Arrhenius Theory

- Introduced first comprehensive theory on acids and bases

  - Ionic compounds dissociate into separate cations and anions

    ionic compound → cation + anion

    $NaCl \rightarrow Na^+ + Cl^-$

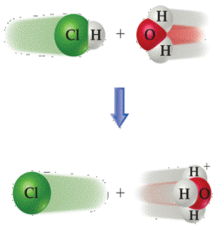
  - Bases are ionic compounds that dissociate into a cation and a hydroxide ion

    base → cation + $OH^-_{(aq)}$ $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

  - Acids ionize in water to produce hydrogen ions plus an anion

    acid → $H^+_{(aq)}$ + anion $HCl_{(g)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

Modified Arrhenius Theory



- **Acids** are substance that can give up a hydrogen ion in a reacon **with water**

  - react with water to produce hydronium ions ($H_3O^+_{(aq)}$)
  - Special cases: water can both give up and accept hydrogen ions
  - If the formula starts with an H or ends in COOH it can donate a hydrogen ion

exception NH_4^+

H_2CO_3
HCO_3^-
HSO_4^-

$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

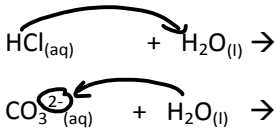
- **Bases** are substances that can receive an hydrogen ion in a reacon **with water**

  - react with water to produce hydroxide ions ($OH^-_{(aq)}$)
  - If the formula has a negave charge, it can accept a hydrogen ion
  - Ionic compounds contain a negave ion, and when they dissociate in water, the negave ion can take an H^+ away from water
  - NH_3 can accept a hydrogen ion even though it doesn't have a negave charge

$NH_{3(l)} + H_2O_{(l)} \rightarrow NH_4^+ + OH^-_{(aq)}$

Writing Chemical equations using the Modified Arrhenius Theory

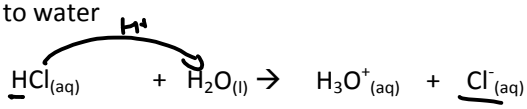
- Write the chemical formula for the polyatomic ion or molecule + water



$$HCl_{(aq)} + H_2O_{(l)} \rightarrow$$

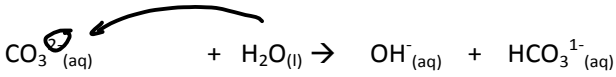
$$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow$$

- If the reactant is an acid (has and H or ends in COOH) transfer a hydrogen from the acid to water



$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

- If the reactant is a base (has a negative charge or is NH_3), transfer a hydrogen from water to the base



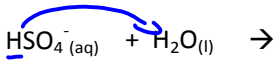
$$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + HCO_3^{1-}{}_{(aq)}$$

Example:
How does a solution of sodium hydrogen sulfate produce an acidic solution? (Use litmus test to prove)

- The ionic compound dissociates

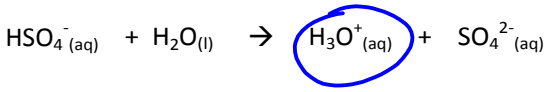
$$NaHSO_{4(aq)} \rightarrow Na^+_{(aq)} + HSO_4^-{}_{(aq)}$$

- Hydrogen sulfate gives a hydrogen to water



$$HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightarrow$$

- The hydronium ion is produced



$$HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

Example:
In a test of the modified Arrhenius theory, a student tested the pH of a solution made by dissolving solid sodium cyanide in water, and found it to have a pH greater than 7. Can the modified Arrhenius theory explain this evidence? Provide your reasoning.

Practice Sheet 11

1. Use the modified Arrhenius theory to suggest a chemical reaction equation to explain the acidic properties of each of the following solutions:
(a) $HI_{(aq)}$

(b) $HOCl_{(aq)}$

(c) $H_3PO_{4(aq)}$

2. Where possible, use the modified Arrhenius theory to explain the basic properties of each of the following solutions. Include appropriate chemical reaction equations:
(a) $Na_2SO_{4(aq)}$

(b) $NaCH_3COO_{(aq)}$

(c) $Sr(OH)_{2(aq)}$

3. Test the explanatory power of the modified Arrhenius definitions by explaining the following evidence. For each of the following compounds, write a dissociation equation where appropriate, and then write a chemical equation showing reactions with water to produc either hydronium or hydroxide ions (consistent with the evidence):
(a) HBr(g) in solution shows a pH of 2 on pH paper.

(b) Na3PO4(s) forms a solution with a pH of 8.

(c) NaHSO3(s) in solution turns blue litmus red.

(d) Na2HPO4(s) in solution turns red litmus blue.

(e) KOH(s) yields a solution with a pH of 12.