EXPERIMENT 5

ACIDS, BASES AND SALTS
(الأحماض والقواعد والأملاح)

BY

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Purposes:

1) To become familiar with the chemical properties of acids, bases, and salts
2) To estimate the pH of household preparations and laboratory common acids, bases, and salts
3) To write equations that account for observations from chemical reactions

Some Definitions

- Arrhenius acids and bases
  - Acid: Substance that, when dissolved in water, increases the concentration of hydrogen/hydronium ions (protons, H^+ or H_3O^+).

$$HCl\,(aq) \leftrightarrows H^+(aq) + Cl^-(aq)$$

  - Base: Substance that, when dissolved in water, increases the concentration of hydroxide ions, OH^-.

$$NaOH\,(aq) \leftrightarrows Na^+(aq) + OH^-(aq)$$

- **Brønsted–Lowry**: must have *both*

Brønsted-Lowry acids and bases are always paired.

1. **An Acid: proton donor**

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

and

2. **a Base: proton acceptor** (...must have a pair of nonbonding electrons)

Which is the acid and which is the base in each of these rxns?

$$HCl + H_2O \rightleftharpoons [Cl^- \cdots H^+ \cdots H_2O] \rightleftharpoons H_3O^+ + Cl^-$$

$$NH_3 + H_2O \rightleftharpoons [NH_3 \cdots H^+ \cdots OH^-] \rightleftharpoons NH_4^+ + OH^-$$

Properties of Acidic solutions

An Acid is a substance that produces hydrogen ions (H^+ or Hydronium ion, H_3O^+) in H_2O; pH < 7

1) Taste sour or tart (طعم حامض أو لاذع)
2) Cause a pricking sensation (الإحساس بالوخز) on the skin
3) Turn blue litmus (vegetable dye) red
4) React with several metals (e.g., Zn and Mg) releasing $H_{2(g)}$ $\Rightarrow$ acids corrode metals.
5) Corrosive: burn your skin (مادة أكالة: تحرق بشرتك)
6) react with base to form salt and water ($HCl + NaOH \rightarrow NaCl + H_2O$)
7) Act as electrolytes in solution ➡ conduct electricity
8) React with carbonates releasing $CO_{2(g)}$

- Most of the foods and drinks are acidic,

Example: think of lemon juice as being quite acidic to taste but milk not quite so (slightly acidic)

Types of acids

1) **Nonoxidixing acids such as HCl [26], acetic acid [35] and H_3PO_4 [7]**

Example: $HCl(aq) + Zn(s) \rightarrow H_2(g) + ZnCl_2(aq)$

2) **Oxidizing acids: these are concentrated and strong acids**

- **dilute HNO_3[13] and H_2SO_4[1] (oil of vitriol (زيت الزاج), ranked no 1 in usage), generate hydronium ions in water.**

For conc HNO_3(aq), $Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2$(aq, blue) + $2NO_2$(g, red-brown gas) + $2H_2O$

- **Concentrated HNO_3[13] and H_2SO_4[1] are of excellent oxidizing properties**

Acidic aqueous solutions result from the reaction of a

1-Nometallic hydride with water

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

2-Nometallic oxide with water

$SO_3(g) + 2H_2O \rightarrow H_3O^+(aq) + HSO_4^-(aq)$

$CO_2(g) + 2H_2O \rightarrow H_3O^+(aq) + HCO_3^-\,(aq)$

3- molecular species with water such as citric acid, ascorbic acid (vitamin C) and acetic acid found in vinegar,

$CH_3COOH(aq) + H_2O \rightarrow H_3O^+(aq) + CH_3COO^-(aq)$

Acids you must know:

Common Strong Acids:

100% dissociation in water, good proton donors

- Sulfuric acid, H_2SO_4
- Hydrochloric acid, HCl
- Nitric acid, HNO_3
- Perchloric acid, $HClO_4$

Common Weak Acids:

