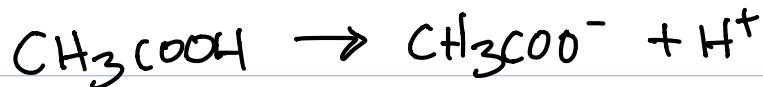


What are the key characteristics of molecules & ions that are acidic & basic?

- 3 types, and no one type is more "correct" than the other

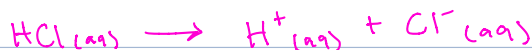
① Arrhenius Definition



↳ Acid: a substance that produces H^+ ions in aqueous solution

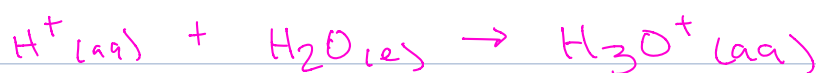
↳ Base: a substance that produces OH^- ions in aqueous solution

- according to this HCl would be considered an acid bc it produces H^+ ions



↳ HCl is covalent, however, in water it ionizes completely to form H^+ & Cl^- ions. H^+ ions are highly reactive

and in aqueous solutions will react w/ water to form H_3O^+ (hydronium ions)



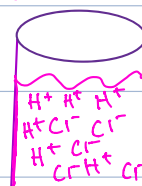
- often H^+ & H_3O^+ are used interchangeably

- according to Arrhenius def, NaOH would be a base because it produces OH^- ions

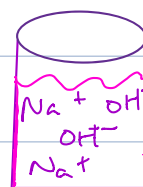


* NaOH is an ionic compound, when it's added to water, it completely dissociates

* w/ this definition when acids & bases combine they will always form water, and thus neutralizing themselves in the process



bc of this theory we get the term strong & weak acid
↓
think vinegar



- get strong & weak bases

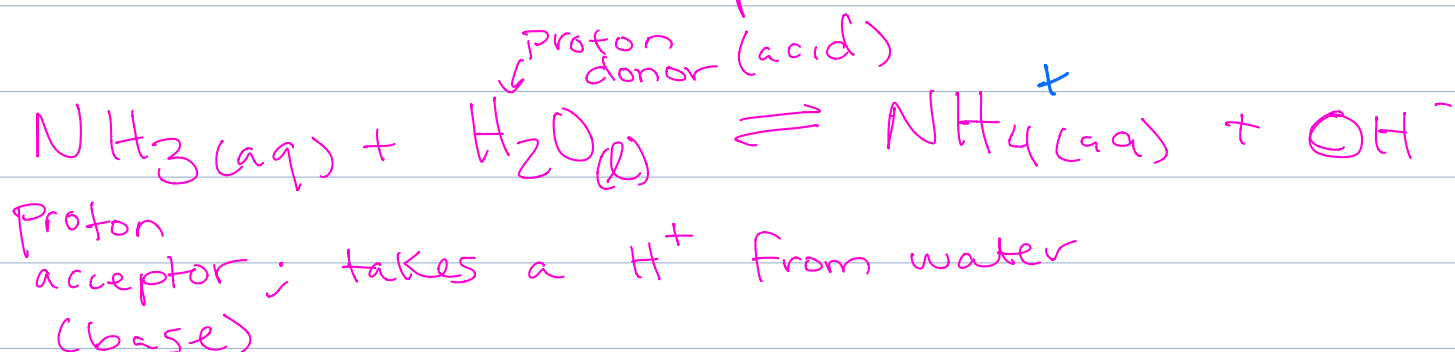
② Brønsted-Lowry Definition

- focuses on the transfer of H^+ ions
- since H^+ is a proton w/o its e^- , this focuses on the idea of proton donor & acceptor

