Name: ______________________ Date: __________ Period: ______

SL Acids and Bases - Guided Notes

Slide 3: Arrhenius Acids/Bases

- Acid: **substance that ____________ in water to form hydrogen (H^+) ions**
- Base: **substance that ____________ in water to form hydroxide (OH^-) ions**
- Recognized:
- *hydrogen and ____________ ions could form water
- *____________ and anions form a salt
- Focus was only on ____________ systems
- Did not take into account ____________ occurring without water or insoluble bases
- **Fun fact:** ____________ wrote his ideas as part of his doctoral thesis, but it was not well received and he only received the lowest possible class of degree. Later, he won the Nobel Prize in Chemistry in 1903.
- He also was the first person to document ____________ of global warming due to rising CO_2 levels

Slide 5: Calculating pH

- $pH = -\log[H^+]$
- $pOH = -\log[OH^-]$
- $pH + pOH = 14$
- $[H^+] = 10^{-pH}$
- $[OH-] = 10^{-pOH}$
- At pH 7:
- $[H^+] = 1\times10^{-7}$
- $[OH-] = 1\times10^{-7}$
- At 298K:
- $[H^+][OH^-] = 1\times10^{-14} = K_w$
- **____________ constant water**

Slide 6: Amphoteric

- **____________ that can act as both an acid and a base**

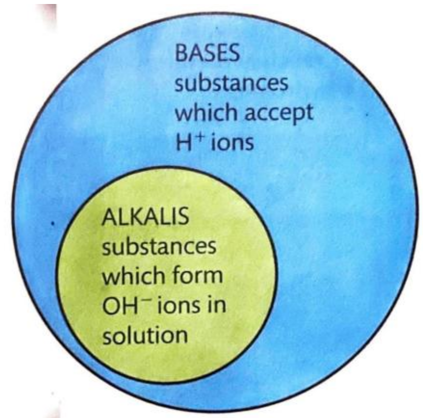
Slide 7: Properties of Bases

- ____________ bases are known as **alkalis**
- ____________ acids to produce water
- Dissolve in water to release ____________ (OH^-) ions
- They include:
- Metal oxides and ____________ (this does
- not include ____________ compounds).
- Ammonia
- Soluble ____________ (e.g. Na_2CO_3, K_2CO_3)

- and hydrogen ____________ (e.g. $KHCO_3$)
- **$K_2O(s) + H_2O(l) \rightarrow 2K^+(aq) + 2OH^-(aq)$**
- **$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$**
- **$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$**
- **$HCO_3^-(aq) \rightleftharpoons CO_2(g) + OH^-(aq)$**

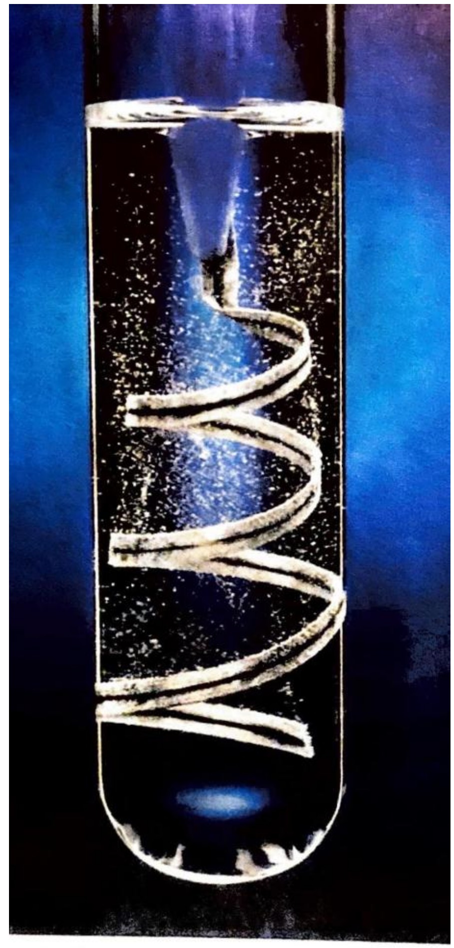
Slide 8: Acids react with metals, bases, and carbonates to form salts

- Salt: ionic ____________ formed when hydrogen of an acid is replaced by a metal or another positive ion
- Salts form from reaction of acids and bases (____________ referred to as **parent acid** and **parent base**).
- Three main types of ____________ where acids react to form salt:
- **Acid + metal → salt + ____________**
- **Acid + base → salt + water**
- **Acid + ____________ → salt + water + carbon dioxide**



