CHEM 205 section 03

LECTURE #13 Thurs., Feb.14, 2008

LECTURE TOPICS:

TODAY'S CLASS: continue Ch.5

NEXT CLASS: **continue Ch.5**

Midterm exam: Tues. March 4th during class
will cover: Ch.1-5 & 20.1

See sample exams on website:
http://faculty.concordia.ca/rogers
Click on Teaching, then Chem 205…

5.3 Acids and Bases… & their reactions (5.4)

What do we know about acids & bases?

- Sour taste (vinegar, lemon juice…)
- Turn litmus paper RED
- Produce bubbles of $CO_2(g)$ when added to carbonate rocks
- React with many metals to produce bubbles of $H_2(g)$
- **ACIDS = substances that, when dissolved in water, ↑ the concentration of H^+**

- Bitter taste (soap…)
- Slippery feel (soap, bleach…)
- Turn litmus paper BLUE
- Counter-act the 'acidic nature' of acids…
- **BASES = substances that, when dissolved in H_2O, ↑ the conc. of OH^-**

THEORIES DESCRIBING ACIDS & BASES:

Svante Arrhenius: *ions involved…*

late 19th century

Acids & bases yield ions when dissolved in water
- Completely ➡ "strong" acid/base
- Only partially ➡ "weak" acid/base

"Strong acids" are strong electrolytes…
…quantitatively yield H^+ & anion when dissolved in water

Common strong acids (Memorize these 6)

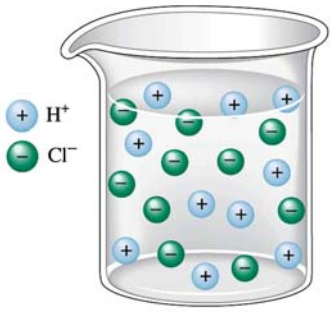
- **HCl, HBr, HI** = hydrohalic acids *(except HF)*
- **H_2SO_4** = sulfuric acid
- **HNO_3** = nitric acid
- **$HClO_4$** = perchloric acid

Note: acids are unusual molecules
- actually **react** with water when they dissolve…

When hydrogen chloride HCl(g) dissolves, hydrochloric acid HCl(aq) forms:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

For strong acids: Quantitative yield of ions when dissolved in water.



Zumdahl Figure

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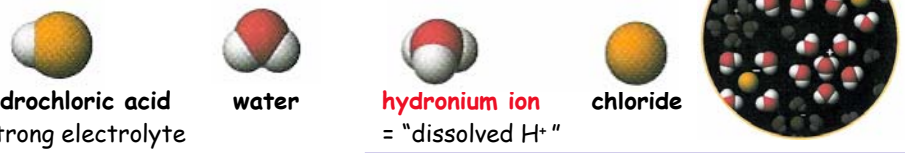
Acid(aq): deeper insight

Kotz p.188 "A Closer Look"

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



hydrochloric acid = strong electrolyte = 100% ionized in H_2O

water

hydronium ion = "dissolved H^+"

chloride

- H^+ covalently bonded to water molecule
- not simply dissolved…
- BUT often shown as $H^+(aq)$ for simplicity

$$HA(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + A^-(aq)$$

FOR ANY STRONG ACID "HA"
- Weak covalent bond to H^+
- H_2O pulls off this H^+
  - rxn, not just dissolution…
- **Quantitative yield of A^- & "H^+"**

RESULT:
- New covalent bond to H^+ (in H_3O^+)
  - stronger bond than in HA…
  - H^+ does not go back onto A^-

"Weak acids" are weak electrolytes (partially ionize)

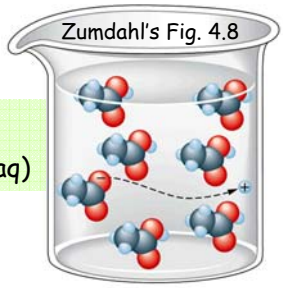
Small % of acid molecules lose H^+:

$$HA(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + A^-(aq)$$

FOR ANY WEAK ACID "HA"
- Moderately weak bond to H^+
- Sometimes: H_2O pulls off H^+
- **Low yield of A^- & " H^+ "**

