7.7: Reactions of Acids & Bases in Aqueous Solutions

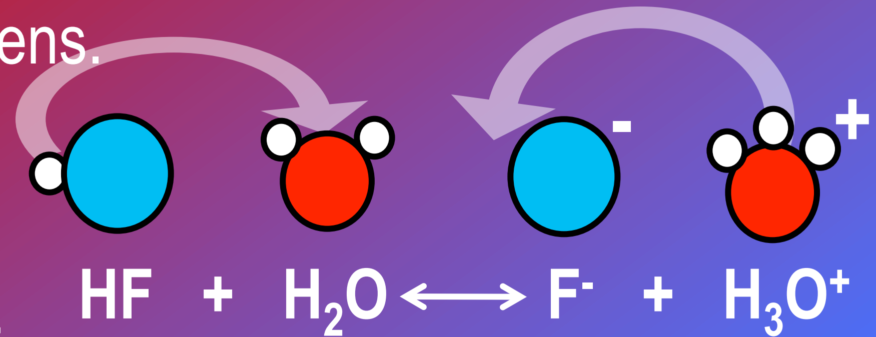
Remember:

- Have your **7.7 notesheet** ready!
- You can **pause** the video anytime.
- You can **rewind** the video anytime.
- Write down **questions/comments** as you go for discussion in class.

Are you ready???

Part I: Proton-Transfer Reactions—General Description

- we use the Brønsted-Lowry Acid-Base Theory to describe acid-base reactions that occur in aqueous solutions, since it takes into account the proton (H^+) transfer that happens.
- imagine the following scenario:



  - a **B-L acid** (HF) gives up a **proton** (the H^+)
  - the **remaining ion** is fluoride, F^-
  - the **proton** (H^+) can then be **re-accepted** by the F^-
  - this makes the F^- a **proton acceptor**, and thus, the F^- is then considered to be a **base**.
  - so the **original acid** consists of a **hydrogen** and what is known as a **conjugate base**.
  - **conjugate base** = a base (proton acceptor) that forms as a result of the ionization/dissociation of an acid. In other words, the conj. base is always the **ion/molecule left over after the H^+ comes off** of the original acid.

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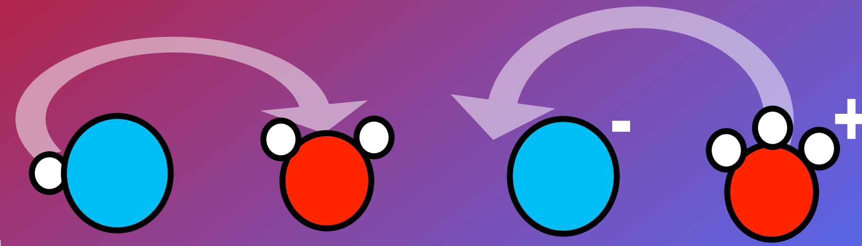
- using the same logic, the H_3O^+ that forms can then become a **proton donor**, so it can be called a **conjugate acid**.



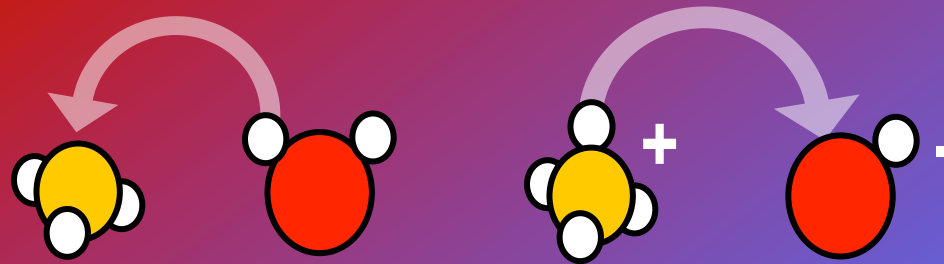
$$HF + H_2O \longleftrightarrow F^- + H_3O^+$$

- **conjugate acid** = an acid (proton donor) that forms as a result of the **base accepting a proton** from the original acid.

- the acid (HF) forms a conj. base (F^-), and the base (H_2O) forms a conj. acid (H_3O^+). These are known as **conjugate acid-base pairs**.
- another example:

$$NH_3 + H_2O \longleftrightarrow NH_4^+ + OH^-$$

- another example:
  - a B-L base (NH_3) accepts a proton from the H_2O
  - the new ion formed is ammonium (NH_4^+) the NH_4^+ can then donate a proton to the OH^-
  - thus, the OH^- is then a proton acceptor and, as a result, considered to be a conj. base.



$$NH_3 + H_2O \longleftrightarrow NH_4^+ + OH^-$$

base (NH₃) **acid** (H₂O) **conj. acid** (NH_4^+) **conj. base** (OH^-)

- notice that in both examples shown above, the **double-headed arrow** was used. This indicates a **reversible reaction** will take place.
- reversible reactions indicate **weak acids and/or bases** are involved (remember, weak = does **not** ionize/dissociate completely)

Part II: Proton-Transfer Reactions—Direction and Strength

- the extent to which a proton-transfer reaction takes place depends on the **strength** of the acids and bases involved in the reaction.

