CONCENTRATION

Aqueous Solutions & Reactions

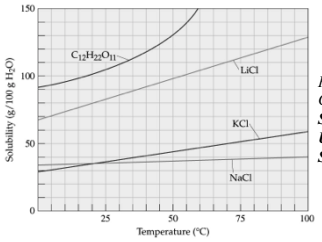
Dr. Ron Rusay

http://chemconnections.org/crystals/

Solutions

- *Homogeneous solutions are comprised of **solute**(s), the substance(s) dissolved, [The lesser amount of the component(s) in the mixture], and*
- ***solvent**, the substance present in the largest amount.*
- *Solutions with less solute dissolved than is physically possible are referred to as "**unsaturated**". Those with a maximum amount of solute are "**saturated**".*
- *Occasionally there are extraordinary solutions that are "**supersaturated**" with more solute than normal.*

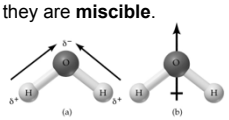
Concentration and Temperature



Relative Solution Concentrations:
Saturated
Unsaturated
Supersaturated

DHMO, dihydromonoxide: "The Universal" Solvent

The oil (nonpolar) and water (polar) mixture don't mix and are **immiscible**. If liquids form a homogeneous mixture, they are **miscible**.



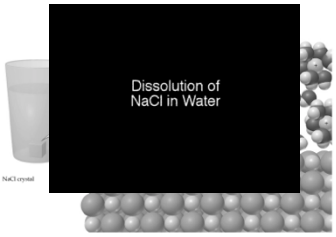
http://www.dhmo.org

Generally, likes dissolve likes, i.e. polar-polar and nonpolar-nonpolar. Polar and nonpolar do not mix , eg. oil and water

Aqueous Reactions & Solutions

- *Many reactions are done in a homogeneous liquid or gas phase which generally improves reaction rates.*
- *The prime medium for many inorganic reactions is water which serves as a solvent (the substance present in the larger amount), but does not react itself.*
- *The substance(s) dissolved in the solvent is (are) the solute(s). Together they comprise a solution. The reactants would be the solutes.*
- *Reaction solutions typically have less solute dissolved than is possible and are "unsaturated".*

Salt dissolving in a glass of water



http://chemconnections.org/general/movies/NaCl%20Dissolving.MOV

Aqueous Solutions Questions

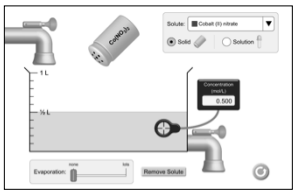
Refer to the simulation for the following 6 questions

http://phet.colorado.edu/sims/html/concentration/latest/concentration_en.html

---

Which action(s) will **increase** the concentration of the solution?

① Add more $Co(NO_3)_2$
② Evaporate water
③ Drain solution

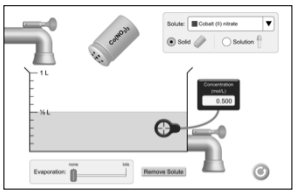


A. (1) only
B. (1) and (2)
C. (2) and (3)
D. (1) and (3)
E. (1), (2), and (3)

Molarity (M) = Moles solute / Liter solution

Which action(s) will change the number of moles of solute in the container?

① Add water
② Evaporate water
③ Drain solution

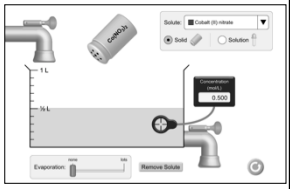


A. (1) only
B. (2) only
C. (3) only
D. (1) and (2)
E. (2) and (3)

Molarity (M) = Moles solute / Liter solution

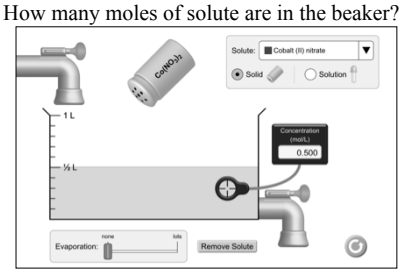
What will happen to the concentration and the number of moles when water is added?