RESULT:
- New covalent bond to H^+ (in H_3O^+)
  - slightly weaker than in HA
  - most H^+s stay bonded to A^-

Note: chemical equations do not imply that the process "goes to completion"... only that it happens "to some extent"



Aqueous acetic acid - simplified view:

$$HC_2H_3O_2(aq) \rightarrow H^+(aq) + C_2H_3O_2^-(aq)$$

Common weak acids: (see Table 5.2)

H_3PO_4	H_2CO_3	CH_3COOH	$H_2C_2O_4$
phosphoric	carbonic	acetic	oxalic

"Strong bases" are strong electrolytes...
...quantitatively yield OH^- & cation when dissolved in water

TWO KINDS:

a) Molecules that quantitatively steal H^+ from water to give OH^- ions ***(not seen in Chem205)***

b) **soluble hydroxide salts**

Sodium hydroxide solution:

$$NaOH(aq) \rightarrow \underbrace{Na^+(aq) + OH^-(aq)}$$

For strong bases: Quantitative yield of ions when dissolved in water.

"Weak bases" are weak electrolytes (partially ionize)

- Small % of weak base molecules REACT with water (steal an H^+):

$$B(aq) + H_2O(\ell) \rightarrow B\text{-}H^+(aq) + OH^-(aq)$$

FOR ANY WEAK BASE "B"
- B reacts to pull H^+ from H_2O
- leaves behind OH^- (H_2O – H^+)
- Low yield of BH^+ & OH^-

RESULT:
- New covalent bond to H^+ (in BH^+)
  - slightly weaker than in H_2O
  - most H^+s stay bonded to H_2O

Aqueous ammonia
some molecules steal an H^+ from H_2O:

$$NH_3(aq) + H_2O(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$$

…process happens to some extent…

Common weak bases: memorize
ammonia (N with 3 Hs) **& "amines"** (N with 3 bonds to…)

Extra help: How to recognize an acid or base…

ACIDS (release H^+)

Formulas beginning with H
HCl HBr HCN

Formulas containing –COOH
CH_3COOH, HCOOH

Nonmetal hydroxides (-OH) & oxides (-O)
HNO_3 H_2SO_4 H_3PO_4

Protonated amines
$^+NH_4$ $^+HN(CH_3)_3$

BASES (pick up H^+)

Anions (**not if H^+ form is a strong acid**)
$NaHCO_3$ $CaCO_3$ Na_2SO_3

Metal hydroxides $M_x(OH)_y$ & oxides $M_x(O)_y$
NaOH $Mg(OH)_2$
CaO

Ammonia & amines
$:NH_3$ $:N(CH_3)_3$

Less obvious cases: *no H or OH in formula…*

Oxides of nonmetals ***vs.*** **Oxides of metals**

"Acidic oxides"
- React with water
- Produce substances that release H^+

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$
carbonic acid

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
sulfuric acid

$NO_2(g) + H_2O(l) \rightarrow HNO_3(aq)$
nitric acid

Acid-rain generators…

"Basic oxides"
- React with water
- Produce substances that release OH^-

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$
"lime" "slaked lime"

5.9 pH: a concentration scale for acids & bases

Acidic solutions:
- Properties due to "dissolved H^+"
- More concentrated acid solution ⇨ higher $[H^+]$

Basic solutions:
- Properties due to OH^- ions
- In water: more OH^- means less H^+ *(quantified soon…)*
- More concentrated base solution ⇨ lower $[H^+]$

In aqueous solutions,
H^+ concentrations are numerically quite small:

$[H^+]$ 10^{-14} M → 1 M
concentrated base *concentrated acid*

$[H^+]$'s are small #s requiring scientific notation…
so we abbreviate it for $[H^+]$'s ⇨ "pH"

MATHEMATICALLY:
- any number can be expressed in "base-10" form
  i.e., any number = 10^x

AS SUCH:
- a number's "logarithm" is the exponent "x" *(power)* needed to do this

The term "pH" derives from "power of hydrogen"

