Aqueous Reactions

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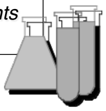
Aqueous Reactions

- *There are several general types:*

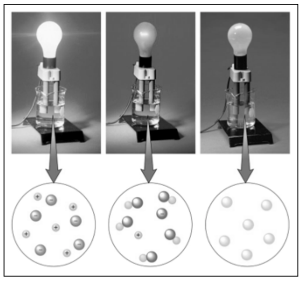
  *1) **Precipitation:** An insoluble salt forms from the addition of solutions. **(Refer to Solubility Rules)***

  *2) **Acid-Base Reactions (Neutralization)** generally produces a salt plus water*

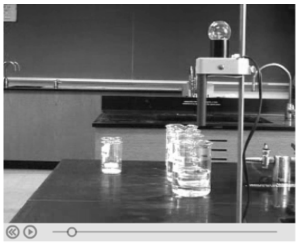
  *3) **Oxidation-Reduction (Redox)** there is a change in oxidation numbers between reactants and products*

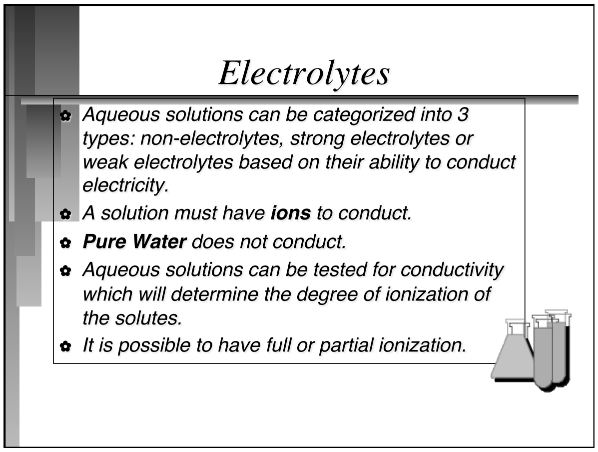


Solution Test Apparatus for Electrolytes



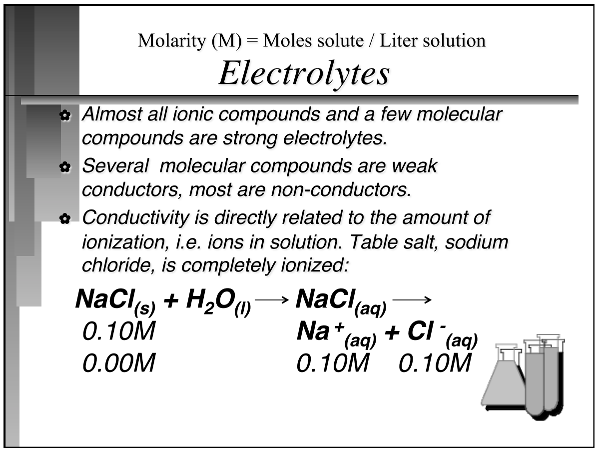
Conductivity





Electrolytes

- Aqueous solutions can be categorized into 3 types: non-electrolytes, strong electrolytes or weak electrolytes based on their ability to conduct electricity.
- A solution must have **ions** to conduct.
- **Pure Water** does not conduct.
- Aqueous solutions can be tested for conductivity which will determine the degree of ionization of the solutes.
- It is possible to have full or partial ionization.



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

0.00M 0.10M 0.10M

Molarity (M) = Moles solute / Liter solution

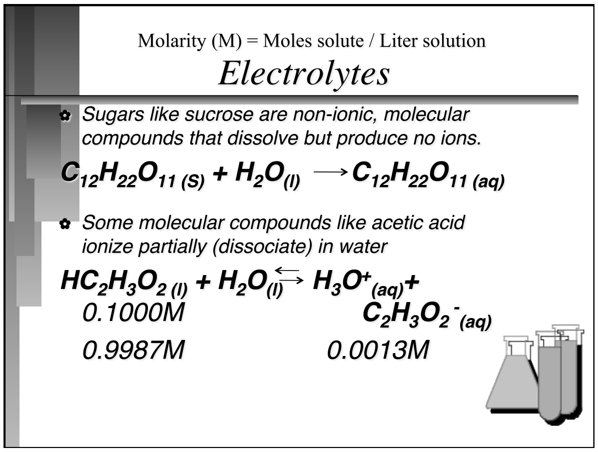
Electrolytes

ð Concentrations:

ð $CaCl_{2\,(s)} + H_2O_{(l)} \longrightarrow CaCl_{2(aq)} \longrightarrow$

0.10M $Ca^{2+}_{(aq)} + 2\ Cl^-_{(aq)}$

0.00M 0.10M 0.20M



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

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

0.1000M $C_2H_3O_2^-{}_{(aq)}$

0.9987M 0.0013M

Aqueous Acids

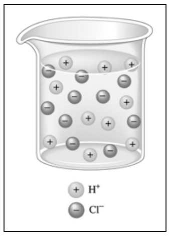
- Any compound that provides a proton can be considered an acid. Strong acids are sulfuric acid, nitric acid, perchloric acid, HI, HBr and HCl.

