Solutions

Learning Objectives

I. **Solutions Are Around Us.**
II. **Solutions Definition**
III. **Classification of Solutions**
IV. **Solubility**
V. **Solution Concentrations**
VI. **Concentrations Calculations in Chemical Reactions**
VII. **Colligative Properties of Solutions**
VIII. **Dialysis**

I. Solutions Are Around Us

Solutions are surrounding us and are found in the environment, oceans, air, soils etc.

For example the air is a homogeneous mixture made of mainly nitrogen gas (about 78%) and oxygen (about 21%) and some other gases in small amounts (about 1%). Air is considered a solution which is based on homogeneous mixture of nitrogen and oxygen mainly.

Also brass is considered as an alloy (homogenous mixture) made of copper (in access amount) and zinc (in limited amount). Steel also considered as another alloy made of iron (in access amount) and carbon (in limited amount).

Oceans are made of hard water which contains higher content of Magnesium and Calcium ions. Oceans are considered homogeneous mixtures and hence solutions.

In this chapter we will learn more about solutions: types, concentrations, solubility and properties.

The table below summarizes the different solute and solvent types with examples

Solute	Solvent	Type of solution	Example
liquid	liquid	liquid	alcohol - water
solid	liquid	liquid	salt - water
gas	liquid	liquid	oxygen - water
gas	gas	gas	air = oxygen - nitrogen
gas	solid	solid	hydrogen - Palladium
liquid	gas	gas	water in air
solid	gas	gas	smog
liquid	solid	solid	Alloy -Mercury Zinc
solid	solid	solid	Alloy- Copper and Zinc

II. Solutions Definition

A solution is a homogeneous mixture made of a solute and a solvent. A solute is a chemical compound that is limited in the amount and soluble in the solvent. The solvent in a chemical compound that has the ability to dissolve the solute and it has excess amount compared with the solute amount. To assure solubility both solute and solvent share similar polarity.

An example of a homogenous mixture is the solubility of sodium chloride NaCl in water. Sodium chloride is considered as a solute with the least amount and water is considered as a solvent with a large amount.

Also solubility of an oil (none polar compound) in cyclohexane solvent (none polar) makes a homogenous mixture.

If the solute and solvent have different polarities, then they form heterogeneous mixture which is not considered as a solution.

The Phet Simulation Activity of the different solubility outcome of sugar and salt in water. Both sugar and salt are soluble in water. However, the solubility of salt in water will produce ions which can conduct electricity.

The simulation can be accessed and downloaded through the link below:

https://phet.colorado.edu/en/simulation/legacy/sugar-and-salt-solutions

You will have to download this Phet simulation first.

You will:
• Compare the behavior of sugar and salt in water
• Identify sugar and salt as either an electrolyte or a nonelectrolyte
• Draw a particulate representation of salt in water and sugar in water
• Propose an explanation for why a light bulb glows or does not glow
• Extend the definition of electrolytes versus nonelectrolytes to other substances and qualitatively relate bond type to this observation

Procedure

Part I: Open Exploration

1. Students may share how the conductivity tester works; how to shake the shaker; how to add water to the container; and how the evaporation slider works.

Part II: Macro (First Tab)

Fill in the Table below with your findings:

Compound	What Happens to the Light Bulb? Glows / Does Not Glow	Observation
Water		
Salt		
Sugar		

Questions:

1. Which of these compounds are electrolyte and which are nonelectrolytes?

2. Which of these compounds are conducting electricity and which are not?

Part III: Water (Third Tab)

What happens as you add sugar or salt to water?

Fill in the Table below with your findings:

Compound	Electrolytes or Nonelectrolytes?	Drawing of Ions Surrounded by Water	Observation
Salt			
Sugar			

Questions:

1. Using the observations made with salt in water and sugar in water in the first tab (macro); propose one possible explanation for the bulb glowing?

2. If the evaporation is allowed to continue until all of the water is gone, a thin white layer forms on the bottom of the container representing the salt and the sugar. What happens if the conductivity tester is left in the beaker during evaporation with the salt first? And then with sugar?

3. Which compound breaks apart into ions and which compound does not?

Part IV: Micro (Second Tab)

What happens when other compounds are added to water?

Fill in Table below with what your findings:

Compound	Breaking Apart or Staying together		Electrolyte or Nonelectrolyte	Ionic or Covalent?
	Prediction	Observation		

Salt NaCl				
Sugar $C_{12}H_{22}O_{12}$				
Sodium chloride NaCl				
Sodium nitrate $NaNO_3$				
Glucose $C_6H_{11}O_6$				

Activities:

1. Using the "Periodic Table" button, work with your partner to identify two other combinations of elements that might be considered an ionic compound. Explain your reasoning.