Definitions: $[H^+] = 10^{-pH}$ ➡ $pH = -\log[H^+]$

Concentrated base: $[H^+] = 10^{-14}$ M ➡ pH = 14

Concentrated acid: $[H^+] = 10^0$ M *(= 1 M)* ➡ pH = 0

Why bother?
more convenient to talk using short, +ve numbers…

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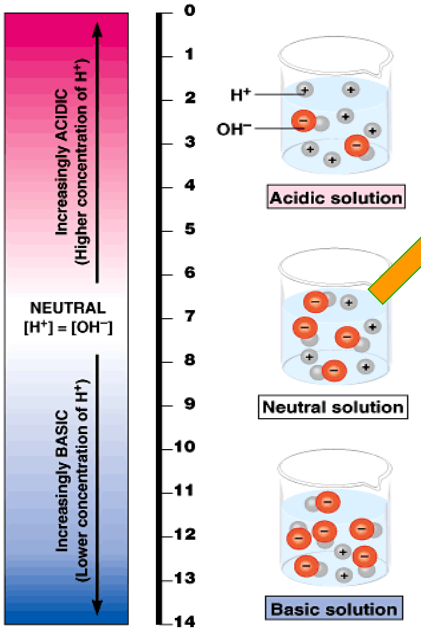
The pH scale

$pH = -\log[H^+]$ $pOH = -\log[OH^-]$



In pure water:

$[H^+] = [OH^-] = 1.0\times10^{-7}$ M

$pH = -\log(1.0\times10^{-7}) = pOH = 7.00$

significant figures

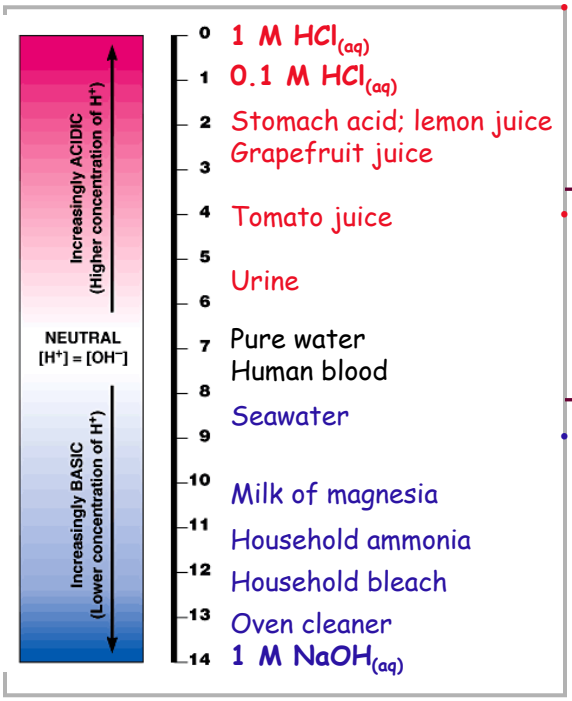
SF in concentration data = # decimal places in pH value

In any aqueous solution:

$pH + pOH = 14.00$

- Remember: $H^+ + OH^- \rightarrow H_2O$
- So: as $[H^+] \uparrow$ due to acid, $[OH^-] \downarrow$
  as $[OH^-] \uparrow$ due to base, $[H^+] \downarrow$

Details in Chem 206…



- For 1.0 M HCl:
  $[H^+] = 1.0$ M
  ⇩
  $pH = -\log(1.0\times10^0)$
  $= 0.00$

- Gastric juices:
  $pH \approx 1.0 \rightarrow 2.5$
  ⇩
  $[H^+] \approx 10^{-2.5} \rightarrow 10^{-1.0}$ M
  $\approx 0.003 \rightarrow 0.1$ M

- For 0.635 M NaOH:
  $[OH^-] = 6.35\times10^{-1}$ M
  ⇩
  $pOH = -\log(6.35\times10^{-1})$
  $= 0.197$
  ⇨ $pH = 14 - 0.197$
  $= 13.803$

So…back to asking questions about REACTIONS…
Reactions between acids & bases?

Q1: WHAT is in the REACTANT SOLUTIONS?

