E4 Acids, Bases, and Salts

Session One of two session lab

- **Complete Parts 1 and 2 in lab. If time allows, start or complete Part 3.**

Reminder:

Pre-lab report, page 112, due at start of lab.

Acids and Bases

Q. Are acid-base properties of substances predictable based on their chemical composition?

Common consumer products

Household acids

Household bases

Part 1. Structure and Acid-Base Properties

Information

- **Acids and Bases *usually* contain O, H, and another element (X).**
- **Teams will be provided with compounds labeled with the formula $X_cO_aH_b$**

  (X= some element; a, b, and c = some number)

Lab

- **Determine if compounds labeled with the formula $X_cO_aH_b$ are acids or bases by measuring the pH**

$X_cO_aH_b$ compounds and Acid-Base formulas

- The formulas for acids are written in the form $H_bX_cO_a$.

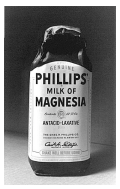
H_2CO_3 (carbonic acid)

H_3PO_4 (phosphoric acid)

$X_cO_aH_b$ compounds and Acid-Base formulas

- The formulas for bases are written in the form $X_c(OH)_n$.

NaOH



$Mg(OH)_2$

$Ca(OH)_2$

NH_4OH

$X_cO_aH_b$ compounds and Acid-Base formulas

Q. Acid and base compounds typically contain oxygen, hydrogen, and another element (X). Based on formulas of common acids and bases, what distinguishes acids from bases with regard to element X?

Common acids: H_2CO_3, H_3PO_4, HClO, HNO_3
Common bases: NaOH, $Mg(OH)_2$, $Ca(OH)_2$, NH_4OH

Answer: _____

Part 1 Objectives

- **Based on pH data and the chemical composition of tested compounds, determine if acid-base properties can be predicted from:**
  - **the number of oxygen and/or hydrogen atoms in $X_cO_aH_b$ compounds?**
  - **the electronegativity of element X?**

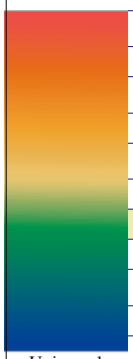
Disccussion questions 1-3, page 125

pH measurement

pH paper

DEMO

pH meter



pH
1
2
3
4
5
6
7
8
9
10
↓↑
14

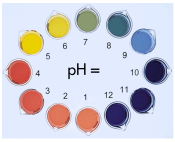
Universal indicator

- **ACID = pH < 7**
- **BASE = pH > 7**

Universal Indicator Demo

- Dry ice is added to water that contains a few drops of universal indicator to produce carbonic acid

Dry ice = $CO_2(s)$



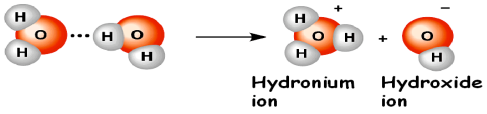
Universal indicator

H_2O (l)	+	CO_2 (s)	→	H_2CO_3 (aq)
Water		dry ice		carbonic acid

- Universal indicator changes colors when pH changes; as the solution becomes more acidic, the pH drops

pH scale? Why?

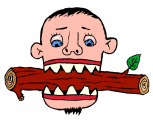
- **On average, at 25°C, only 1 in 10,000,000 H_2O molecules ionize:**



$$\frac{1}{10{,}000{,}000} = 1 \times 10^{-7}\ M$$

pH

$$pH = -\log [H_3O^+]$$



Example:

$pH\ 7 = -\log [\ 1 \times 10^{-7}]$

- **$[H_3O^+]$ = mole/liter units**
- **pH values are unitless**

pH and $[H_3O^+]$

- **DIGIT/S LEFT of the pH decimal point = POWER of TEN by which the hydronium concentration value is multiplied.**

  If pH = 3.27, $[H_3O^+]$ = [?] x 10^{-3}

$[H_3O^+]$	pH
10^{-1}	1
10^{-2}	2
10^{-3}	3
10^{-4}	4
10^{-5}	5
10^{-6}	6
10^{-7}	7
10^{-8}	8
10^{-9}	9
10^{-10}	10
↓↑	↓↑
10^{-14}	14

- **Δ pH = 1 reflects a ten fold change in $[H_3O^+]$; Δ pH = 2 reflects a hundred fold change in $[H_3O^+]$, etc.**
- **As $[H_3O^+]$ increases, pH decreases:**

$[H_3O^+]$  pH

$[H_3O^+]$	pH
10^{-1}	1
10^{-2}	2
10^{-3}	3
10^{-4}	4
10^{-5}	5
10^{-6}	6
10^{-7}	7
10^{-8}	8
10^{-9}	9
10^{-10}	10
↓↑	↓↑
10^{-14}	14

Check pH data for errors

Q. Your teammate indicates that 0.001 M HNO_3 = pH 2.0. You correctly respond, *"your pH reading must be wrong!"* Why?

Assume the acid ionizes completely:

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$

0.001 M 0.001 M 0.001 M

$[H_3O^+]$	pH	$[OH^-]$
10^{-1}	1	10^{-13}
10^{-2}	2	10^{-12}
10^{-3}	3	10^{-11}
10^{-4}	4	10^{-10}
10^{-5}	5	10^{-9}
10^{-6}	6	10^{-8}
10^{-7}	7	10^{-7}
10^{-8}	8	10^{-6}
10^{-9}	9	10^{-5}
10^{-10}	10	10^{-4}
↓↑	↓↑	↓↑
10^{-14}	14	10^{-0}

$K_w = [H_3O^+]\,[OH^-]$
$= 1.0 \times 10^{-14}$

Q. A sample of 0.1 M NH_3 has a pH = 11.0. What is $[OH^-]$?

Answer: _____

Bronsted Acids and Bases

- An acid is a proton (H^+) donor - forms hydronium ions.