↳ acid: proton donor

↳ base: proton acceptor

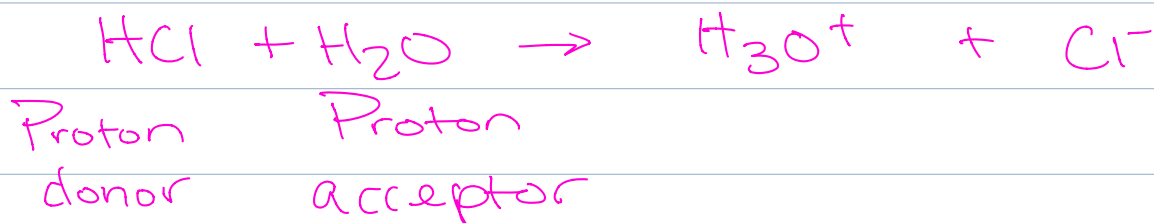
HCl would still be considered an acid bc it donates a proton to water.

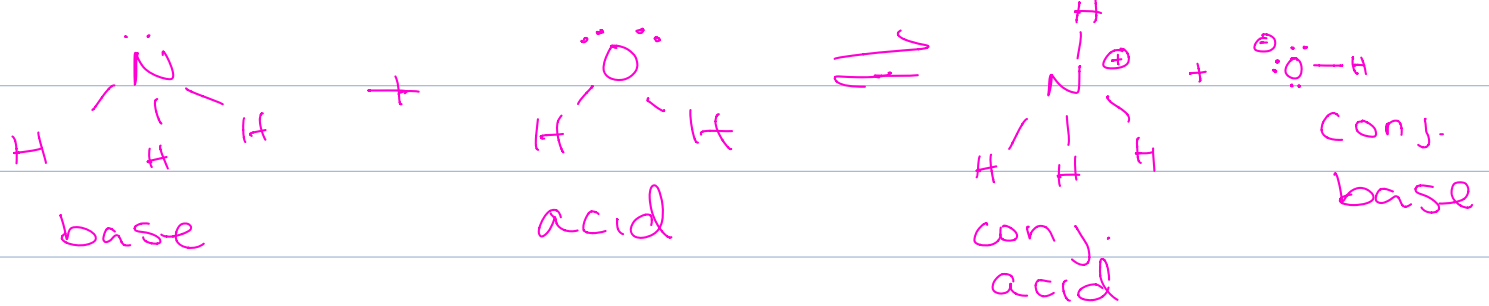


- some substances can act as both an acid and a base, we call these amphoteric (or amphiprotic)

↳ in the equ above, water acted as an acid...

however, water can also act as a base

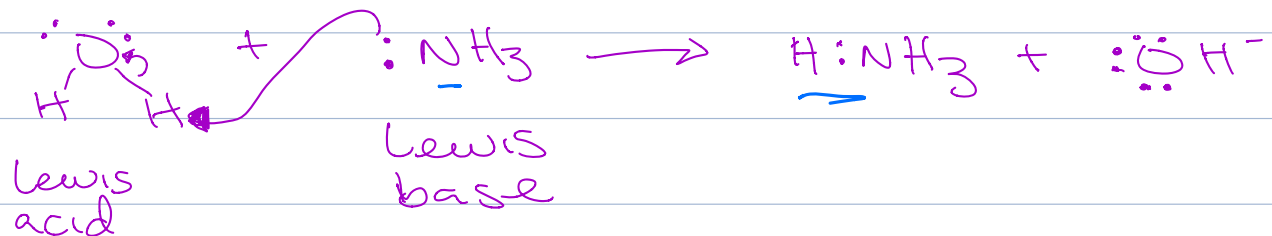




- a base accepts a proton and becomes a conj. acid
- an acid donates a proton and becomes a conj. base

③ Lewis Acids & Bases

- focuses on the electron pair
- ↳ acid: electron pair acceptor
- ↳ base: electron pair donor



- a LA has an empty orbital that can accept an e^- pair

Hydrochloric acid (HCl) is one of the substances found in gastric juices secreted by the lining of the stomach. HCl is needed by the enzyme pepsin to catalyze the digestion of proteins in the food we eat. Heartburn is a symptom that results when the stomach produces too much acid (hyperacidity).

