Aqueous Reactions
(Solutions/ Molarity)

Electrolytes/ Acids & Bases and Solution Calculations

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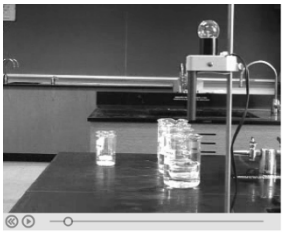
Electrolytes
Ions in an aqueous (water) solution

- **Pure Water** does not conduct electricity.
- A water solution must have **ions** to conduct electricity.
- Aqueous solutions can be categorized into 3 types: non-electrolytes, strong electrolytes or weak electrolytes based on their ability to conduct electricity in a homogeneous aqueous solution (aq).
- Aqueous solutions can be tested for conductivity which will determine the degree of ionization of the solute, that is, the substance dissolved in water.
- It is possible to have full or partial ionization.

Conductivity

Conductivity



http://chemconnections.org/general/movies/html-swf/electrolytes.htm

Molarity (M) = moles solute / Liter solution

Electrolytes

- Almost all ionic compounds and a few molecular compounds are strong electrolytes.
- Several molecular compounds are weak conductors, most are non-conductors.
- Conductivity is directly related to the amount of ionization, i.e. ions in solution. Table salt, sodium chloride, is completely ionized:

$NaCl_{(s)} + H_2O_{(l)} \longrightarrow NaCl_{(aq)} \longrightarrow$
0.10M
$Na^+_{(aq)} + Cl^-_{(aq)}$
0.10M 0.10M

Add 5.8g of sodium chloride to water to make 1.0 L of solution = 0.10M = 0.10 mol/L

All of the sodium chloride ionizes to make 1.0 L of solution = 0.10M Na^+ and 0.10M Cl^-

Molarity (M) = moles solute / Liter solution

Electrolytes

- Concentrations:
- $CaCl_{2\,(s)} + H_2O_{(l)} \longrightarrow CaCl_{2(aq)} \longrightarrow$ 0.10M
  $Ca^{2+}_{(aq)} + 2\,Cl^-_{(aq)}$
  0.10M 0.20M

How many grams of calcium chloride (MM =111 g/mol) should be added to water to make 1.00 L of a 0.10M solution of calcium chloride?

All of the calium chloride ionizes to make 1.0 L of solution = 0.10M Ca^{2+} and 0.20M Cl^-

11.1 g $CaCl_{2\,(s)}$ (0.100 mol)

Molarity (M) = moles solute / Liter solution

Electrolytes

- Sugars like sucrose are non-ionic, molecular compounds that dissolve but produce no ions.

$C_{12}H_{22}O_{11\,(S)} + H_2O_{(l)} \longrightarrow C_{12}H_{22}O_{11\,(aq)}$

- Some molecular compounds like acetic acid ionize partially (dissociate) in water

$HC_2H_3O_{2\,(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$

0.1000M

0.09987M ⇌ 0.00013M

Acetic Acid ($HC_2H_3O_2$)

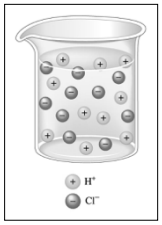
NOT Completely Ionized

Example of equilibrium

Conductivity

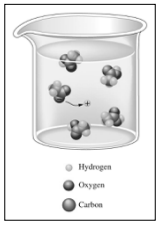
Which of these solutions will have highest conductivity?

A	B	C
0.1 M $KCl_{(aq)}$	0.2 M $HCl_{(aq)}$	0.3M x 0.013% 0.3 M $HC_2H_3O_{2(aq)}$



100%

HCl Completely Ionized



0.013%

Acetic Acid ($HC_2H_3O_2$)

Conductivity

Which of these solutions will have highest conductivity?