< 5% dissociation in water, poor proton donors

- Phosphoric acid, H_3PO_4
- Acetic acid, $HC_2H_3O_2$
- Citric acid, $C_6H_8O_7$

Uses of acids

- H_3PO_4 - soft drinks, fertilizer, detergents
- H_2SO_4 - fertilizer, car batteries
- HCl - gastric juice, Stomach acid
- $HC_2H_3O_2$ - vinegar

Properties of Bases

Produce or cause an increase in hydroxide ions (OH^-) in H_2O, pH > 7

- ❖ Taste bitter (طعم مر)
- ❖ Have a slippery touch (ملمس انزلاقي), 'soapy' feel
- ❖ Turn red litmus blue
- ❖ Destroy body tissue/ dissolve fatty (lipid) material
- ❖ Strong bases are caustic (كاوية)
- ❖ Act as electrolytes in solution
- ❖ Neutralise solutions containing hydrogen ions (H^+)

- ➢ Most of hand soaps, detegents and drain cleaners are bases

Properties of Acids and Bases

- **Acids**
  - turn blue litmus red
  - taste sour
  - Acids corrode metals
  - positively charged hydrogen ions (H^+)
- **Bases**
  - turn red litmus blue
  - taste bitter
  - Negatively charged hydroxide ions (OH^-)
  - Feel slippery
  - Most hand soaps and drain cleaners are bases
  - Strong bases are caustic

Basic aqueous solutions can result from

1- action of water on a soluble oxides (e.g., CaO) or hydroxides (e.g., NaOH)

O^{2-}(aq, from CaO) + H_2O → $2OH^-$(aq)

2-Anion that reacts with water

CO_3^{2-}(aq, from Na_2CO_3) + H_2O → HCO_3^-(aq) + OH^-(aq)

3- molecular species that reacts with water

NH_3(aq) + H_2O → OH^-(aq) + NH_4^+(aq)

Uses of bases

- NaOH [8] – lye (غسول), drain and oven cleaner, preparation of soaps and detergents

- $Mg(OH)_2$ - laxative, antacid,

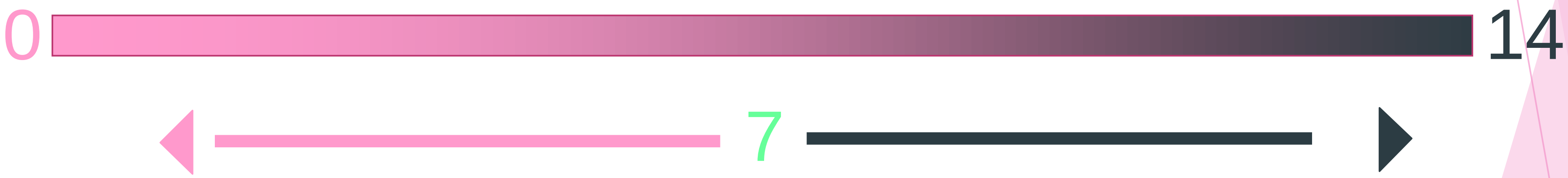
clinical applications ***of*** **Antacids: to** neutralize excess stomach acid

$$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$$

- NH_3 [5] - cleaners, fertilizer

pH Scale

- **pH**
  - a measure of the concentration of H_3O^+ ions in solution
  - measured with a pH meter or an indicator with a wide color range
  - $pH = -\log [H^+] = -\log [H_3O^+]$