Antacids are bases used to neutralize the acid that causes heartburn. Despite the many commercial brands, almost all antacids act on excess stomach acid by neutralizing it with weak bases. The most common of these bases are hydroxides, carbonates, or bicarbonates. The following table contains a list of the active ingredients found in several common commercial antacids, and the reactions by which these antacids neutralize the HCl in stomach acid.

M (OH)₄

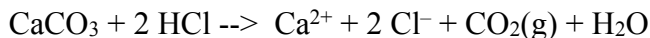
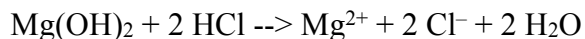
Compound	Chemical Formula	Chemical Reaction
Aluminum hydroxide	Al(OH)_3	$\text{Al(OH)}_3(\text{s}) + 3 \text{HCl}(\text{aq}) \rightarrow \text{AlCl}_3(\text{aq}) + 3 \text{H}_2\text{O}(\text{l})$
Calcium carbonate	CaCO_3	$\text{CaCO}_3(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Magnesium carbonate	MgCO_3	$\text{MgCO}_3(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Magnesium hydroxide	Mg(OH)_2	$\text{Mg(OH)}_2(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$
Sodium bicarbonate	NaHCO_3	$\text{NaHCO}_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

An acid is a source of aqueous $\text{H}^+(\text{aq})$. For example, $\text{HCl}(\text{aq})$ is the acid in your stomach: $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$. In a healthy stomach, pH is regulated naturally and digestion functions properly when the pH is around 3 (recall neutral is $\text{pH} = 7$). Excess stomach acid can be combated with bases, or "antacids". Bases are $\text{H}^+(\text{aq})$ acceptors; in water, they provide species that can react with $\text{H}^+(\text{aq})$.

Common ingredients in antacids are metal hydroxide and metal carbonate salts. The hydroxides provide hydroxide ion, OH^- , which can react with $\text{H}^+(\text{aq})$ to form H_2O . Carbonates provide the carbonate ion, CO_3^{2-} , which can react with $\text{H}^+(\text{aq})$ to form H_2O and CO_2 . The reactions of interest in this lab are neutralization reactions.

In this experiment, several brands of antacids will be analyzed to determine the number of moles of acid neutralized per tablet and the cost analysis of each tablet. The analytical procedure used is known as **back titration**. In this procedure, a known amount of HCl, which is in excess, will be reacted with a weighed portion of a ground antacid tablet. The HCl remaining after the

antacid neutralization reaction occurs will be determined by titration with a standardized NaOH solution to a phenolphthalein endpoint. The number of moles of HCl neutralized by the antacid ($\text{HCl}_{\text{neutralized}}$) is the difference between the moles of HCl initially present in the excess ($\text{HCl}_{\text{initial}}$) and the moles of HCl titrated by the NaOH ($\text{HCl}_{\text{titrated}}$).



Notice the 2-to-1 mole ratio of HCl-to-base.

To determine the amount of base in an actual tablet, ideally you would dissolve it in water and titrate with acid. In most titrations, solutions of the acid and the base are used. This is not an option here because CaCO_3 is quite insoluble in water. By the time the tablet completely dissolves, you will have added too much acid. To overcome this problem, the antacid tablet is dissolved in a known amount of excess acid; the excess acid is neutralized with more base.