Introduction to
Aqueous Acids

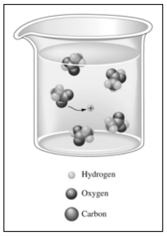
Electrolytes

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

Strong and Weak
Electrolytes



HCl
Completely
Ionized

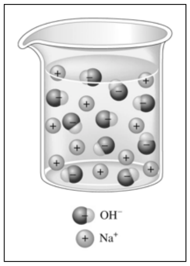


Acetic Acid
($HC_2H_3O_2$)

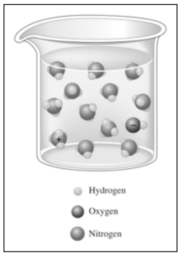
Aqueous Bases

- 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.

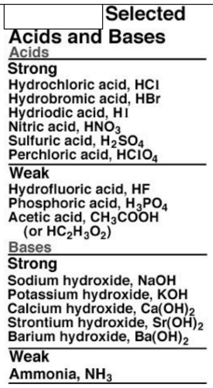
$$NH_{3\,(g)} + H_2O_{(l)} \Leftrightarrow NH_{3\,(aq)} \Leftrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$



An Aqueous Solution of Sodium Hydroxide



NH_3 in Water



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

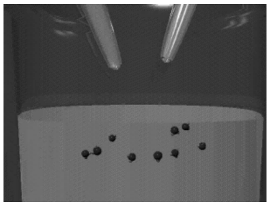
Ammonia, NH_3

QUESTION

All of the following are weak acids *except*:

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

Aqueous Reactions: Neutralization



Aqueous Reactions: Neutralization

Net Ionic Equations

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

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

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

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

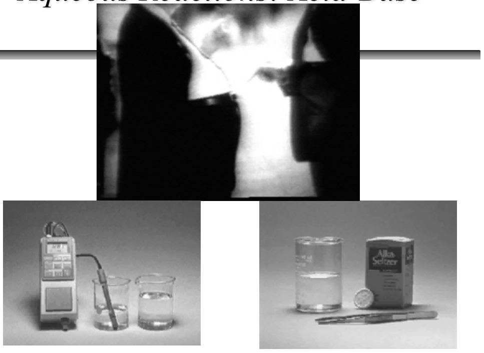
QUESTION

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**

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 M
B.0.010 M
C.0.0030 M
D.0.030 M

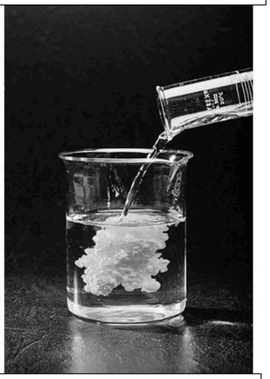
Molarity (M) = Moles solute / Liter solution

QUESTION

In the balanced molecular equation for the neutralization of sodium hydroxide with sulfuric acid, the products are:

A) $NaSO_4 + H_2O$
B) $NaSO_3 + 2H_2O$
C) $2NaSO_4 + H_2O$
D) $Na_2S + 2H_2O$
E) $Na_2SO_4 + 2H_2O$

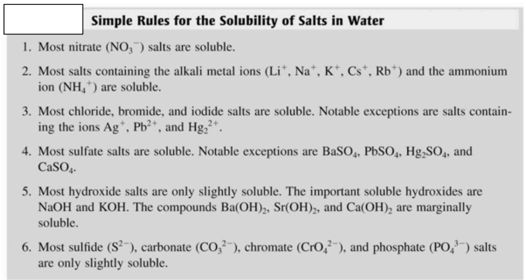
The Reaction of $Pb(NO_3)_2$ and NaI



What type of reaction is it?

Write a balanced equation for the reaction.

How do you know the state of the products?



Simple Rules for the Solubility of Salts in Water

1. Most nitrate (NO_3^-) salts are soluble.
2. Most salts containing the alkali metal ions (Li^+, Na^+, K^+, Cs^+, Rb^+) and the ammonium ion (NH_4^+) are soluble.
3. Most chloride, bromide, and iodide salts are soluble. Notable exceptions are salts containing the ions Ag^+, Pb^{2+}, and Hg_2^{2+}.
4. Most sulfate salts are soluble. Notable exceptions are $BaSO_4$, $PbSO_4$, Hg_2SO_4, and $CaSO_4$.
5. Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH and KOH. The compounds $Ba(OH)_2$, $Sr(OH)_2$, and $Ca(OH)_2$ are marginally soluble.
6. Most sulfide (S^{2-}), carbonate (CO_3^{2-}), chromate (CrO_4^{2-}), and phosphate (PO_4^{3-}) salts are only slightly soluble.

