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| **Objectives:** | | |
| * Use the three acid-base theories to identify acids and bases under different conditions. * Write the names of binary acids. * Write the names of ternary acids. * Write the anhydrous form of ternary acids. * Predict whether an oxide is an acid anhydride or a basic anhydride. * Use the formula of an acid to determine if it is strong or weak. * Use factor-label for titration calculations. |  |  |

**Acids and Bases**

**There are three "theories" used to define acids and bases.** Each of these theories focuses on a slightly different property. As you go down the list, the definition broadens to include a wider range of substances.



**1. Arrhenius Theory:**

* **Acid - produces hydrogen ions, H + in water solution.**
  + In an equation, the positive part of a Arrhenius acid will be hydrogen.
* **Base - produces hydroxide ions, OH - in water solution.**
  + In an equation, the negative part of a Arrhenius base will be hydroxide.
* Acids and bases are thought of as electrolytes. When each dissolves, it ionizes to release the appropriate ion.
* While this is not completey accurate, it is a good description of those chemicals we call acids and bases.
* **Practice Problems:**

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| Each of the following unbalanced equations represents a reaction between a Arrhenius acid and base. Identify those in each reaction:   1. H2CO3 + NH4OH (NH4)2CO3 + H2O  1. KOH + H3PO4 K3PO4 + H2O  1. HF + NaOH NaF + H2O  1. Ba(OH)2 + HNO2 Ba(NO2)2 + H2O |

Arrhenius Practice Problems:

1. (acid) H2CO3 + (base) NH4OH
2. (base) KOH + (acid) H3PO4
3. (acid) HF + (base) NaOH
4. (base) Ba(OH)2 + (acid) HNO2

**2. Bronsted - Lowry Theory:**

* **Acid - proton donor.**
  + In an equation, a Bronsted - Lowry acid must have hydrogen in its formula.
* **Base - proton acceptor.**
  + A Bronsted - Lowry base is hard to generalize for all equations. It may be a negative ion. You may have to look at the products. Find one that contains hydrogen. If the negative part of this product was in a reactant that did not contain hydrogen, that reactant is most likely the base.
* This theory focuses on the action of protons in reactions. Since protons are in the nucleus of an atom, the hydrogen ion is the only source of protons in a normal chemical reaction.
* The definition of acids and bases is broadened because no specific ions must be formed, but hydrogen is needed in the reaction to produce the proton.
* Three important terms are used in association with this theory:
  + **Conjugate base** - the particle that remains after an acid gives up a proton.
  + **Conjugate acid** - the particle formed when a base accepts a proton.

HCl + H2O Cl - + H3O+   
Acid + Base Conjugate Base + Conjugate Acid



* + **Hydronium ion** - formed by a hydrogen ion and a water molecule - **H3O+**

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|  | **Since a hydrogen ion is nothing more than a proton (a bare positive charge), when formed, this proton is immediately attracted to a polar water molecule forming a hydronium ion. For this reason, hydrogen ions never actually exist in water solution.** |

* **Practice Problems:**

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| Each of the following unbalanced equations represents a reaction between a Bronsted - Lowry acid and base. Identify those in each reaction:   1. CaCO3 + HCl CaCl2 + H2CO3  1. H2S + NO3 - S + NO  1. IO3- + H2S I2 + SO3-2  1. H2SeO3 + Br - Se + Br2 |

**3. Lewis Theory:**

* **Acid - electron-pair acceptor.**
  + In an equation, a Lewis acid gets more negative from the left side to the right.
* **Base - electron-pair donor.**
  + In an equation, a Lewis base gets more positive from the left side to the right.
* This theory is the broadest of all.
* According to this theory, any reaction involving the exchange of a pair of electrons will have an acid and base.
* Important terms associated with this theory are:
  + **Complex ion** - a central positive ion surrounded by bonded ligands.
    - The central ion has empty orbitals and can act as an electron pair acceptor, (Lewis Acid).
  + **Ligands** - a negative ion or polar molecule bonded to the central ion in a complex.
    - Ligands have unshared electron pairs to donate, (Lewis Base).
* **Practice Problems:**