- Solution containing an **acid**:
  H^+ if strong acid *e.g.,* HNO_3
  or H^+ donor if a weak acid *e.g.,* HCOOH

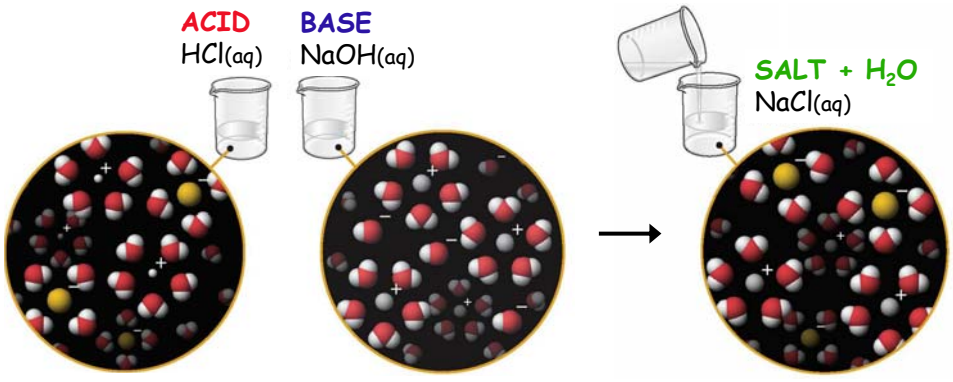
- Solution containing a **base**:
  OH^- if strong base *e.g.,* NaOH
  or other H^+ acceptor if a weak base *e.g.,* NH_3

- AND in each: counter-ions as required to balance charge of H^+ and OH^-

Q2: WHAT HAPPENS when we MIX them?

- an H^+ is transferred from the acid to the base
- new covalent bond formed: between H^+ & the base

Molecular equation $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$



Net ionic equation for any strong acid + strong base: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

A/B rxns: Protons (H^+) transfer from ACID to BASE to yield a salt… but not always water too…

A weak base **A strong acid**

$NH_3(aq) + HCl(aq) \rightarrow ?$

$NH_3(aq) + H^+(aq) + Cl^-(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$

Weak bases take H^+ quantitatively from strong acids

Product has new covalent bond to H^+

NET: $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$ **Net ionic equation**

THUS: $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$ **Molecular equation**

a salt…

Acid-Base Reactions: summary

- A/B rxns sometimes called NEUTRALIZATIONS because the solution is less acidic/basic at the end.
- Proton transferred from acid to base: new bond to H^+…

Is the new bond to H^+ stronger/weaker?

STRONG ACIDS:	WEAK ACIDS:
weak bond to H^+…	strong bond to H^+…

- Rxn will be favoured (lots of product) if new bond is stronger…

- The simplest acid-base reactions yield salt + water:
  e.g., strong acid with strong base

$$HX + MOH \rightarrow MX + H_2O$$

a "salt"

This is another way to make ionic compounds!

M^{n+} comes from the base & X^{n-} comes from the acid

Not all rxns involving acids/bases are "acid-base" rxns (MT F05)

A side reaction in the manufacture of rayon from wood pulp is:

$$3CS_2(aq) + 6NaOH(aq) \rightarrow 2Na_2CS_3(aq) + Na_2CO_3(aq) + 3H_2O(\ell)$$

*Note: **not** a simple H^+-transfer ⇨ **not** an acid-base rxn.*

a) If 92.5 mL of liquid CS_2 (d = 1.26 g/mL) is added to a solution containing 110 g of solid NaOH, and the reaction occurs with 73% yield, what mass of Na_2CS_3 is produced?

Ch.4 material…

Ans: 72 g (2SF)

b) If the pH of the original NaOH solution was 13.87, what was its volume?

Ch.5 material…

Ans: 3.8 L (2SF)

Note: determining the pH of the product mixture, which contains a weak base, CO_3^{2-}, is more complicated… …see Chem 206 for calculating pH of weak acids/bases.

ASSIGNED READINGS

- **BEFORE NEXT CLASS: (Feb.26th)**

  Read rest of Ch.5
  & work on exercises from Ch.4-5

- **Practice** identifying acids & bases
  writing equations for A/B reactions
  sol'n stoichiometry problems (5.10)…