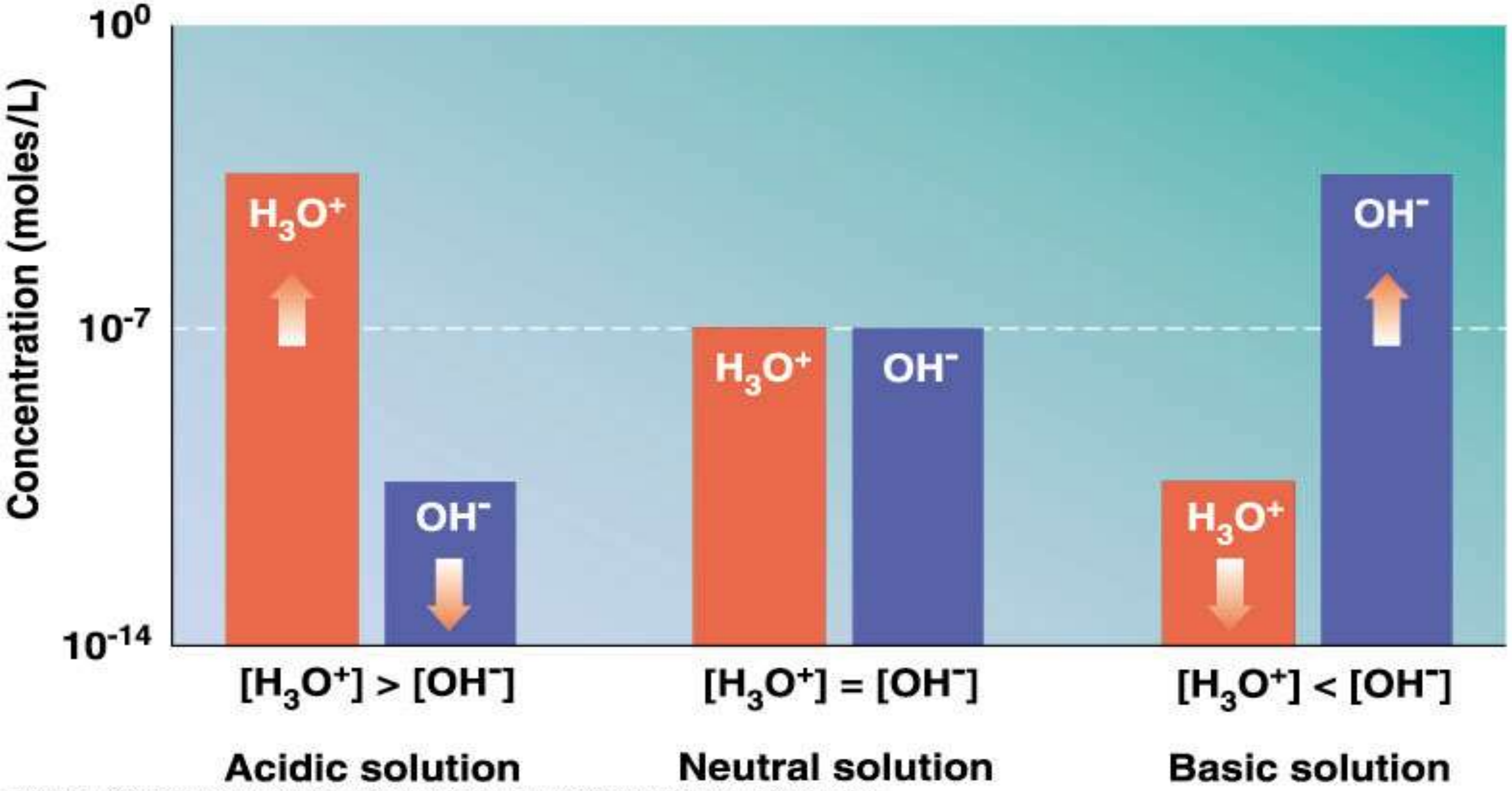
INCREASING ACIDITY

NEUTRAL

INCREASING BASICITY

