Electrolytes
(Solutions/ Molarity)

Why a sodium chloride solution, $NaCl_{(aq)}$, is also described in its ionic form:

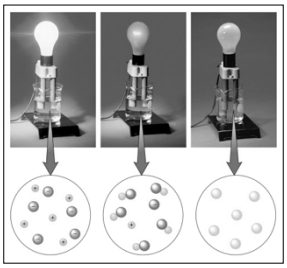
$NaCl_{(aq)} \longrightarrow Na^{+}_{aq)} + Cl^{-}_{(aq)}$

Dr. Ron Rusay

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.*

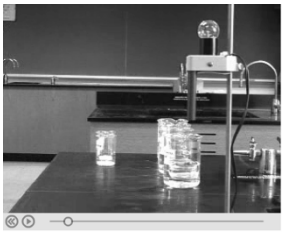
Solution Conductivity Apparatus for Electrolytes (Ions)



Conductivity depends on the amount of ions in solution

strong *weak* *non-*

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?

0.10 mol x *111 g/mol*

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

0.10 mol/2 x *111 g/mol*

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) = moles $AlCl_3$ / Liter solution

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

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

Calculations
Reactant → Product

moles (Reactant) → moles (Product)

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

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

$$\frac{\text{(Volume) 1 L}}{\text{(Volume) 1000 mL}} \times \frac{\text{0.010 mol } (AlCl_3)}{\text{1 L } (AlCl_3)} \times \frac{\text{? mol } Cl^-}{\text{? mol } AlCl_3} \times \text{100.0 mL } (AlCl_3) = \text{? mol (Cl -)}$$

"Gatekeepers" from Balanced reaction

Conductivity

Which of these solutions will have highest conductivity?

A	B
0.1 M $HCl_{(aq)}$	0.1 M $CaCl_{2\,(aq)}$

PhET INTERACTIVE SIMULATIONS

Molarity (M) = moles solute / Liter solution

Electrolytes & Equilibrium

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

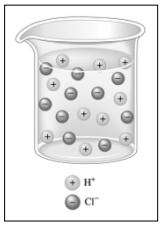
$C_{12}H_{22}O_{11\,(S)} + H_2O_{(l)} \longrightarrow C_{12}H_{22}O_{11\,(aq)}$

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

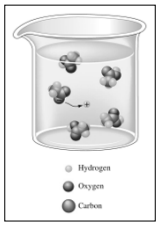
$HC_2H_3O_{2\,(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$

0.1000M ⇌ 0.09987M + 0.00013M

Acetic Acid ($HC_2H_3O_2$)
NOT Completely Ionized
(99.87% un-ionized)
Example of equilibrium



HCl Completely Ionized



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

Electrolytes

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

Strong and Weak Electrolytes

Conductivity

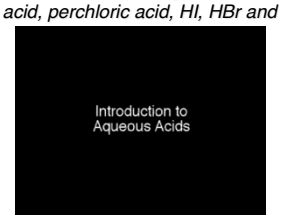
Which of these solutions will have highest conductivity?

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

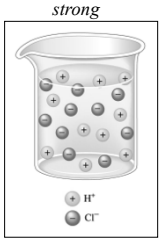
PhET INTERACTIVE SIMULATIONS

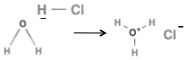
Aqueous Acids

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



strong

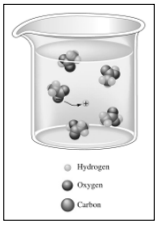


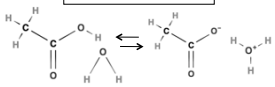


HCl

Completely Ionized

weak





Acetic Acid ($HC_2H_3O_2$)

NOT *Completely Ionized*

Example of equilibrium

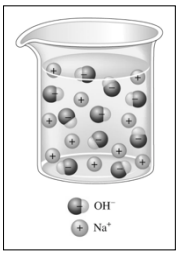
Aqueous Bases

- *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.*

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

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

strong

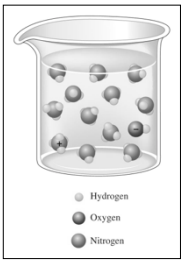


An Aqueous Solution of Sodium Hydroxide

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

Completely Ionized

weak

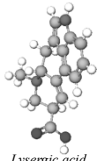


An Aqueous Solution of Ammonia

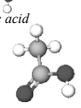
$$NH_{3\,(aq)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

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 $HC_2H_3O_2$)

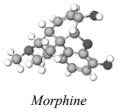
Bases

Strong

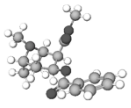
Sodium hydroxide, NaOH
Potassium hydroxide, KOH
Calcium hydroxide, $Ca(OH)_2$
Strontium hydroxide, $Sr(OH)_2$
Barium hydroxide, $Ba(OH)_2$

Weak

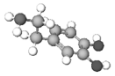
Ammonia, NH_3



Morphine



Cocaine



Dopamine

QUESTION

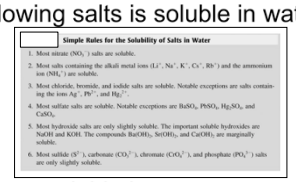
All of the following are weak acids *except*:

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

QUESTION

Which of the following salts is soluble in water?

A) Na_2S
B) K_3PO_4
C) $Pb(NO_3)_2$
D) $CaCl_2$
E) All of these are soluble in water.



ANSWER

E) All of these are soluble in water.

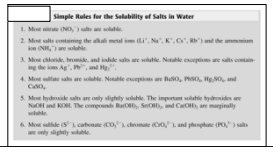
According to the solubility rules for ionic compounds, compounds containing Group IA ions or nitrate ions will always be soluble. Compounds containing halides are generally soluble, aside from silver, lead and mercury(I) halides.

QUESTION

If you began a reaction with the following ions in solution (all would be written with an *(aq)* subscript how would you represent the proper final net ionic equation? (Consult solubility Table.)

$$6Na^+ + 2PO_4^{3-} + 3Fe^{2+} + 6NO_3^- \rightarrow$$

A. $3Na^+ + PO_4^{3-} + Fe^{2+} + 2NO_3^- \rightarrow$ No Reaction
B. $6Na^+ + 2PO_4^{3-} + 3Fe^{2+} + 6NO_3^- \rightarrow Fe_3(PO_4)_2$ (s)+ 6 $NaNO_3$
C. $3Na^+ + PO_4^{3-} + Fe^{2+} + 2NO_3^- \rightarrow Fe_3(PO_4)_2$ (s)+ 6 Na^+ + 6 NO_3^-
D. $2PO_4^{3-} + 3Fe^{2+} \rightarrow Fe_3(PO_4)_2$ (s)



QUESTION

An aqueous solution of H_2SO_4 is added to aqueous $Ba(OH)_2$. 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

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Aqueous Reactions: Neutralization

Net Ionic Equations

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

- $HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$
- $NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$
- $NaCl_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$Na^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \longrightarrow$
$Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$

$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$

Aqueous Reactions: Precipitation

Net Ionic Equations

- *50mL of a 0.1M solution of sodium sulfate is mixed with 50mL of a 0.2M solution of silver nitrate. What is the result?*
- *Molecular Equation:*

$?Na_2SO_{4(aq)} + ?AgNO_{3(aq)} \rightleftharpoons$

1 2

$?Ag_2SO_{4(s)} + ?NaNO_{3(aq)}$

1 2

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

QUESTION & ANSWER

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

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