QUESTION

Given the insoluble compound $Al_2(CO_3)_3$ predict the ions and coefficients that would be necessary to complete the following net ionic equation:

$$\_\_ \ \_\_\_\_\_ + \_\_\_\_ \ \_\_\_\_\_ \rightarrow Al_2(CO_3)_3$$

A.2 $AlCl_3 + 3\ Na_2CO_3$ also include 6 NaCl on right
B.3 $Al^{3+} + 2\ CO_3^{2-}$
C.2 $Al^{3+} + 3\ CO_3^{2-}$
D.2 $Al^{3+}\ \ 6\ Cl^- + 3\ CO_3^{2-} + 6\ Na^+$

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:*

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

$\underline{1}$ $\underline{2}$

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

$\underline{1}$ $\underline{2}$

Aqueous Reactions: Precipitation

Net Ionic Equations

$Na_2SO_{4(aq)} + 2\ AgNO_{3(aq)} \rightarrow Ag_2SO_{4(s)} + 2\ NaNO_{3(aq)}$

0.1M *0.2M*

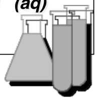
Ionic Reaction (Reactants):

$Na_2SO_{4(aq)} \longrightarrow \underline{2}\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

$\underline{2}\ AgNO_{3(aq)} \longrightarrow \underline{2}\ Ag^+_{(aq)} + \underline{2}\ NO_3^{1-}{}_{(aq)}$

$2\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ Ag^+_{(aq)} + 2\ NO_3^{1-}{}_{(aq)}$

0.2M *0.1M* *0.2M* *0.2M*



Aqueous Reactions: Precipitation

Net Ionic Equations

$Na_2SO_{4(aq)} + 2\ AgNO_{3(aq)} \rightarrow Ag_2SO_{4(s)} + 2\ NaNO_{3(aq)}$

0.1M *0.2M*

Ionic Reaction (Products):

$2\ NaNO_{3(aq)} \longrightarrow \underline{2}\ Na^+_{(aq)} + 2\ NO_3^{1-}{}_{(aq)}$

$Ag_2SO_{4(s)} \rightarrow$ ***Does not dissolve (ionize)***

$2Na^+_{(aq)} + 2NO_3^{1-}{}_{(aq)} + Ag_2SO_{4(s)}$

0.2M *0.2M* *solid*

Aqueous Reactions: Precipitation

Net Ionic Equations

$Na_2SO_{4(aq)} + 2\ AgNO_{3(aq)} \longrightarrow Ag_2SO_{4(s)} + 2\ NaNO_{3(aq)}$

Overall Ionic Reaction:

$\cancel{2Na^+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Ag^+_{(aq)} + \cancel{2NO_3^{1-}}{}_{(aq)} \longrightarrow$

$\cancel{2Na^+}_{(aq)} + Ag_2SO_{4(s)} + \cancel{2NO_3^{1-}}{}_{(aq)}$

Net Ionic Equation: (Subtract Spectator Ions)

$2Ag^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightleftarrows Ag_2SO_{4(s)}$

How many moles?

$M \times V_{solution} = mol$

$= M_{Na2SO4} \times V_{Na2SO4}\ /\ 1{:}1$ *stoichiometry*

$= 0.10M \times 0.050\ L/\ 1$

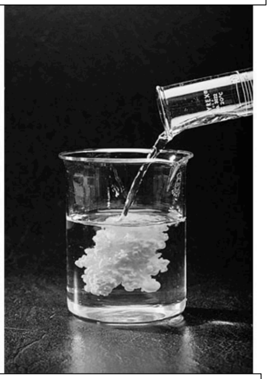
$= 0.0050\ mol$

QUESTION

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) $2Al(OH)_3(s)$

The Reaction of $Pb(NO_3)_2$ and NaI



$Pb(NO_3)_{2\,(aq)} + 2\ NaI_{\,(aq)} \rightarrow$
$2\ NaNO_{3(aq)} + PbI_{\,2(s)}$

Write a balanced Net Ionic equation for the reaction.

What are the spectator ions in the reaction?

QUESTION

Which of the following salts is insoluble 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.

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 a solubility Table.)