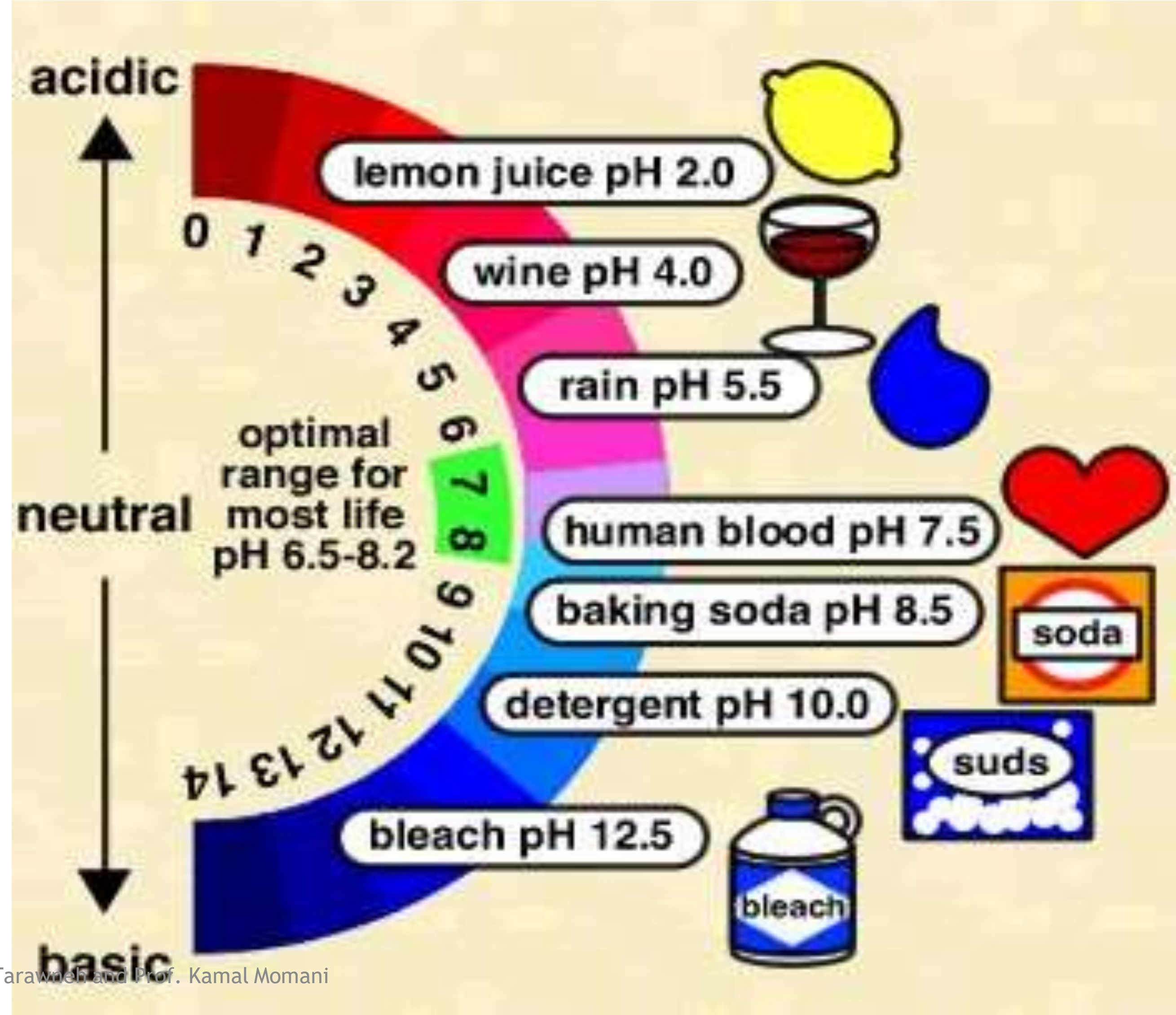
Lower pH value indicates a stronger acid.

Higher pH value indicates a stronger base.