- tablet[$\text{Mg}(\text{OH})_2/\text{CaCO}_3$] + HCl $\rightarrow$ neutralized tablet + excess acid $\rightarrow$ acidic solution
excess HCl + NaOH $\rightarrow$ neutral solution

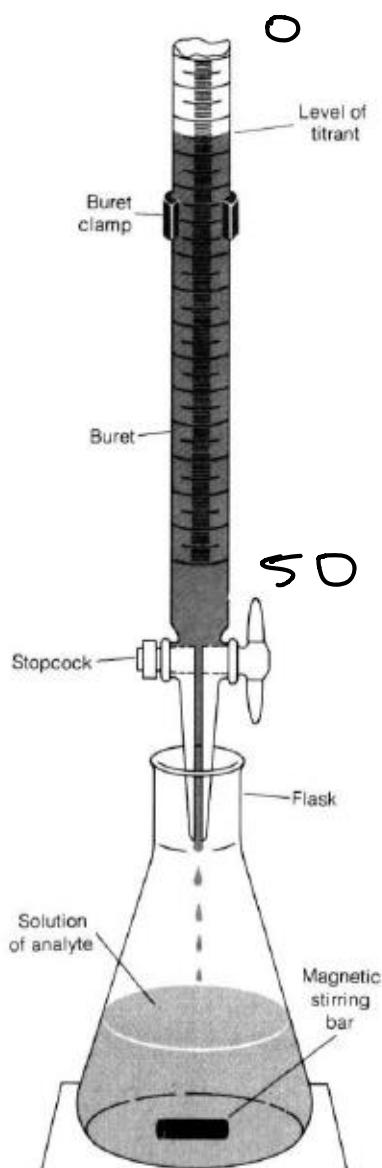
The excess HCl is titrated with NaOH(aq) until enough OH^- (from the NaOH solution) has been added to completely react with the excess H^+ (from the excess HCl in the solution). So, part of the added acid is neutralized by the antacid tablet; the remainder is neutralized by the NaOH added. This is called **back titration**.

The equivalence point is when the number of moles of NaOH added equals the number of moles of HCl remaining after the reaction with the tablet. HCl is the $\text{H}^+(\text{aq})$ source; NaOH is the $\text{OH}^-(\text{aq})$ source. At the endpoint of the titration, the acid has been neutralized by the base.

$$\text{HCl}_{\text{initial}} - \text{HCl}_{\text{titrated}} = \text{HCl}_{\text{neutralized}}$$

Analytical Procedure

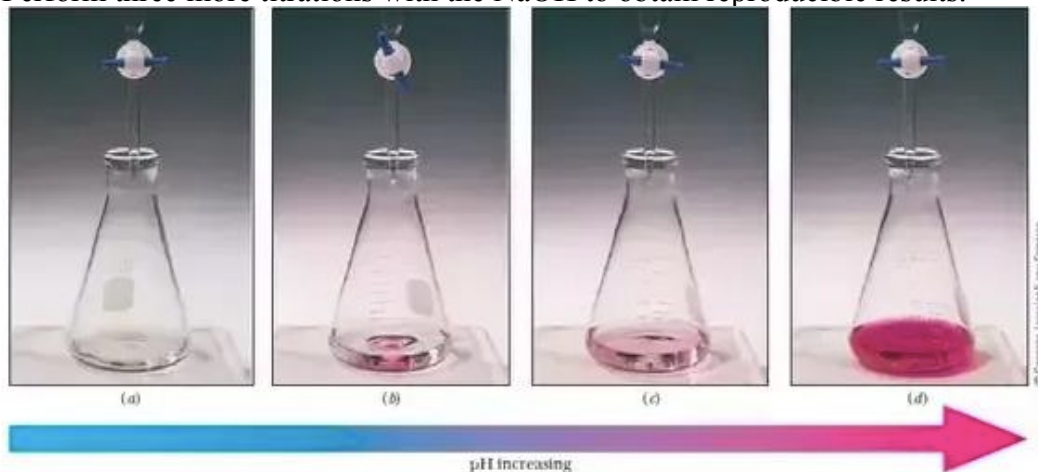
1. Weigh an antacid tablet in a weighing boat and record the mass (± 0.01 g). Transfer the tablet to a clean mortar and crush the tablet into a fine powder using the pestle.
2. Transfer it to a clean 250 mL Erlenmeyer flask.
3. Transfer about 50 mL (± 0.02 mL) of the HCl to the flask from the acid buret located on the reagent bench. Record the molarity of the HCl and the initial and final volume readings from the buret (± 0.02 mL).
4. Swirl the flask to help dissolve the antacid. Since the antacid tablet may contain inert ingredients, much of the tablet may not dissolve and the liquid will be cloudy. The active antacid ingredient will dissolve and react with the acid very quickly while the liquid will remain cloudy. (if needed gently heat)
5. Repeat this analysis on two other antacid tablets.