	Concentration	Number of moles
a.	Increase	Decrease
b.	Increase	Increase
c.	No change	No change
d.	Decrease	Decrease
e.	Decrease	No change



Molarity (M) = Moles solute / Liter solution

How many moles of solute are in the beaker?



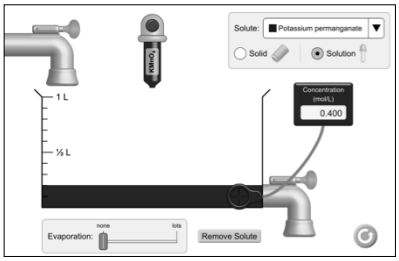
a. 0.05 moles b. 0.50 moles c. 1.00 moles

d. 1.50 moles e. None of these

Molarity (M_1) x Volume (V_1) = Molarity (M_2) x Volume (V_2)

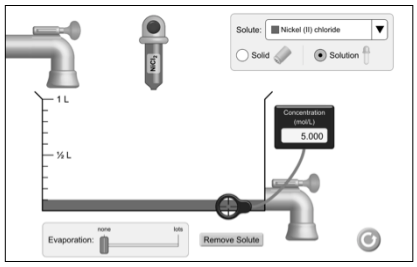
You are given 200 mL of a 0.400 M solution of $KMnO_4$.
If you add water until total volume is 800 mL, what will be the final concentration of the solution?

a. 0.080 M
b. 0.10 M
c. 0.20 M
d. 0.40 M
e. 1.6 M



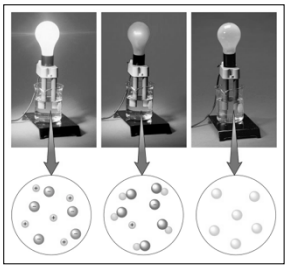
You start with 0.1 L of a 5.00 M solution of $NiCl_2$, and you plan to dilute it (by adding water) to make a solution with a concentration of 0.625 M. How far should you fill the beaker?

a. 200 mL
b. 400 mL
c. 600 mL
d. 800 mL
e. 1 L

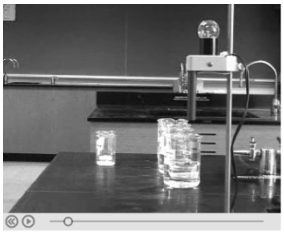


PhET INTERACTIVE SIMULATIONS

Solution Test Apparatus for Electrolytes



Conductivity



http://chemconnections.org/general/movies/Conductivity.MOV

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:*

$$NaCl_{(s)} + H_2O_{(l)} \longrightarrow NaCl_{(aq)} \longrightarrow$$
$$0.10M \qquad\qquad Na^+_{(aq)} + Cl^-_{(aq)}$$
$$0.00M \qquad\qquad 0.10M \quad 0.10M$$

You have prepared a 1.0 M solution of NaCl in the laboratory.

What is the concentration of ***chloride ions*** in the solution?

a. 0.50 M
b. 1.0 M
c. 1.5 M
d. 2.0 M

PhET INTERACTIVE SIMULATIONS

Molarity (M) = Moles solute / Liter solution

Electrolytes

- *Concentrations:*
- $CaCl_{2\,(s)} + H_2O_{(l)} \longrightarrow CaCl_{2(aq)} \longrightarrow$
  $0.10M \qquad Ca^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)}$
  $0.00M \qquad 0.10M \quad 0.20M$

You have prepared a 1.0 M solution of $CaCl_2$ in the laboratory.

What is the concentration of ***chloride ions*** in the solution?

a. 0.50 M

b. 1.0 M

c. 1.5 M

d. 2.0 M

Molarity (M) = Moles solute / Liter solution

Electrolytes

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

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

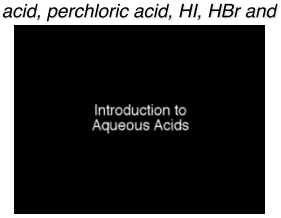
- *Some molecular compounds like acetic acid ionize partially (dissociate) in water*

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

$0.1000M \qquad 0.09987M \qquad 0.013M$

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.*



http://chemconnections.org/general/movies/acid-intro.mov

Electrolytes

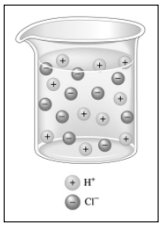
- *How would the conductivity of acetic acid compare to hydrochloric acid?*

http://chemconnections.org/general/movies/strong-weak-elect.MOV

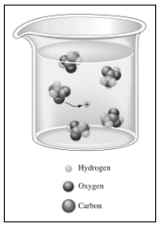
Conductivity

Which of these solutions will have highest conductivity?