Slide 9: Acid + metal → salt + hydrogen

- Examples:
- **$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$**
- **$H_2SO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + H_2(g)$**
- **$2CH_3COOH(aq) + Mg(s) \rightarrow Mg(CH_3COO)_2(aq) + H_2(g)$**
- The equations can also be written as ionic equations:
- **$2H^+(aq) + 2Cl^-(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$**
- **$2H^+(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + H_2(g)$**
- Acids have corrosive properties on most metals, but different metals have different reactivities to acid
- Group 1 metals most reactive, while some transition metals are not very reactive (makes them more valuable because they are resistant to corrosion)



Slide 10: Acid + base → salt + water

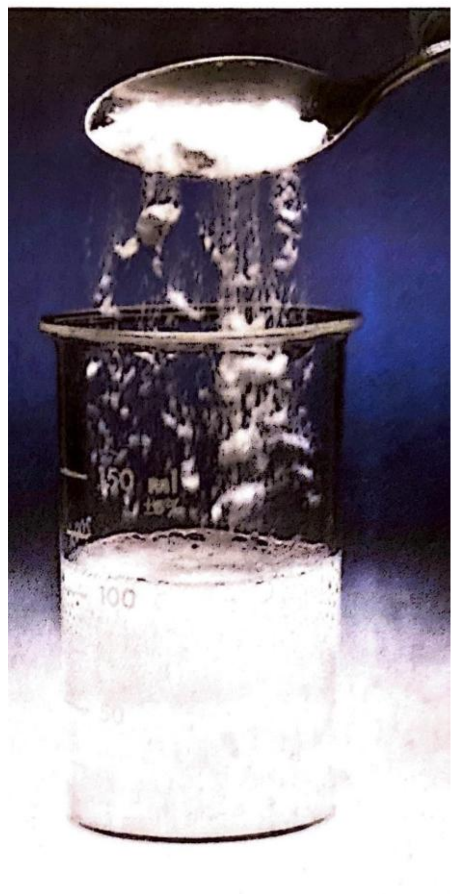
- **Examples:**
- **$HCl(aq)$ + $NaOH(aq) \rightarrow NaCl(aq)$ + $H_2O(l)$**
- **$HNO_3(aq)$ + $NH_4OH(aq) \rightarrow NH_4NO_3(aq)$ + $H_2O(l)$**
- **$2CH_3COOH(aq)$ + $CuO(aq) \rightarrow Cu(CH_3COO)_2(aq)$ + $H_2O(l)$**
- Can all be represented by one common ionic equation:
- **$H^+(aq)$ + $OH^-(aq) \rightarrow H_2O(l)$**
- Neutralization reactions are exothermic
- **Enthalpy of neutralization:** enthalpy change that occurs when an acid and a base react to form 1 mole of water
- Strong acid/strong base reactions have a **high enthalpy of neutralization ($\Delta H = -57\ kJmol^{-1}$)**
- **Neutralization Reactions** occur when acids and bases react to form salt and water

Slide 11: Turn and Talk

- Bee stings are _____________ acidic, while wasp stings are claimed to be alkali. Discuss what "home remedies" you think are often used to treat these ailments.

Slide 12: Acid + carbonate → salt + water + carbon dioxide

- **Examples:**
- **$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$**
- **$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$**
- **$CH_3COOH(aq) + KHCO_3(aq) \rightarrow KCH_3COO(aq) + H_2O(l) + CO_2(g)$**
- Can all be represented by one common ionic equation:
- **$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$**
- These reactions visibly produce bubbles due to carbon dioxide gas being released
- **effervescence**



Slide 13: BrØnsted-Lowry: a theory of proton transfer

- **Focuses on the transfer of H^+ ions during acid-base ____________**
- BrØnsted-Lowry acid: **a proton (H^+) donor**
- BrØnsted-Lowry base: **a proton (H^+) ____________**
- $$HCl + NH_3 \rightleftharpoons NH_4^+ + Cl^-$$
- **Note: H^+ is equivalent to a proton, so the words are used ____________**