Part 2: Standardization of NaOH

Determine the concentration of the base, NaOH, by titrating a known mass of the monoprotic acid, KHP, to neutral (the equivalence point). The molar mass of KHP is 204.11 g/mol, and it has one acidic hydrogen per molecule.

1. Gather 4 125 mL Erlenmeyer flasks and label them KHP 1-4
2. Precisely weigh out approximately 1.500 g potassium acid phthalate (KHP) 4 times
3. Place the KHP and 30–40 mL water in each flask. It does not need to dissolve completely.
4. Use a few drops of phenolphthalein as indicator in each flask.
5. Get 100 mL of NaOH and add 50 mL to your buret
6. Record the initial volume of NaOH from the buret and then begin the titration. As you turn the stopcock, push it into the barrel so it doesn't loosen and leak.
7. Slowly add NaOH to your solution (approx. 1-2 mL each time) and swirl after each addition for approx. 15 seconds
8. As you approach the pale pink color, start adding dropwise; we do not want a hot pink color!!
9. Record the color change at the end point and the final volume on the buret. The volume of NaOH used = $V_{\text{final}} - V_{\text{initial}}$.
10. Perform three more titrations with the NaOH to obtain reproducible results.



Phenolphthalein. Drawings show the acid and base forms of phenolphthalein, an indicator commonly used for the titration of an acid with strong base. (a) The acidic solution is initially clear. (b) When base is added, the solution turns pink momentarily but disappears with swirling. (c) The first permanent pink indicates the endpoint. (d) The solution is vividly colored beyond the equivalence point, where base is in excess.

	KHP 1	KHP 2	KHP 3	KHP 4
KHP wt.	_____ g	_____ g	_____ g	_____ g
initial NaOH buret reading	_____ mL	_____ mL	_____ mL	_____ mL
final NaOH buret reading	_____ mL	_____ mL	_____ mL	_____ mL
mL NaOH delivered	_____ mL	_____ mL	_____ mL	_____ mL
moles of NaOH / KHP	_____ moles	_____ moles	_____ moles	_____ moles
molarity of NaOH	_____ M	_____ M	_____ M	_____ M



1 to 1 molar ratio

* note: not actual formula of complex formed

example

$$2.31 \text{ g} \cdot \frac{1 \text{ mol KHP}}{204.11 \text{ g}} \cdot \frac{1 \text{ mol NaOH}}{1 \text{ mol KHP}} = 0.01132 \text{ mol NaOH}$$

$$\frac{0.01132 \text{ mol NaOH}}{0.0234 \text{ L}} = 0.483 \text{ M NaOH}$$

↑
convert your mL to L for molarity

Average the molarities

Part 3: Standardization of HCl

To determine the precise molarity of the HCl solution, titrate it with the same ^{conc. of} NaOH from part 2 to the endpoint

- 1 Use a buret to transfer 20-25 mL of stock HCl into a 125 mL Erlenmeyer flask. Add indicator.
- 2 Record the initial volume of NaOH and titrate the HCl.
- 3 Record the color change at the end point and the final volume of NaOH. The volume of NaOH used = $V_{\text{final}} - V_{\text{initial}}$.
- 4 Repeat 2 more times so you can get reproducible results.