A	B	C
0.1 M $HCl_{(aq)}$	0.1 M $CaCl_{2\,(aq)}$	0.2M x 0.013% 0.2 M $HC_2H_3O_{2(aq)}$

Aqueous Acids

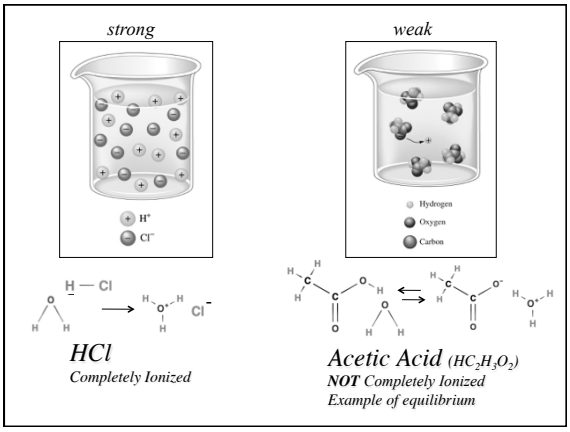
- Any compound that provides a proton can be considered an acid. Strong acids are sulfuric acid, nitric acid, perchloric acid, HI, HBr and HCl.

Introduction to Aqueous Acids

Electrolytes

- How would the conductivity of acetic acid compare to hydrochloric acid?

Strong and Weak Electrolytes



HCl
Completely Ionized

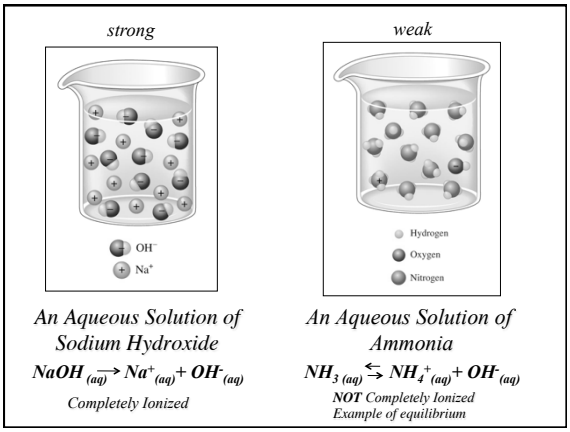
Acetic Acid ($HC_2H_3O_2$)
NOT *Completely Ionized*
Example of equilibrium

Aqueous Bases

- *Any compound that accepts a proton is a base.*
- *The common bases are group IA & IIA metal hydroxide compounds. They are strong bases, dissociating completely in water.*
- *An example of a weak base is ammonia.*

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

Consider that aqueous ammonia is in equilibrium with ammonium hydroxide. The names have often been used interchangeably.



An Aqueous Solution of Sodium Hydroxide

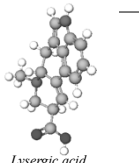
$$NaOH_{(aq)} \longrightarrow Na^+{}_{(aq)} + OH^-{}_{(aq)}$$

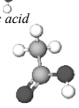
Completely Ionized

An Aqueous Solution of Ammonia

$$NH_{3\,(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

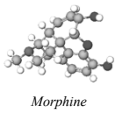
NOT *Completely Ionized*
Example of equilibrium

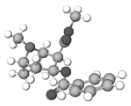

Lysergic acid

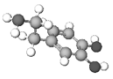

Acetic acid

Selected Acids and Bases

Acids
Strong
Hydrochloric acid, HCl
Hydrobromic acid, HBr
Hydriodic acid, HI
Nitric acid, HNO_3
Sulfuric acid, H_2SO_4
Perchloric acid, $HClO_4$
Weak
Hydrofluoric acid, HF
Phosphoric acid, H_3PO_4
Acetic acid, CH_3COOH (or $HC_2H_3O_2$)
Bases
Strong
Sodium hydroxide, NaOH
Potassium hydroxide, KOH
Calcium hydroxide, $Ca(OH)_2$
Strontium hydroxide, $Sr(OH)_2$
Barium hydroxide, $Ba(OH)_2$
Weak
Ammonia, NH_3


Morphine


Cocaine


Dopamine

QUESTION

All of the following are weak acids *except*:

A) HCNO.
B) HBr.
C) HF.
D) HNO_2.
E) HCN.