Slide 14: Conjugate Pairs

- A proton donor must always have a proton acceptor (it does not happen in ____________)
- General formula for an acid-base ____________:
- $$HA + B \rightleftharpoons A^- + BH^+$$
- **____________ acid-base pair**
- **____________ acid-base pair**
- **Conjugate Acid:** proton donor (must ____________ and release H^+)
- **____________ Base:** proton acceptor (must be able to have alone pair of electrons to accept H^+)

Slide 15: Conjugate Pairs

- Example:
- $$H_2O(l) + H^+(aq) \rightleftharpoons H_3O^+(aq)$$
- **Conjugate Acid: H_3O^+**
- **Conjugate Base: H_2O**
- **Hydronium ion:** always the form of hydrogen ions in aqueous solution; convenient to write as $H^+(aq)$
- **Note: conjugate acids always have one more proton compared to conjugate bases**

Slide 16: You Try!

- **Identify the conjugate acid-base pairs in the following reaction:**

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Slide 17: Let's Practice!

Worked example

1 Write the conjugate base for each of the following.

(a) H_3O^+ (b) NH_3 (c) H_2CO_3

2 Write the conjugate acid for each of the following.

(a) NO_2^- (b) OH^- (c) CO_3^{2-}

Slide 18: Amphiprotic Species

- Some ____________ can act as acids and bases
- ____________: species that can act as proton donors and acceptors
- Note: ____________ refers only to species that transfer protons
- **Amphoteric** are species that act as acids and bases that don't ____________ involve transfer of protons
- **$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$**
- **$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$**
- Water is ____________ **and amphoteric**

Slide 19: You Try!

- Write equations to show HCO_3^- acting (a) as a Bronsted-Lowry acid and (b) as a Bronsted-Lowry base.

Slide 20: Strong and weak acids

- **The strength of an acid/base depends on the extent of its ____________ in solution**
- Acids produce H^+ ions, bases produce OH^- ions (____________)

- **Strong Acids:** _____________ fully and exists entirely as ions in solution; good proton donors
- **$HA(aq) + H_2O(l) \rightarrow A^-(aq) + H_3O^+(aq)$**
- **$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$**
- **Strong acid base _____________ acid conjugate base**
- **Weak Acids:** dissociate partially to produce an equilibrium mixture (_____________ form dominates); weak proton donors
- **$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$**
- **weak acid base _____________ acid conjugate base**
- **Weak acids form stronger _____________ bases**
- **_____________ lies to the left**

Slide 21: Strong and weak bases

- Strong Bases: _____________ fully and exists entirely as ions in solution; good proton acceptors
- **$BOH(aq) \rightarrow B^+(aq) + OH^-(aq)$**
- **$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$**
- **Weak Bases: dissociate partially to produce an equilibrium mixture (_____________ form dominates); weak proton acceptors**
- **$B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)$**
- **$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$**
- **weak base acid _____________ acid conjugate base**
- Tip: don't confuse acid/base strength with _____________; a **strong** acid/base can still be **diluted** and have a **low concentration**
- **Weak bases form stronger _____________ acids**
- **_____________ lies to the left**

Slide 22: Weak acids and bases are common

- More _____________ acids/bases listed in section 21 of the Data Booklet

	Acid		Base	
common examples of **strong** forms	HCl	hydrochloric acid	LiOH	lithium hydroxide
	HNO_3	nitric acid	NaOH	sodium hydroxide
	H_2SO_4	sulfuric acid	KOH	potassium hydroxide
			$Ba(OH)_2$	barium hydroxide
some examples of **weak** forms	CH_3COOH and other organic acids	ethanoic acid	NH_3	ammonia
	H_2CO_3	carbonic acid	$C_2H_5NH_2$ and other amines	ethylamine
	H_3PO_4	phosphoric acid		

Slide 23: Distinguish between strong and weak acids/bases

- _____________ of ions can be used to distinguish between strong and weak acids and bases
- Can only compare solutions with the **same _____________ at the**

same temperature

- Electrical ____________
- Strong acids and bases will have higher conductivity than weak acids and bases of the same ____________ (measured using conductivity meter
- Rate of reaction
- Strong acids and bases will have higher reaction rate than weak acids and bases of the same ____________ (not easy to quantify)
- pH
- ____________ acids will have a lower pH; stronger bases will have a higher pH
- HCl + Mg
- CH_3COOH + Mg

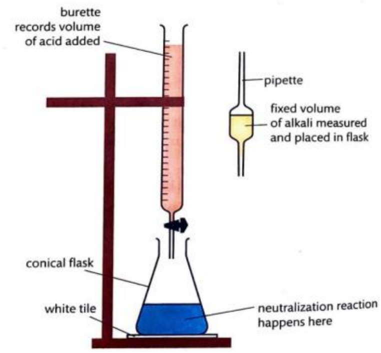
Slide 24: Let's Practice!

