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) $HI_{(aq)}$

$$HI_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + I^-_{(aq)}$$

(b) $HOCl_{(aq)}$

$$HOCl_{(aq)} + H_2O_{(l)} \rightarrow OCl^-_{(aq)} + H_3O^+_{(aq)}$$

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

$$H_3PO_{4(aq)} + H_2O_{(l)} \rightarrow H_2PO_4^-{}_{(aq)} + H_3O^+_{(aq)}$$

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) $Na_2SO_{4(aq)}$

$$Na_2SO_{4(aq)} \rightarrow 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

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

(b) $NaCH_3COO_{(aq)}$

$$NaCH_3COO_{(aq)} \rightarrow Na^+_{(aq)} + CH_3COO^-_{(aq)}$$

$$CH_3COO^-_{(aq)} + H_2O_{(l)} \rightarrow CH_3COOH_{(aq)} + OH^-_{(aq)}$$

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

$$Sr(OH)_{2(aq)} \rightarrow Sr^{2+}_{(aq)} + 2OH^-_{(aq)}$$

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 produce either hydronium or hydroxide ions (consistent with the evidence):

(a) HBr(g) in solution shows a pH of 2 on pH paper.

$$HBr_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Br^-_{(aq)}$$

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

$$Na_3PO_{4(s)} \rightarrow 3Na^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

$$PO_4^{3-}{}_{(aq)} + H_2O_{(l)} \rightarrow HPO_4^{2-} + OH^-_{(aq)}$$

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

$$NaHSO_{3(s)} \rightarrow Na^+_{(aq)} + HSO_3^-{}_{(aq)}$$

$$HSO_3^-{}_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + SO_3^{2-}{}_{(aq)}$$

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

$$Na_2HPO_{4(s)} \rightarrow 2Na^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

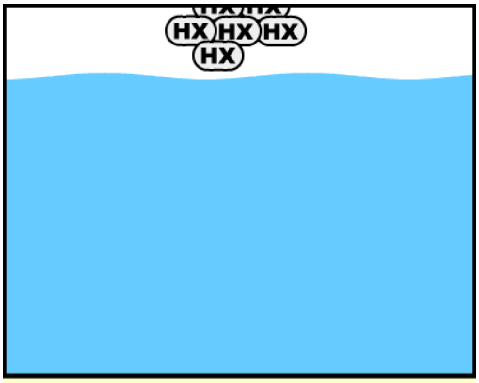
$$HPO_4^{-2}{}_{(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + H_2PO_4^-{}_{(aq)}$$

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

$$KOH_{(s)} \rightarrow K^+_{(aq)} + OH^-_{(aq)}$$

Strong acids and Weak acids

- **Strong Acids** – react completely (>99%) with water to produce hydronium ions

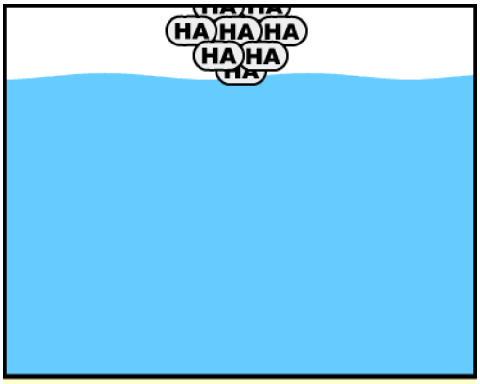


In this animation, we will see what happens when a strong acid, HX, is dissolved in water.

For clarity we will assume that HX is a solid.

- **Weak Acids** – reacts incompletely with water to from relatively few hydronium ions

http://www.chembio.uoguelph.ca/educmat/chm19104/chemtoons/chemtoons4.htm



In this animation, we will see what happens when a weak acid, HA, is dissolved in water.

For simplicity we will assume that HA is a solid.

$$HCl_{(aq)} + H_2O_{(l)} \xrightarrow{>99\%} H_3O^+_{(aq)} + Cl^-_{(aq)}$$

1.0 m/L → 1.0 m/L

- This reaction tells me that over 99% of the reactants are used up to produce the products. Essentially, no reactants are left over when the reaction is complete.

1.3% percent rxn

$$CH_3COOH_{(aq)} + H_2O_{(l)} \xrightarrow{<50\%} H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

1.0 m/L → 0.013 m/L

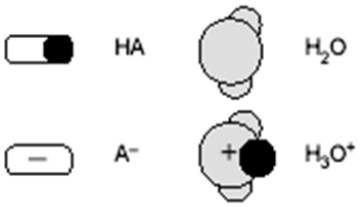
- This reaction tells me that less than 50% of the reactants are used up to produce products. There is still reactants left when the reaction is complete.