Selected Acids and Bases

Acids
Strong
Hydrochloric acid, HCl
Hydrobromic acid, HBr
Hydriodic acid, HI
Nitric acid, HNO_3
Sulfuric acid, H_2SO_4
Perchloric acid, $HClO_4$
Weak
Hydrofluoric acid, HF
Phosphoric acid, H_3PO_4
Acetic acid, CH_3COOH (or $HC_2H_3O_2$)
Bases
Strong
Sodium hydroxide, NaOH
Potassium hydroxide, KOH
Calcium hydroxide, $Ca(OH)_2$
Strontium hydroxide, $Sr(OH)_2$
Barium hydroxide, $Ba(OH)_2$
Weak
Ammonia, NH_3

ANSWER

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D) HNO_2.
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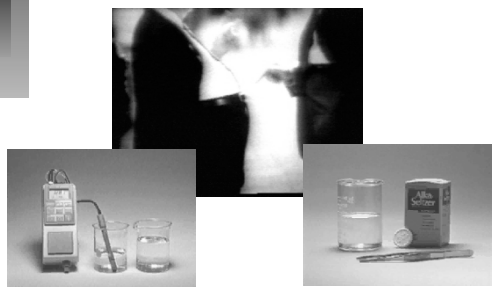
Aqueous Reactions: Acid-Base



QUESTION

If an antacid contains $Al(OH)_3$ it will form $AlCl_3$ upon neutralization of stomach acid. How many moles of Cl^- ions are in 100.0 mL of 0.010 M $AlCl_3$?

A.0.0010 mol
B.0.010 mol
C.0.0030 mol
D.0.030 mol

Molarity (M) = mol $AlCl_3$ / Liter solution

mol $AlCl_3$ = Molarity $AlCl_3$ x Volume solution (L)

Calculations
*Reactant → **Product***

moles (Reactant) → moles (Product)

$AlCl_3$ dissociates into 3 moles of Cl^-.

$AlCl_{3\,(aq)} \rightarrow Al^{3+}_{(aq)} + 3\,Cl^-_{(aq)}$

(Volume) 1 L	0.010 mol ($AlCl_3$)	? mol Cl⁻	100.0 mL ($AlCl_3$)	= ? mol (Cl -)
(Volume) 1000 mL	1 L ($AlCl_3$)	? mol $AlCl_3$		

"Gatekeepers" from Balanced reaction

ANSWER

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$AlCl_{3\,(aq)} \rightarrow Al^{3+}_{(aq)} + 3\,Cl^-_{(aq)}$

(Volume) 1 L	0.010 mol ($AlCl_3$)	3 mol Cl⁻	100.0 mL ($AlCl_3$)	= 0.0030 mol (Cl -)
(Volume) 1000 mL	1 L ($AlCl_3$)	1 mol $AlCl_3$		

"Gatekeepers" from Balanced reaction

Molarity (M) = moles solute / Liter solution

QUESTION

The net ionic equation for the reaction of aluminum sulfate and sodium hydroxide to produce a precipitate of aluminum hydroxide contains which of the following species?

A) $3Al^{3+}(aq)$
B) $OH^-(aq)$
C) $3OH^-(aq)$
D) $2Al^{3+}(aq)$
E) $2Al(OH)_3(s)$

$2\,PO_4^{3-}(aq) + Al^{3+}(aq) \rightarrow Al(OH)_3(s)$

ANSWER

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B) $OH^-(aq)$
C) $3OH^-(aq)$
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E) $2Al(OH)_3(s)$

QUESTION

$H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \longrightarrow BaSO_{4\,(s)} + 2\,H_2O_{(l)}$

20 drops of a 0.10M aqueous solution of sulfuric acid$_4$ is added to 20 drops of a 0.10M solution aqueous solution of barium hydroxide, $Ba(OH)_2$. The reaction is monitored using a conductivity tester. Predict the correct statement(s).

I) Both H_2SO_4 and $Ba(OH)_2$ are strong electrolytes.

II) This is a neutralization reaction.

III) This is a precipitation reaction.

IV) The light bulb will glow at the neutralization point.

A) II **B) I and II**

C) I, II and III **D) I, II, III and IV**

Answer

$H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \longrightarrow BaSO_{4\,(s)} + 2\,H_2O_{(l)}$

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