- Which of the following 1 mol dm^{-3} solutions will be the poorest conductor of electricity?
- HCl
- CH_3COOH
- NaOH
- NaCl
- 2. Which methods will distinguish between equimolar solutions of a strong base and a strong acid?
- Add magnesium to each solution and look for the formation of gas bubbles.
- Add aqueous sodium hydroxide to each solution and measure the temperature change.
- Use each solution in a circuit with a battery and lamp and see how brightly the lamp glows.
- I and II only B. I and III only C. II and III only D. I, II, and III
- 3. Which acid in each of the following pairs has the stronger conjugate base?
- H_2CO_3 or H_2SO_4
- HCl or HCOOH

Slide 25: Acids and bases distinguished using indicators

- Indicators change color reversibly according to the ____________ of H^+ ions in solution
- Used as aqueous ____________ or absorbed onto "test paper"
- Occurs because they are weak acids and bases whose ____________ have different colors
- Best known is **litmus**, which turns pink in the ____________ of acid and blue in the presence of alkalis
- **More ____________ are in Section 22 of the Data Booklet**
- **Universal Indicator is formed by mixing together several ____________ and changes color many times across a range of acids and alkalis**

Slide 26: Acid-Base Titrations



- Involve reacting a measured volume of one solution and adding the other gradually until the **equivalence point** is reached (____________ occurs).
- Indicators are used to determine when ____________ point is reached.
- A good indicator gives a distinct color change at the ____________ point.
- **Note: Don't always assume ____________ show acid as pink and alkali as blue**

Slide 27: Let's Practice!

- Write equations for the following reactions:
- Sulfuric acid and copper oxide
- Nitric acid and sodium hydrogencarbonate
- Phosphoric acid and potassium hydroxide
- Ethanoic acid and aluminum
- An aqueous solution of which of the following reacts with calcium metal?
- Ammonia C. hydrogen chloride
- Potassium hydroxide D. sodium hydrogencarbonate
- Which of the following is/are formed when a metal oxide reacts with a dilute acid?
- A metal salt II. water III. carbon dioxide gas
- I only B. I and II only C. II and III only D. I, II, and III
- Suggest by name a parent acid and parent base that could be used to make the following salts. Write equations for each reaction.
- Sodium nitrate (c) copper (II) sulfate
- Ammonium chloride (d) potassium methanoate

Slide 28: Acid Deposition

- **2 main types:**
- Wet acid deposition: rain, snow, sleet, hail, fog, mist, dew fall to the ground as **aqueous ____________**
- Dry acid ____________: acidifying particles, gases fall to ground as dust and smoke, later dissolve in water to form acids
- All rain water is acidic due to presence of ____________ carbon

dioxide that dissolves in water to produce carbonic acid

- $$H_2O(l) + CO_2(g) \rightleftharpoons H_2CO_3(aq)$$
- $$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$
- **All processes by which acidic components as ____________ or gases leave the atmosphere**
- Rain water can react with calcium carbonate in limestone to produce calcium ____________, which is soluble and washes away. This can lead to erosion and is why caves are commonly found in limestone regions.

Slide 29: Acid Rain

- Contain ____________ acids (other than carbonic)
- Main ____________ to acid rain are oxides of sulfur and nitrogen (pollutants)
- **Refers to ____________ with a pH < 5.6**
- **Rain water**
- **Acid rain**

Slide 30: Sulfur oxides

- SO_2 produced from burning of fossil fuels (coal, oil); also released in smelting (____________ metals from ores)
- About 50% of global annual SO_2 ____________ come from coal
- $$S(s) + O_2(g) \rightarrow SO_2(g)$$
- SO_2 ____________ in water to form sulfurous acid
- $$H_2O(l) + SO_2(g) \rightarrow H_2SO_3(aq)$$
- SO_2 can also be oxidized to SO_3, which then ____________ in water to form sulfuric acid
- $$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
- $$H_2O(l) + SO_3(g) \rightarrow H_2SO_4(aq)$$
- Hydroxyl free radicals (formed in ____________ between water and O_2 or O_3) can also react form SO_3
- $$\cdot HO + SO_2 \rightarrow \cdot HOSO_2$$
- $$\cdot HOSO_2 + O_2 \rightarrow \cdot HO_2 + SO_3$$