	1	2	3
initial HCl buret reading	_____ mL	_____ mL	_____ mL
final HCl buret reading	_____ mL	_____ mL	_____ mL
mL HCl delivered	_____ mL	_____ mL	_____ mL
initial NaOH buret reading	_____ mL	_____ mL	_____ mL
final NaOH buret reading	_____ mL	_____ mL	_____ mL
mL NaOH delivered	_____ mL	_____ mL	_____ mL
molarity of NaOH	_____ M	_____ M	_____ M
Ang. from Part 2	_____ M	_____ M	_____ M
molarity of HCl	_____ M	_____ M	_____ M

$$M_1 V_1 = M_2 V_2 \leftarrow \text{are you sick of it yet?}$$

$$M_1 = \frac{M_2 V_2 \leftarrow (\text{NaOH } V \text{ from Part 3})}{V_1 \leftarrow \text{amount of HCl used in part 3}}$$

$$M_1 = \frac{.466 \text{ M} \cdot .0275 \text{ L}}{.0247 \text{ L}} = 0.519 \text{ M HCl}$$

Avg Molarity

Part 4: Determination of the Amount of Acid Neutralized by an Antacid Tablet

1. Gather your flasks from part 1 and add a few drops of indicator.
2. Record the initial volume of NaOH to 0.01 mL.
3. Add NaOH in about 1 mL portions while swirling the solution. Stop between additions to swirl for a moment and observe the color. When you begin to see temporary faint color changes, add the NaOH in 0.5-mL increments. Near the endpoint, add the NaOH dropwise.
4. Record the final volume on the buret to 0.05 mL when you reach the endpoint. Save the solution in the flask as a reminder of the final color. The volume of NaOH required is $V_{\text{final}} - V_{\text{initial}}$; report the volume needed to 0.05 mL.
5. Accurately titrate the ~~one~~^{two} remaining samples.
6. **Dispose of your waste solutions in the waste containers in the back hood. Clean your bench top and rinse your glassware. Return any equipment that you borrowed (clean).**
7. Calculate the number of moles of HCl, using the volume and molarity of the HCl solution. This is the total amount of acid requiring neutralization (by the tablet and the NaOH).
8. Calculate the number of moles of NaOH titrant that you added to four significant figures using molarity and volume. This is the number of moles of HCl neutralized by the NaOH.

- 1) The rxn is 1 to 1 so moles of NaOH = mol of HCl neutralized and you can subtract this from amount of acid needing to be neutralized to see how much was neutralized by tablet.
- 2) HCl needing neutralization - HCl neutralized by NaOH = HCl neutralized by tablet.

	Tablet 1	Tablet 2	Tablet 3
1 Antacid brand name			
2 antacid tablet wt.	_____ g	_____ g	_____ g
3 crushed antacid sample wt.	_____ g	_____ g	_____ g
4 initial HCl buret reading	_____ mL	_____ mL	_____ mL
5 final HCl buret reading	_____ mL	_____ mL	_____ mL
6 mL HCl delivered	_____ mL	_____ mL	_____ mL
7 moles of HCl (initial)	_____ moles	_____ moles	_____ moles
8 initial NaOH buret reading	_____ mL	_____ mL	_____ mL
9 final NaOH buret reading	_____ mL	_____ mL	_____ mL
10 mL NaOH delivered	_____ mL	_____ mL	_____ mL
11 moles of NaOH	_____ moles	_____ moles	_____ moles
12 moles of HCl neutralized by antacid sample	_____ moles	_____ moles	_____ moles

moles of NaOH = moles of HCl neutralized by NaOH

So to get the value for # 12 moles of HCl neutralized by antacid tablet, subtract

$$\begin{array}{rcl} 6 - 11 & = & \text{moles HCl neutralized by tablet} \\ \downarrow & & \downarrow \\ \text{initial HCl moles} & & \text{moles neutralized by NaOH} \end{array}$$

* you get moles by taking molarity you solved for in parts 2 & 3 & multiply by mL dispensed in

$\downarrow$ NaOH $\downarrow$ HCl Part 4