Strong/Weak vs Concentrated/Dilute

- The terms **concentrated** and **dilute** have nothing to do with the strength of an acid
    - Tell you the concentration of the acid not how much the acid reacts
    - Ex. You can have a concentrated weak acid
    - Ex. You can have a dilute strong acid

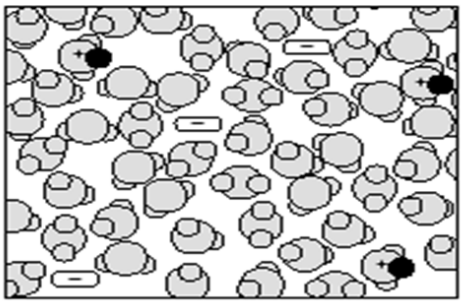
Example:

HA is a general formula for an acid, where HA is the acid, H is the hydrogen ion and A is the anion in the acid molecule

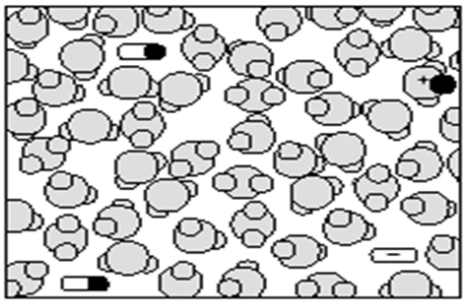


Label each of the four solutions as strong or weak, and concentrated or dilute (Hint: Look at the number of HA molecules that are still together vs. the number of HA molecules that have split into H_3O^+ and A^-)

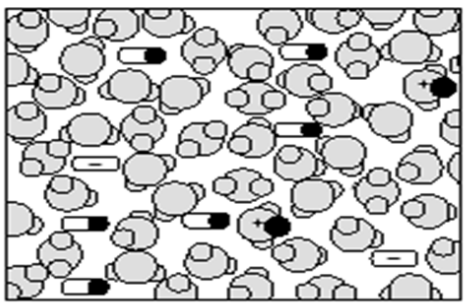
1. Strong, dilute



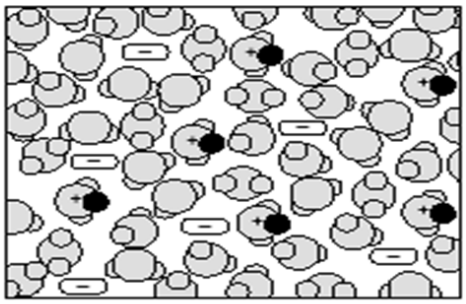
2. weak, dilute



3. weak, concentrated



4. strong, conc.



Strong and Weak Bases

- **Strong base** – a soluble ionic compound containing OH^-

$$NaOH_{(aq)} \xrightarrow{>99\%} Na^+_{(aq)} + OH^-_{(aq)}$$

$$Ba(OH)_{2(aq)} \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$$

- **Weak base** – a base which reacts only partially with water to produce hydroxide ions

$$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \xrightarrow{<50\%} HCO_3^-{}_{(aq)} + OH^-_{(aq)}$$

SUMMARY ***Strong and Weak Acids and Bases***

Table 2 Strong and Weak Acids and Bases in Aqueous Solution

	Strong acids	Weak acids	Strong bases	Weak bases
empirical properties (same *c* and *t*)	very low pH (<< 7)	medium to low pH (<7)	very high pH (>> 7)	medium to high pH (>7)
	high conductivity	low conductivity	high conductivity	low conductivity*
	fast reaction rate	slow reaction rate	fast reaction rate	slow reaction rate
modified Arrhenius theory	completely react with water to form H_3O^+(aq)	partially react with water to form H_3O^+(aq)	completely dissociate to form OH^-(aq)	partially react with water to form OH^-(aq)

* applies only to weak bases that are molecular

Polyprotic Substances

Monoprotic acid – an acid that can only react once with water to produce a hydronium ion (H_3O^+)

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

Polyprotic acid - an acid that can react more than once with water to produce a hydronium ion (H_3O^+)

$$H_3PO_{4(aq)} + H_2O_{(l)} \xrightarrow{<50\%} H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$$

$$H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \xrightarrow{<1\%} H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

$$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \xrightarrow{\sim 0\%} H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

Monoprotic Bases – can react only once with water to produce hydroxide ions

$$CH_3COO^-_{(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + CH_3COOH_{(aq)}$$

Polyprotic bases – can react more than once with water to produce hydroxide ions

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

$$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + H_2CO_{3(aq)}$$