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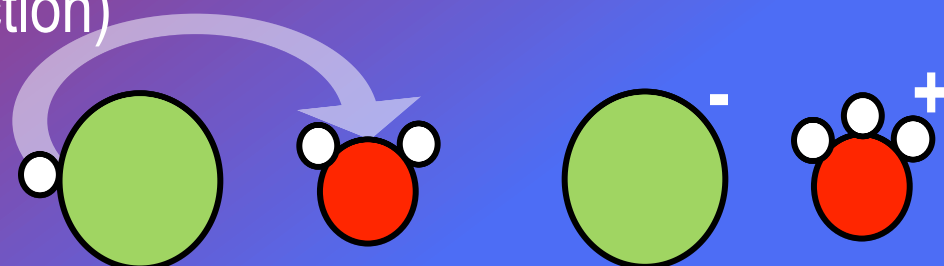
  - the 2 examples above involved a relatively **weak** acid (HF) and a **weak** base (NH_3). Weak acids/bases do not ionize completely, so they tend to **re-form** in aqueous solution. Therefore, the reactions those compounds undergo with water are **reversible**.
  - when a **strong** acid or base reacts with water in aqueous solution, a **non-reversible** (single-direction) reaction occurs. Example:
    - the strong acid HCl **ionizes completely** in water due to its high polarity



$$HCl + H_2O \longrightarrow Cl^- + H_3O^+$$

    - once it is broken apart, it **does not reform**, hence the single-sided arrow pointing to the **right**.

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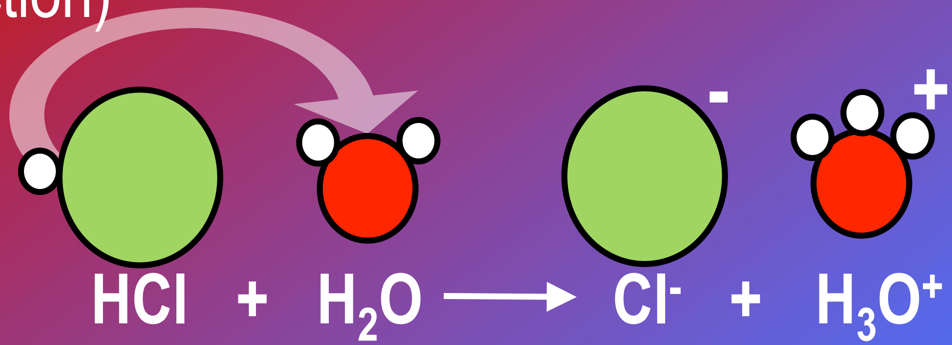

  - once it is broken apart, it **does not reform**, hence the single-sided arrow pointing to the **right**.
- the reason HCl (and all other strong acids) do not re-form is because the **conj. bases** they make are **very weak** and have trouble re-gaining the proton from the conj. acid.
- therefore, when a strong acid (or base) breaks up, it does not re-form again, so we says it "**ionizes/dissociates completely**."
- two important **rules** about proton-transfer reaction can be made now:

- two important **rules** about proton-transfer reactions can be made:
  1. the stronger an **acid** is, the weaker its **conj. base** will be; the stronger a **base** is, the weaker its **conj. acid** will be
  2. proton-transfer reactions tend to favor the production of the **weaker** acid and the **weaker** base
- consult the table to the right to find the **strength** of any acid or base:

	Conjugate acid	Formula	Conjugate base	Formula	
Strong acids	chloric acid	$HClO_3$	chlorate ion	ClO_3^-	Very weak bases
	hydrobromic acid	HBr	bromide ion	Br^-	
	hydrochloric acid	HCl	chloride ion	Cl^-	
	hydriodic acid	HI	iodide ion	I^-	
	nitric acid	HNO_3	nitrate ion	NO_3^-	
	perchloric acid	$HClO_4$	perchlorate ion	ClO_4^-	
	sulfuric acid	H_2SO_4	hydrogen sulfate ion	HSO_4^-	
Increasing acid strength (↑)	hydronium ion	H_3O^+	water	H_2O	Increasing base strength (↓)
	chlorous acid	$HClO_2$	chlorite ion	ClO_2^-	
	hydrogen sulfate ion	HSO_4^-	sulfate ion	SO_4^{2-}	
	phosphoric acid	H_3PO_4	dihydrogen phosphate ion	$H_2PO_4^-$	
	hydrofluoric acid	HF	fluoride ion	F^-	
	acetic acid	CH_3COOH	acetate ion	CH_3COO^-	
	carbonic acid	H_2CO_3	hydrogen carbonate ion	HCO_3^-	
	hydrosulfuric acid	H_2S	hydrosulfide ion	HS^-	
	dihydrogen phosphate ion	$H_2PO_4^-$	hydrogen phosphate ion	HPO_4^{2-}	
	hypochlorous acid	$HClO$	hypochlorite ion	ClO^-	
	ammonium ion	NH_4^+	ammonia	NH_3	
	hydrogen carbonate ion	HCO_3^-	carbonate ion	CO_3^{2-}	
	hydrogen phosphate ion	HPO_4^{2-}	phosphate ion	PO_4^{3-}	
	water	H_2O	hydroxide ion	OH^-	
	ammonia	NH_3	amide ion	NH_2^-	
	hydrogen	H_2	hydride ion	H^-	

- consult the table to the right to find the strength of any acid or base:
- try **labeling** and drawing the **appropriate arrow direction** for these reactions:

$$HClO_4 + H_2O \longrightarrow H_3O^+ + ClO_4^-$$

$HClO_4$	H_2O	H_3O^+	ClO_4^-
acid (strong)	base	conj. acid	conj. base

$$CH_3COOH + H_2O \longleftrightarrow H_3O^+ + CH_3COO^-$$

CH_3COOH	H_2O	H_3O^+	CH_3COO^-
acid (weak)	base	conj. acid	conj. base

- as you can see, the arrowhead will **always point towards the weaker acid and the weaker base**, never towards the stronger acid and stronger base.

Part III: Amphoteric Compounds

- you have probably noticed that water can act as an acid or a base in the reactions above.

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- you have probably noticed that water can act as an acid or a base in the reactions above.
- **amphoteric** = describes a compound that can react as an acid or a base in a chem. rxtn.
- water acts as an acid when it is in the presence of a stronger base, and it acts as a base when it is in the presence of a stronger acid.
- other amphoteric compounds behave as an acid or base based on another set of criteria:
  - when –OH is found in a molecule, that –OH group is referred to as a **hydroxyl group**.
  - the hydroxyl group is bonded to a central atom in the molecule.
  - as the number of other oxygen atoms bonded to this central atom increases, the acidity of the molecule increases as well