Acid Base

- A base is a proton (H^+) acceptor - forms hydroxide ions.

Acid Base

Acid-Base Ionization and Concentration

- Acid-base ionization is solvent and concentration dependent.

base + water ⟷ cation + OH^-

DEMO: Addition of water to glacial acetic acid

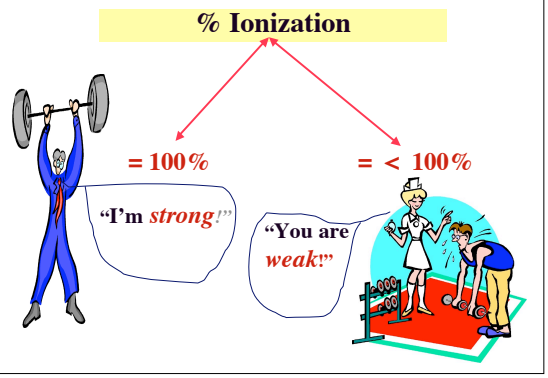
$[H_3O^+]$	pH
10^{-1}	1
10^{-2}	2
10^{-3}	3
10^{-4}	4
10^{-5}	5
10^{-6}	6
10^{-7}	7
10^{-8}	8
10^{-9}	9
10^{-10}	10
↓↑	↓↑
10^{-14}	14

Acid Strength and pH

- Stronger acids donate protons/ionize to a greater extent than weak acids.
- Stronger acids exhibit a lower pH than equimolar concentrations of weaker acids.

DEMO:
pH of 0.10 M H_3BO_3 versus 0.10 M $HClO_4$

Acid-Base Strength and % Ionization



Acid-Base Strength and % Ionization

$$\% \text{ ionization acid} = \frac{[H_3O^+]_i}{[\text{acid}]_i} \times 100\%$$

$$\% \text{ ionization base} = \frac{[OH^-]_i}{[\text{base}]_i} \times 100\%$$

Value in numerator determined from pH

Q. 0.001 M $HClO_4$ = pH 3.0; 0.010 M H_2CO_3 = pH 3.0

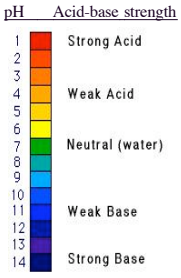
1. Calculate the % ionization of $HClO_4$ and H_2CO_3.
2. Indicate if the acids are strong or weak.

% ionization $HClO_4$

% ionization H_2CO_3

Strength: _____

Q. The textbook figure below depicting pH and acid-base strength is misleading. How?

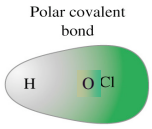


Acid-Base Strength and Structure

- **Acid-base strength is dependent on structure.**
- **If H in a compound is a bare proton it will be an electron pair seeker and readily bond to water molecules to form $[H_3O]^+$**

Example

H is a bare proton when bonded to an O atom, which in turn is attached to highly electronegative Cl in HClO



- **Bond polarity is a dominant factor in determining relative strength of the oxyacids.**

Electronegativity of X vs. pH of $X_cO_aH_b$ compounds

Electronegativity of the elements*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIIIB		IB	IIB	IIIA	IVA	VA	VIA	VIIA
H 2.1																
Li **1.0**	Be 1.5															
Na **0.9**	**Mg** **1.2**															
K **0.8**	**Ca** **1.0**	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	**Se** **2.4**	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	-Lu 1.3	Hf 1.5	Ta 1.7	W 1.9	Re 2.2	Os 2.2	Ir 2.2	Pt 2.4	Au 1.9	Hg 1.8	Tl 1.8	Pb 1.9	Bi 2.0	Po 2.2	At
Fr 0.7	Ra 0.9	Ac 1.1	Th 1.3	Pa 1.5	U 1.7	Np-	No 1.3									

B **2.0**	**C** **2.5**	**N** **3.0**
Al 1.5	Si 1.8	**P** **2.1**
		S **2.5**
		Cl **3.0**

Q. Based strictly on electronegativity values, predict the acid strength of HBrO versus HIO.

Answer: _____>_____

= Metalloids = Nonmetals = Metals

Acid strength and structure

Q. The electronegativity of N = 3.0 and C = 2.5. Predict the comparative rate of reaction of 5 M HNO_3 and 5 M $HC_2H_3O_2$ with zinc:

$$Zn_{(s)} + 2H^+_{(aq)} = Zn^{2+}_{(aq)} + H_{2(g)}$$

Rate:_____>_____

DEMO

Acid Strength

Part 2. Conjugate Acid-Base Pairs

Lab

- **Determine and compare the pH of conjugate acids and bases.**

Information

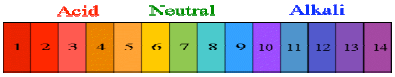
- **Conjugate acids and bases differ by one proton.**
  - *Conjugate acid of HCO_3^- is H_2CO_3*
  - *Conjugate base of HCO_3^- is CO_3^{2-}*
- **Teams will be provided with 0.10 M acids; conjugate bases will be provided as 0.10 M sodium salts**

Conjugate Acid-Base Pairs

- **Exhibit predictable pH relationships**

pH $H_2CO_3(aq)$ versus $HCO_3^-(aq)$ versus $CO_3^{2-}(aq)$?

DEMO

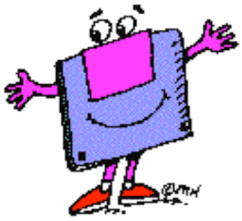


Indicator pH scale

Conjugate Acid-Base Pairs

pH $H_2CO_3(aq)$ versus $HCO_3^-(aq)$ versus $CO_3^{2-}(aq)$

pH _____(increase or decrease) ?



Any Questions?
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