10^0
10^{-7}
10^{-14}
Concentration (moles/L)
H_3O^+
OH^-
H_3O^+
OH^-
H_3O^+
OH^-
$[H_3O^+] > [OH^-]$
$[H_3O^+] = [OH^-]$
$[H_3O^+] < [OH^-]$
Acidic solution
Neutral solution
Basic solution

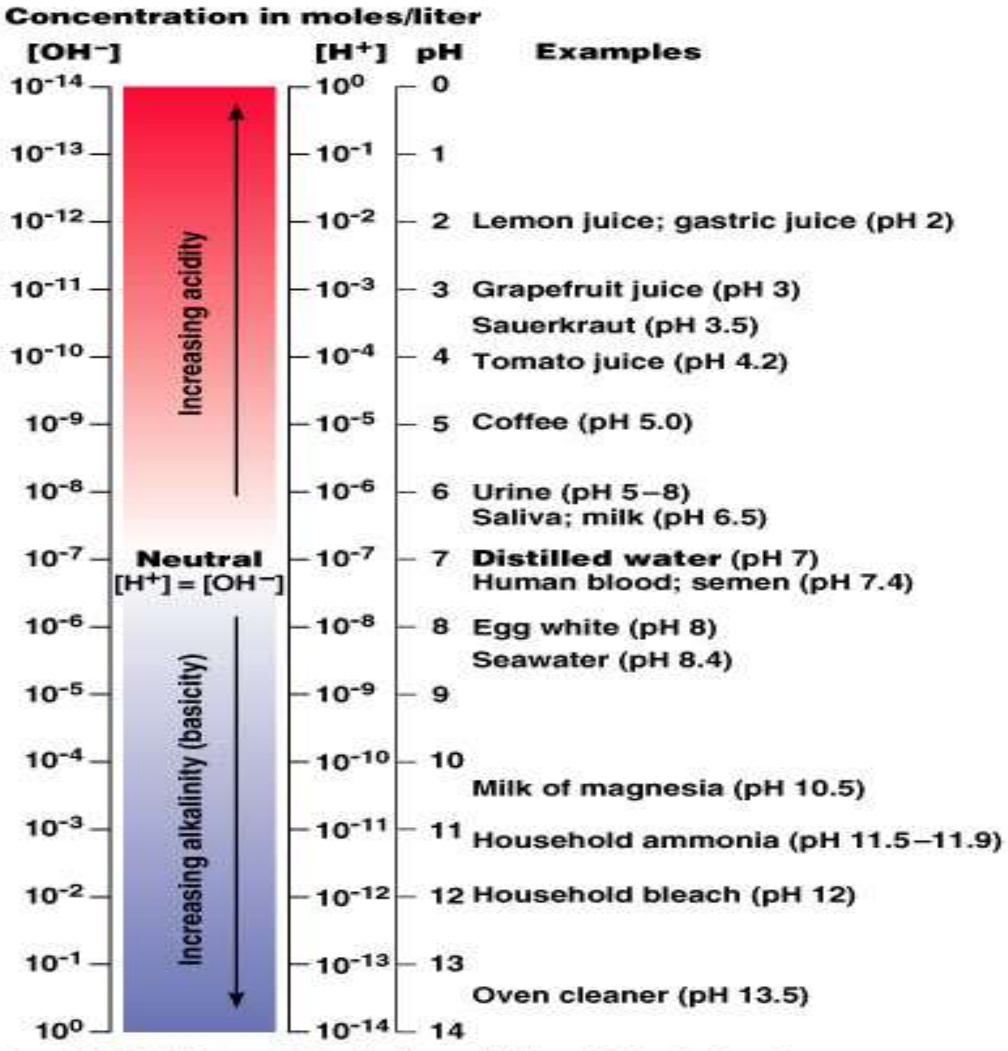
pH of Common Substances



Acids Have a pH less than 7

Bases have a pH greater than 7

pH of Common Substances



Estimation the pH of aqueous solutions

- **Acid-base indicators: organic compounds whose color depends on the pH of the solution**
  - Litmus paper: RED in an acidic solution and BLUE in a basic solution
  - Universal indicator or color plate (دليل عام أو شريحة الالوان): a mixture of acid-base indicators that can be used to approximate the pH of the solutions
  - Phenolphthalein (phph): colorless (in acidic solution) to pink (in basic soln)
- **pH meter:** give a precise value of pH

Solutions of salts as acids or bases

- Neutral salts: $NaCl$ and Na_2SO_4

- Acidic salts: $FeCl_3$, $AlCl_3$ and NH_4Cl

- Basic salts: $CaCO_3$, Na_2CO_3 and Na_3PO_4

❑ Reactions of acids with metals

Acids take part in reactions in which salts are produced. In these reactions, the hydrogen ions in the acids are replaced by metal ions.