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



HCl Completely Ionized



Acetic Acid ($HC_2H_3O_2$)

Conductivity

Which of these solutions will have highest conductivity?

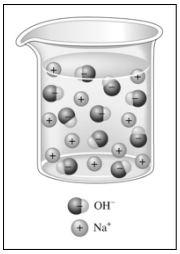
A	B	C
0.1 M $HCl_{(aq)}$	0.1 M $CaCl_{2\,(aq)}$	0.2 M $HC_2H_3O_{2(aq)}$

Aqueous Bases

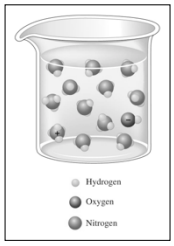
- *Any compound that accepts a proton is a base.*
- *The common bases are group IA & IIA metal hydroxide compounds. They are strong bases, dissociating completely in water.*
- *An example of a weak base is ammonia.*

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

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



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.

ANSWER

All of the following are weak acids *except*:

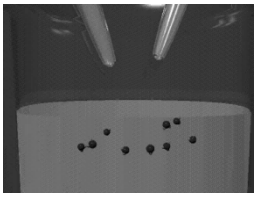
A) HCNO.
B) HBr.
C) HF.
D) HNO_2.
E) HCN.

Aqueous Reactions

- *There are several general types, but we will focus on two:*
  - *1)* ***Acid-Base Reactions (Neutralization)*** *generally produces a salt plus water*
  - *2)* ***Oxidation-Reduction (Redox)*** *there is a change in oxidation numbers between reactants and products*

Precipitation: *An insoluble salt forms from the addition of solutions.*

Aqueous Reactions: Neutralization



http://chemconnections.org/general/movies/neutralizationofastrongacid.mov

QUESTION

An aqueous solution of H_2SO_4 is added to aqueous $Ba(OH)_2$. A white cloudiness is observed and the reaction is monitored using a light conductivity tester. The reactants both produced strong light, which dimmed as they were added together and the reaction proceeded 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

An aqueous solution of H_2SO_4 is added to aqueous $Ba(OH)_2$. A white cloudiness is observed and the reaction is monitored using a light conductivity tester. The reactants both produced strong light, which dimmed as they were added together and the reaction proceeded 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.

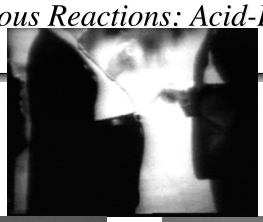
IV) The light bulb will glow at the neutralization point.

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

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

Aqueous Reactions: Acid-Base

http://chemconnections.org/general/movies/Stomach.MOV



http://chemconnections.org/general/movies/Stomach-bicarb.mov

http://chemconnections.org/general/movies/alka-seltzer.mov

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 1000.0 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

ANSWER

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 1000.0 mL of 0.010 M $AlCl_3$?

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

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

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) $Na_2SO_4 + 2H_2O$

ANSWER

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

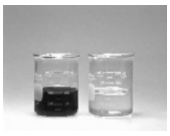
A) $NaSO_4 + H_2O$
B) $NaSO_3 + 2H_2O$
C) $2NaSO_4 + H_2O$
D) $Na_2S + 2H_2O$
E) $Na_2SO_4 + 2H_2O$

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).*

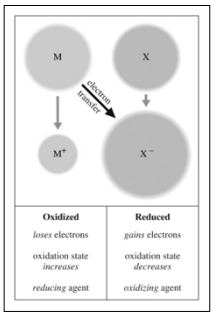
Aqueous Reactions: Oxidation - Reduction

- *In the following reaction, identify what is being oxidized and what is being reduced?*



What gains electrons and what looses?

http://chemconnections.org/general/movies/Mn-Fe-redox.MOV



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.

ANSWER

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.

http://chemconnections.org/general/movies/Oxid%20States.MOV