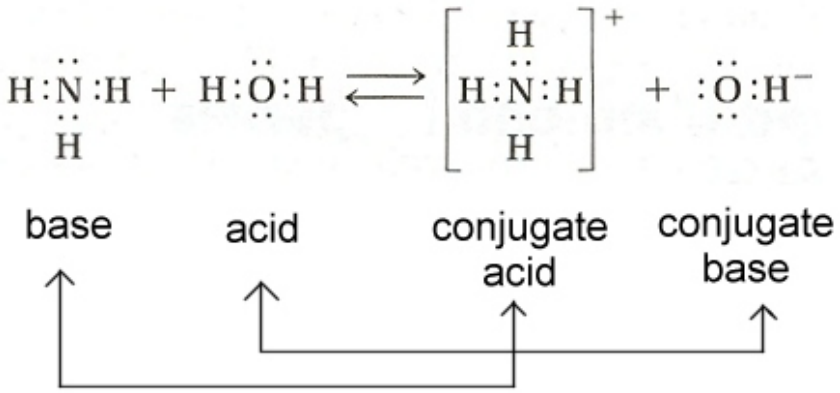
Board Question

- Show the ionization equation between hydrofluoric acid (HF) and water and label each acid/base as parent and conjugate.



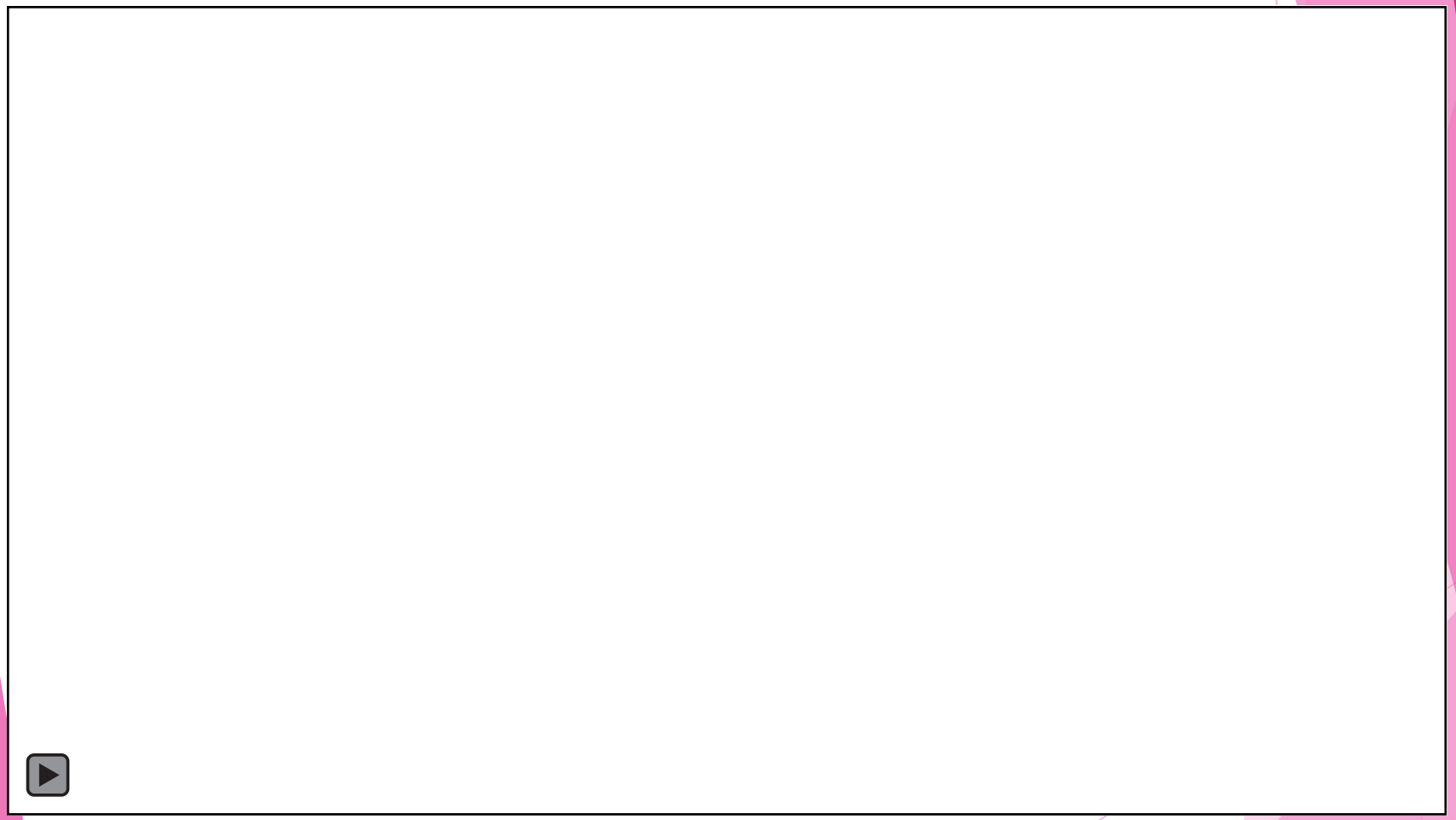
Examples: write the balanced chemical reactions between the following substances. For each equation, label the acid, base, conjugate acid & conjugate base

- Ammonia and water



- sulfuric acid (H_2SO_4) and water

Hydrofluoric acid (1 min)



Reactions without water

- Sulfuric acid, $H_2SO_4(aq)$, spilled during a lab procedure, reacts with the hydrogen carbonate ion, $HCO_3^-(aq)$, present within an acid spill kit.

- $H_2SO_4 + HCO_3^- = HSO_4^- + H_2CO_3$

Parent Acid Conjugate base

Board Question

- During the production of fertilizer, aqueous ammonia, $NH_3(aq)$, reacts with phosphoric acid, $H_3PO_4(aq)$