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| Each of the following unbalanced equations represents a reaction between a Lewis acid and base. Identify those in each reaction:   1. Cl - + Br2 Cl2 + Br -  1. Mn + Co+2 Mn+2 + Co  1. Cl2 + Sn+2 Cl - + Sn+4  1. Fe+2 + ClO3 - Fe+3 + Cl - |

1. Why are hydrogen ions NEVER found in an aqueous solution?
2. HCN(aq) + SO4-2(aq) HSO4-(aq) + CN -(aq)



* 1. What is the Bronsted - Lowry acid in this equation?
  2. What is the Bronsted - Lowry base in this equation?
  3. What is the conjugate acid in this equation?
  4. What is the conjugate base in this equation?

1. 2NH3 + Ag+ Ag(NH3)2+



* 1. What is the Lewis acid in this equation?
  2. What is the Lewis base in this equation?

1. O-2 + SO3 SO4-2   
   In this equation, the O-2 is the Lewis base and the SO3 is the Lewis acid.



* 1. Draw the **electron dot diagram** for the acid.
  2. Draw the electron dot diagram for the base.
  3. Draw the electron dot diagram for the product, SO4-2

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| **Binary acids: made up of only two elements -** hydrogen and one other element. |

* **Naming binary acids:**
  + Begin with the prefix hydro.
  + Determine the "stem" - part of the name of the element that combines with hydrogen.
  + **Add the suffix ic.**

**Examples:**

* + HCl - **hydro chlor ic** - hydrochloric acid
  + HBr - **hydro brom ic** - hydrobromic acid

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| **Ternary acids: made up of three elements -** hydrogen, oxygen, and another element. |

* **Naming ternary acids:**
  + Determine the "stem" - part of the name of the third element.
  + **The most common acid is given the suffix ic.**
  + **Add the prefix per for the acid with one more oxygen.**
  + **The suffix ous is given to the acid with one less oxygen.**
  + **Add the prefix hypo for the acid with two less oxygen atoms.**

**Examples:**

* + HClO4 - **per chlor ic** - perchloric acid - one more oxygen atom.
  + HClO3 - **chlor ic** - chloric acid - the most common form of the acid.
  + HClO2 - **chlor ous** - chlorous acid - one less oxygen atom.
  + HClO - **hypo chlor ous** - hypochlorous acid - two less oxygen atoms.

**Other important terms:**

* **Amphoteric** - a substance that acts as either acid or base, depending on what it reacts with.
  + Water is the most common amphoteric substance. In the presence of a proton donor, it acts like a base. In the presence of a proton acceptor, it acts like an acid.
* **Anhydrous** - without water.
  + Anhydrides are substances that have had water removed.
  + Example: Taking the water out of Ba(OH)2 leaves BaO.
  + Practice Problems: write the anhydrous form of the following
    1. H2SO3
    2. H2C2O4
    3. H3PO4
    4. H4C2O2
* **Acid anhydride** - an oxide that produces an acid when dissolved in water.
  + Oxides of nonmetals are acid anhydrides.
  + Example: SO2 + H2O H2SO3 (an acid)



* + Practice Problems: write the formula of the compound formed when these are dissolved in water.
    1. P2O3
    2. NO2

 **Basic anhydride** - an oxide that produces a base in when dissolved in water.

* Oxides of metals are basic anhydrides.
* Example: Na2O + H2O 2NaOH (a base)



* Practice Problems: write the formula of the compound formed when these are dissolved in water.
  1. MgO
  2. Al2O3

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| |  | | --- | | **Strong acids and bases ionize completely in water solution.**   * **This rule-of-thumb can be used in our class:**    + **HCl, HBr, and HI are the only strong binary acids.**   + **In strong ternary acids, the number of oxygen atoms exceeds the number of hydrogen atoms by two or more. Examples are H2SO4 and HNO3**   + **Hydroxides of groups 1 and 2, except Be, are strong bases.** | |

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| |  | | --- | | **Weak acids and bases ionize only slightly in water solution.**   * **This rule-of-thumb can be used in our class:**    + **Any binary acid not listed above is weak.**   + **A ternary acid is weak if the ratio of oxygen to hydrogen is less than two to one. An example is H3PO4**   + **Any hydroxide not listed above is a weak base.** | |