K	Potassium	most reactive ↑
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
Al	Aluminium	
C	*Carbon*	
Zn	Zinc	
Fe	Iron	
Sn	Tin	
Pb	Lead	
H	*Hydrogen*	
Cu	Copper	
Ag	Silver	
Au	Gold	
Pt	Platinum	least reactive ↓

(added for comparison)

When acids react with metals, the products are a salt and hydrogen. In general:

Acid + metal → salt + hydrogen

For example:

$$2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$$

Zn and Fe also react with hydrochloric acid.

Mg, Zn and Fe also react with sulfuric acid. The products are a salt and hydrogen gas. For example:

$$H_2SO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + H_2(g)$$

Reactivity of Metals with HCl and acetic acid

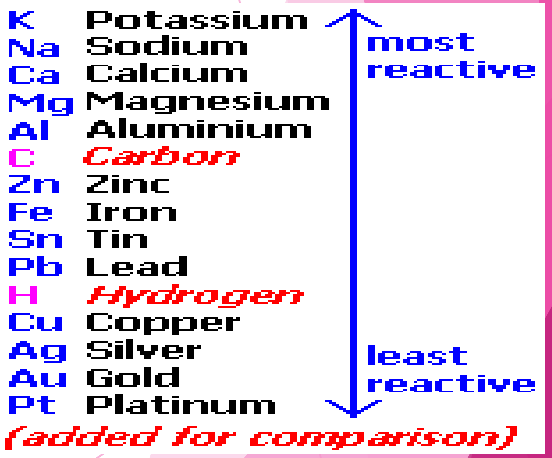
https://www.youtube.com/watch?v=Na_6j9y9ke8

https://www.youtube.com/watch?v=OQDnJZGHWNw

Copper is a very unreactive metal, and it **does** not **react with hydrochloric acid**. It is above **copper** in a metal reactivity series, so **copper** cannot replace the hydrogen in **HCl** to form $CuCl_2$.

❑ Categorizing the metals according to their reactivity:

- ✓ Very rapid reaction: K, Na
- ✓ Rapid reaction: Ca, Mg
- ✓ Slow reaction: Al, Zn, Fe, Sn
- ✓ No reaction: Pb, Cu, Ag, Au



Experimental Procedure

- *-The chemical properties of a range of acids, bases, and salts are observed.*
- *- Write ionic and net ionic Chemical equations to account for the observations.*
- *-The pH of selected acids, bases, and salts are estimated with pH test paper or universal indicator.*
- *-Perform the experiment and record your observation on the Report Sheet.*

Caution:

- Be very careful in handling dilute and concentrated acids and bases ⇒ cause severe skin burns and irritation to mucous membranes (الأغشية المخاطية).
- Clean up acid and base spills directly with excess water, and baking soda, $NaHCO_3$.
- Refer to the Laboratory Safety section at the beginning of this manual.

Action of Acids on Metals

- -Place a small (1 cm) polished strip of Mg, Zn, and Cu into separate small clean test tubes. To each test tube, add just enough 6 *M* HCl to submerge the metal and observe for several minutes. Record your observations on the Report Sheet.

- -Repeat the test of the three metals with 6 *M* HNO_3 and then again with 6 *M* CH_3COOH.

- Relative reactivity of metals with acids:

	Mg	Zn	Cu
6 *M* HCl	Fast	Medium	NR
6 *M* HNO_3	Fast	Slow	Very slow
6 *M* CH_3COOH	slow	slow	NR

Effect of Acid Concentration on Reaction Rate

- Set up 6 small clean test tubes having about 1.5 mL of the acid solutions shown in the following Figure. Add a small (1 cm) polished strip of Mg to each solution and Explain your observations.