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

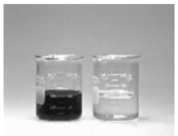
A. $3Na^{+} + PO_4^{3-} + Fe^{2+} + 2NO_3^{-} \rightarrow$ No Reaction
B. $6Na^{+} + 2PO_4^{3-} + 3Fe^{2+} + 6NO_3^{-} \rightarrow Fe_3(PO_4)_2\ (s) + 6NaNO_3$
C. $3Na^{+} + PO_4^{3-} + Fe^{2+} + 2NO_3^{-} \rightarrow Fe_3(PO_4)_2\ (s) + 6\ Na^{+} + 6\ NO_3^{-}$
D. $2PO_4^{3-} + 3Fe^{2+} \rightarrow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

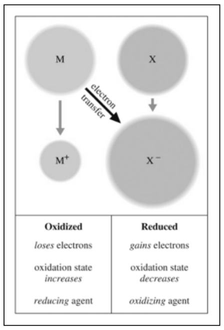
Oxidation-Reduction

- ***Oxidation*** *is the loss of electrons.*
- ***Reduction*** *is the gain of electrons.*
- *The reactions occur together. One does not occur without the other.*
- *The terms are used relative to the change in the* ***oxidation state*** *or* ***oxidation number*** *of the reactant(s).*

Aqueous Reactions: Oxidation - Reduction

- *In the following reaction, identify what is being oxidized and what is being reduced. What is the total number of electrons involved in the process?*





Oxidized	Reduced
loses electrons	*gains* electrons
oxidation state *increases*	oxidation state *decreases*
reducing agent	*oxidizing* agent

Oxidation Reduction Reactions

Oxidation-Reduction Reactions - Part 1

Oxidation-Reduction Reactions - Part 2

QUESTION

In a redox reaction, oxidation and reduction must both occur. Which statement provides an accurate premise of redox chemistry?

A. The substance that is oxidized must be the oxidizing agent.
B. The substance that is oxidized must gain electrons.
C. The substance that is oxidized must have a higher oxidation number afterwards.
D. The substance that is oxidized must combine with oxygen.

Rules for Assigning an Oxidation Number (O.N.)

General rules

1. For an atom in its elemental form (Na, O_2, Cl_2, etc.): O.N. = 0
2. For a monatomic ion: O.N. = ion charge
3. The sum of O.N. values for the atoms in a compound equals zero. The sum of O.N. values for the atoms in a polyatomic ion equals the ion charge.

Rules for specific atoms or periodic table groups

1. For Group 1A(1): O.N. = +1 in all compounds
2. For Group 2A(2): O.N. = +2 in all compounds
3. For hydrogen: O.N. = +1 in combination with nonmetals
   O.N. = −1 in combination with metals and boron
4. For fluorine: O.N. = −1 in all compounds
5. For oxygen: O.N. = −1 in peroxides
   O.N. = −2 in all other compounds (except with F)
6. For Group 7A(17): O.N. = −1 in combination with metals, nonmetals, (except O), and other halogens lower in the group

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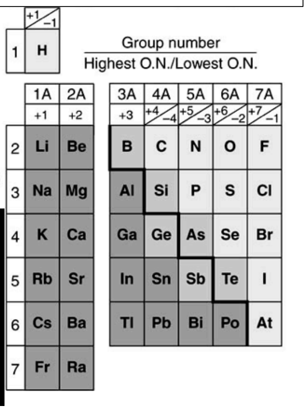
Highest and Lowest Oxidation Numbers of Reactive Main-Group Elements



Group number
Highest O.N./Lowest O.N.

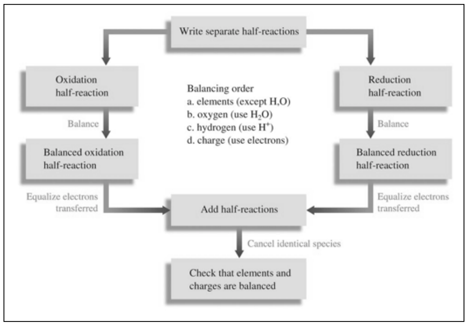
	1A	2A	3A	4A	5A	6A	7A
	+1	+2	+3	+4/−4	+5/−3	+6/−2	+7/−1
1	H (+1/−1)						
2	Li	Be	B	C	N	O	F
3	Na	Mg	Al	Si	P	S	Cl
4	K	Ca	Ga	Ge	As	Se	Br
5	Rb	Sr	In	Sn	Sb	Te	I
6	Cs	Ba	Tl	Pb	Bi	Po	At
7	Fr	Ra					

Periodic Trends:
Common Oxidation States

QUESTION

In which of the following does nitrogen have an oxidation state of +4?

A. HNO_3
B. NO_2
C. N_2O
D. NH_4Cl
E. $NaNO_2$


Write separate half-reactions
Oxidation half-reaction
Reduction half-reaction
Balancing order
a. elements (except H,O)
b. oxygen (use H_2O)
c. hydrogen (use H^+)
d. charge (use electrons)
Balance
Balance
Balanced oxidation half-reaction
Balanced reduction half-reaction
Equalize electrons transferred
Equalize electrons transferred
Add half-reactions
Cancel identical species
Check that elements and charges are balanced