Slide 31: Nitrogen oxides

- NO produced mainly from internal ____________ engines
- $$N_2(g) + O_2(g) \rightarrow 2NO(g)$$
- NO_2 (brown gas) can also be ____________ from a similar reaction
- $$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$$
- NO_2 can also form from ____________ of nitrogen monoxide
- $$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$
- NO_2 ____________ in water to form nitrous and nitric acid

- $H_2O(l) + 2NO_2(g) \rightarrow HNO_2(aq) + HNO_3(aq)$
- NO_2 can also be ____________ to form nitric acid
- $H_2O(l) + 4NO_2(g) + O_2(g) \rightarrow 4HNO_3(aq)$
- Hydroxyl free radicals also ____________ to the formation of nitrous and nitric acid
- $\cdot HO + NO \rightarrow HNO_2$
- $\cdot HO + NO_2 \rightarrow HNO_3$

Slide 33: Turn and Talk

- One of the most ____________ aspects of acid deposition is that its effects often occur far from the source of the pollutants due to atmospheric weather patterns. In many cases, this means countries are suffering the impact of other countries' industrial processes. Discuss possible steps that countries could take to help remedy the effects of acid deposition.

Slide 34: Effects of acid deposition

- **Impact on ____________:** Building materials marble and limestone are both forms of calcium carbonate. SO_2 and H_2SO_4 react with calcium carbonate to form $CaSO_4$. Since calcium sulfate is soluble, is washes out of or flakes off of limestone.
- Nitric acid can also react with ____________ to form calcium nitrate, which is soluble and can also lead to erosion.
- Acid ____________ can corrode metals such as iron and aluminum to form salt. This causes damage to metallic structures such as bridges, rail-road tracks, and vehicles.
- **Impact on plant life:** Acid rain causes slower growth, injury, or death of plants. It washes away ____________ soluble minerals such as magnesium, calcium, and potassium in the soil (**leaching**).
- Acid rain also causes release of toxic ____________, such as aluminum. Dry deposition can block pores for gas exchange. Forests in hilly regions are vulnerable since they are surrounded by acidic clouds.

Slide 35: Effects of acid deposition

- **Impact on water:** Acid rain causes "dead" lakes (unable to support life) due to ____________ pH values. Many fish cannot survive at pH < 5.
- pH levels < 4 cause aluminum ions to be leached out of aluminum ____________ (stored in rocks), which is toxic to aquatic life (interfere with fish's ability to take in oxygen).
- Acid rain causes over-fertilization of water, caused by presence of nitrates in acid rain (____________). This causes algal blooms that deplete oxygen.
- **Impact on human health:** Components of acid rain can react to form fine sulfate and nitrate particles (____________) that can travel long distances, be inhaled, and irritate the eyes and respiratory tract (causing asthma, bronchitis, and emphysema).
- Release of toxic metal ions when acid rain reacts with metal ____________ is also a potential health risk.

Slide 36: Responses to acid deposition

- R**eduction of SO_2 emissions:**
- **Pre-Combustion methods:** Processes that reduce or remove sulfur from coal/oil before combustion. Include **____________ (HDS),** which removes sulfur from petroleum by reacting it with hydrogen to form hydrogen sulfide. Since H_2S is toxic, it is captured and later used in the production of sulfuric acid.
- **Post-Combustion methods: Flue-gas ____________** removes up to 90% of SO_2 from flue gas from coal-fired power stations before it is released into the atmosphere. Calcium oxide and calcium carbonate react with SO_2 to form calcium sulfate.

Slide 37: Responses to acid deposition

- **____________ of NOx emissions:**
- C**atalytic ____________ in vehicles:** hot gases are mixed with air and passed over a platinum or palladium-based catalyst. This converts toxic emissions into carbon dioxide and nitrogen gas.
- Lower temperature combustion: ____________ the exhaust gases back into the engine lowers the temperature, which decreases NO emissions.
- **Others:** lowering demand for fossil fuels, more efficient energy transfer systems, greater use of public ____________, switching to renewable energy sources. Restoration of ecosystems damaged by acid rain is a long-term process. One method is to use calcium oxide or calcium hydroxide to neutralize acids.