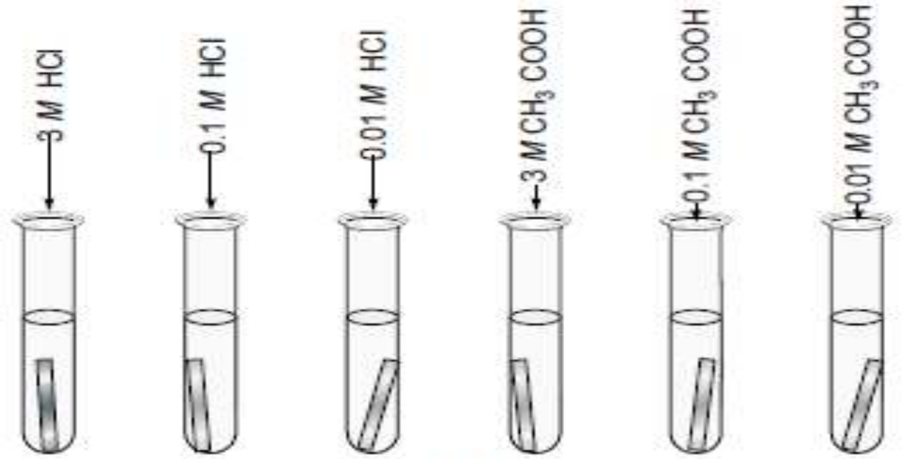


Figure 6.7 A setup for testing the effect of different acids and acid strengths on their reactivity with a metal.

- The reaction rate is greatest with 3 M HCl and lowest with 0.10 M HCl.
- The reaction of the Mg in the HCl solutions (strong acid) is more rapid than in acetic acid (weak acid) solutions of like concentrations.

Oxidizing strength of acids

Observe the color change, if any occur, for the reactions of the following acids with NaI.

- Test tube 1. conc H_2SO_4 + I^- → I_2 (**violet**)+ $H_2S(g)$ + H_2O

- Test tube 2. conc H_3PO_4 + I^- → **???**

3NaI + conc H_3PO_4 ⟶ **3**HI + Na_3PO_4

- -Hold moistened blue litmus paper over each test tube to test for any escaping gases.
- -compare the relative oxidizing strength of these 2 acids

Dehydrating effect of concentrated (conc) acid

- Few drops of conc H_2SO_4 + small amount of sugar

$\rightarrow$ C (blackened charred,أسود متفحم) + H_2O

$\Rightarrow$ Conc H_2SO_4 is a strong dehydrating and oxidizing agent

$$\overbrace{C_{12}H_{22}O_{11}}^{\text{sucrose}} \xrightarrow[\text{(sulfuric acid)}]{H_2SO_4} \underset{\text{(black graphitic foam)}}{12\,C} + 11\,H_2O(g,l)$$

❖ Neutralizing NaOH solution with acid

$NaOH$ (strong base, aq) + HCl (strong acid, aq) $\rightarrow$ $NaCl + H_2O$
Blue litmus paper red litmus paper

❖ Slaking Of Quicklime (اطفاء الجير الحي)

$CaO(s) + H_2O \rightarrow Ca(OH)_2$

Quick lime — slaked lime (جير المطفأ),
A basic oxide — a base

A saturated solution of calcium hydroxide is called lime water, turn red litmus paper blue

AMMONIA GAS

❑ Production of ammonia

$$Ca(OH)_2 \text{ (thin paste)} + 2NH_4Cl \rightarrow 2NH_3(g) + CaCl_2(aq) + 2H_2O$$

NH_3 is a colorless gas with a very pungent (strong) odor

❑ Test for the flammability of ammonia

$$NH_3(g) + O_2 \rightarrow N_2(g) + H_2O$$

❑ Test for the solubility of ammonia

$$NH_3(g) + H_2O \leftrightarrows OH\text{-}(aq) + NH_4^+(aq)\text{, basic solution}$$

Ammonia gas is a weak base, which is soluble in water, and turns phenolphthalein pink

pH Measurements: Measure the pH of the following solutions by using the universal indicator, record the approximate pH and write balance equation.