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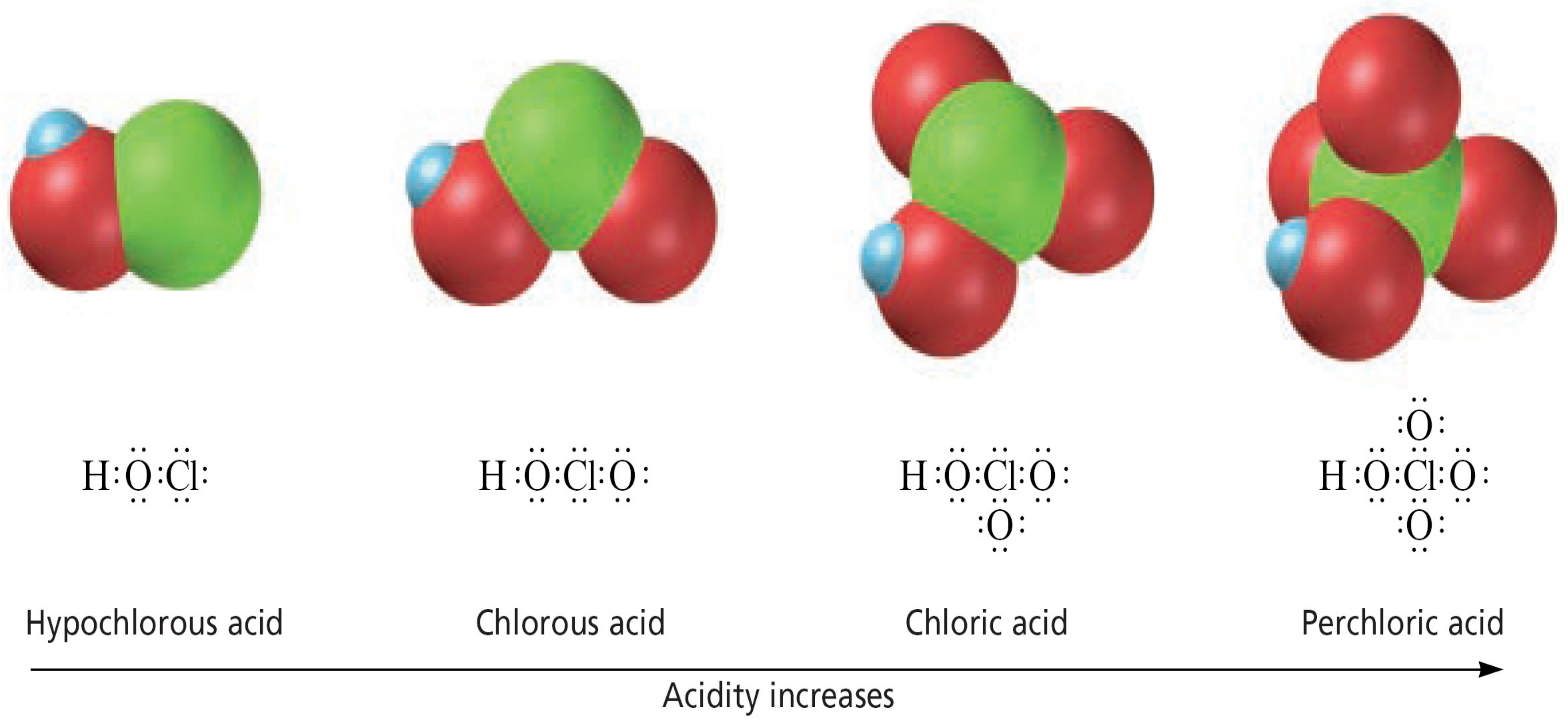
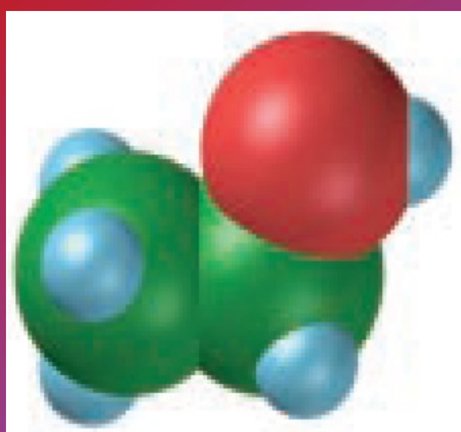
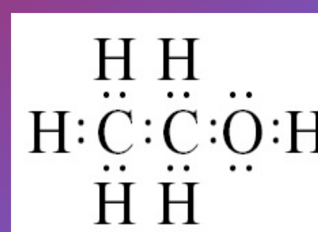
- it increases the acidity because it increases the polarity of the O–H bond (because more atoms = more e- pulled towards the O) Observe:



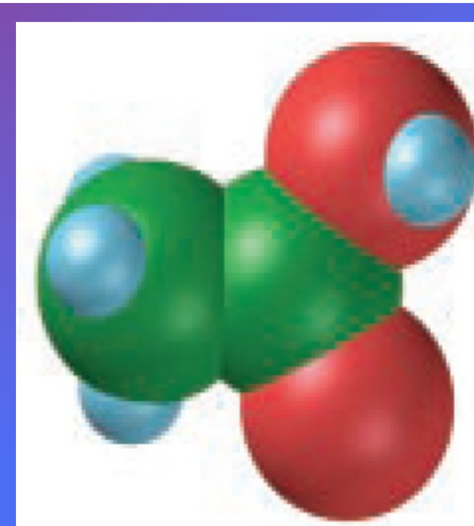
- as the number of <u>other oxygen</u> <u>atoms</u> bonded to this central atom increases, the acidity of the molecule increases as well
- it increases the acidity because it increases the polarity of the O–H bond (because more atoms = more e- pulled towards the O)
- other examples:

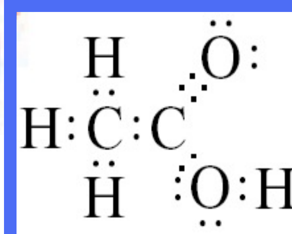
basic	*amphoteric*	*acidic*
$Cr(OH)_2$	$Cr(OH)_3$	H_2CrO_4
chromium(II) hydroxide	chromium(III) hydroxide	chromic acid





C_2H_5OH
Ethanol





CH_3COOH
Acetic acid

Part IV: Neutralization Reactions

- when an acid reacts with a base, a neutralization reaction occurs, and neutral products result. Ex: sodium bicarbonate ($NaHCO_3$—the base) and tartaric acid ($C_4H_6O_6$—the acid) combine in baking powder to produce carbon dioxide (CO_2—neutral) and other compounds.
- also: hydrochloric acid reacts with sodium hydroxide to make sodium chloride and water.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

- Make sure notesheet is **completely filled in**
- Preview the **funsheet** (7.7)
- **Rewind and review** any parts that were not clear
- Bring both **notesheet** and **funsheet packets** to class