1) **pH of water: tap water, boiled deionized water**
2) **Common solutions and salts**
    - 0.10 M and 0.000010 M HCl
    - 0.10 M NaCl (table salt)
    - Vinegar
    - Lemon juice
    - Pepsi cola
    - Household ammonia
    - Detergent solution
    - 0.10 M NaOH
    - 0.10 M Na_2CO_3
    - 0.10 M Na_3PO_4

Review questions

1. List the properties of acids & bases.
2. Discuss the pH scale:
   - ❖ Define the ion product of water and indicate how this is determines the pH scale.
   - ❖ Use the pH scale to determine if a given solution is acidic, neutral or basic.
3. Distinguish between strong acids & weak acids: List clinical uses of these acids & write equations for their dissociation in water
4. Distinguish between strong & weak bases; List clinical uses of these bases & write equations for their dissociation in water.
5. Complete simple equations for the neutralization reaction of an acid & a base; Discuss clinical applications of acid-base neutralization.

***Prelaboratory Assignment:* Acids, Bases, and Salts**

1. In an aqueous solution,
a. name and write the formula of the ion that makes a solution acidic.
b. name and write the formula of the ion that makes a solution basic.
2. a. Muriatic acid is used to adjust the pH of swimming pools. What is the formula of muriatic acid? Does the pH of the swimming pool increase or decrease as a result of adding muriatic acid? Explain.
b. Battery acid is a rather concentrated solution of sulfuric acid. What is the formula of sulfuric acid?
3. Aqueous salt solutions often are *not* neutral with respect to pH. Explain.
4. a. Milk of magnesia is used as a laxative and to treat upset stomachs. What is the formula of milk of magnesia?
b. Washing soda is often added to detergent formulations to make the wash water more basic. What is the formula of the anhydrous form of washing soda? Does it increase or decrease the pH of the wash water? Explain.

5. Three solutions have the following pH:

• Solution 1: pH 7.4,

Solution 2: pH 10.6,

Solution 3: pH 3.7

a. Which solution contains the highest H_3O^+ ion concentration? ________________________

b. Which solution is the most acidic? ________________________

c. Which solution is the most basic? ________________________

6. Metallic ions with a higher positive charge are more strongly hydrated and tend to be more acidic in solution. Comparing a 0.12 *M* $FeCl_3$ solution to a 0.12 *M* $FeCl_2$ solution, which solution would have a lower pH? Explain.

e. What spectator ions remain in solution in the reaction mixture?

f. Write the **net ionic** reaction that accounts for the appearance of the precipitate.

Post-laboratory Questions

1. Part A.1. The observation for the reaction of 6 *M* HCl was obviously different from that of 6 *M* CH_3COOH. What were the contrasting observations? How do the two acids differ? Explain.
2. Part A.2. As the molar concentration of an acid decreases, the reaction rate with an active metal, such as magnesium, is expected to ___________. Explain.
3. Part B.1. 6 *M* H_2SO_4 is carelessly substituted for 6 *M* HCl. Will more or fewer drops of 6 *M* H_2SO_4 be required for the litmus to change color? Explain.
4. Part B.1. Write a net ionic equation for the reaction of hydrochloric acid with sodium hydroxide.
5. Part B.3. Sodium carbonate dissolved in water produces a basic solution. Water-soluble potassium phosphate, K_3PO_4, also produces a basic solution. Write an equation that accounts for the basicity of K_3PO_4.
*__6.__ Part B.3. The setting of mortar is a time-consuming process that involves a chemical reaction of quicklime, CaO, with the carbon dioxide and water of the atmosphere, forming $CaCO_3$ and $Ca(OH)_2$ respectively. Write the two balanced equations that represent the setting of mortar.
7. Part C.1. The unboiled, deionized water has a measured pH less than 7. Explain.