2. Using the "Periodic Table" button, identify two combinations of elements that might be considered a covalent compound. Explain your reasoning

The conclusion of the simulation activity above is given below:

Salt dissolution in water:

$NaCl_{(s)}$ + $H_2O_{(l)}$ → $Na_{(aq)}^+$ + $Cl_{(aq)}^+$ [Two ions are produced from solid NaCl]

The two ions produced are responsible of conducting electricity. The lamp will be lit when its electrodes are immersed into the salt solution.

Sugar dissolution in water:

$C_6H_{12}O_{6(s)}$ + + $H_2O_{(l)}$ → $[C_6H_{12}O_6]_{(aq)}$ [No ions are produced]

The sugar solution does not produce any ions and hence no electricity is conducted and the lamp will not be lit.

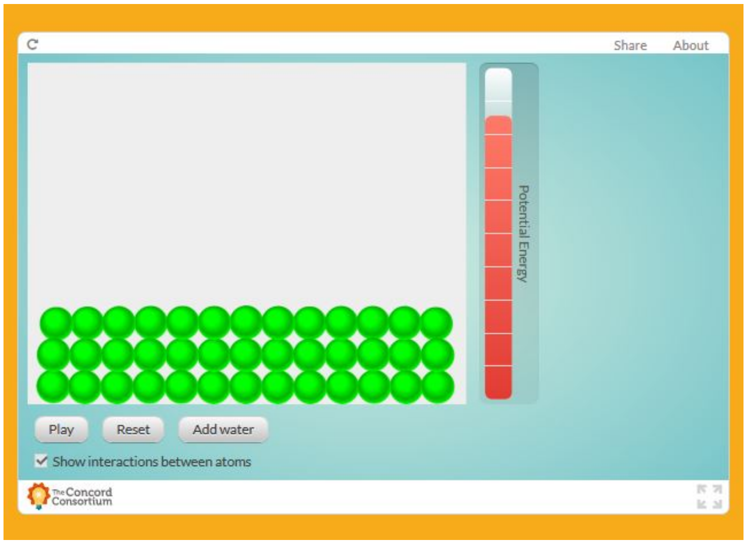
The dissolution of the solute in water can also be practiced in the simulation created by Molecular Workbench. The solid solute is surrounded by water molecules.

At the beginning the solid crystals are sitting very packed together. Water molecules are approaching the solid salute crystals and penetrate through the crystal network with addition of more water and more given time, water will separate the crystal network of the solid salute and start producing ions out the dissolved solute.

The simulation can be accessed and downloaded through the link below:

http://mw.concord.org/nextgen/#interactives/chemistry/solubility/dissolving-chemistry

No water is added:



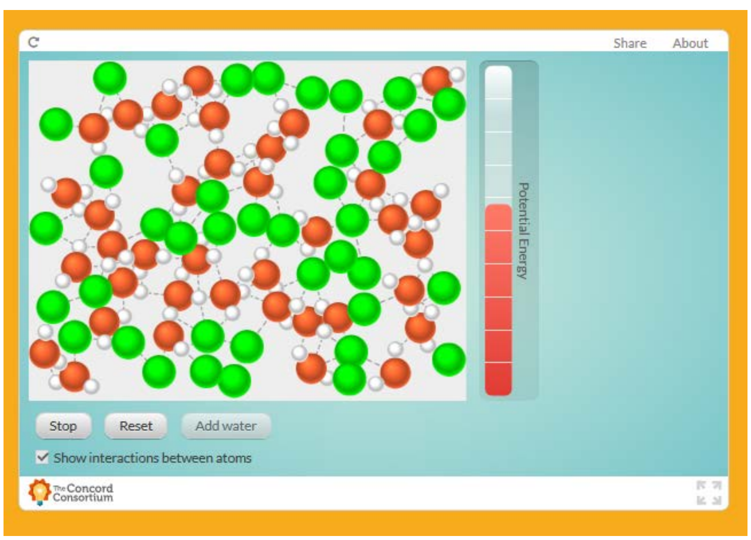
Impact on potential energy when a substance dissolves in water.

Add water to a substance and observe the impact on potential energy as the substance dissolves. Observe the interactions between molecules as the substance dissolves over time and watch what happens to the potential energy of the system as dissolving occurs.

Questions:

1. Write your observation regarding the potential energy and the molecules at the beginning of the experiment when no water is added?

2. Write your observation regarding the potential energy and the molecules at the beginning of the experiment when water is added?



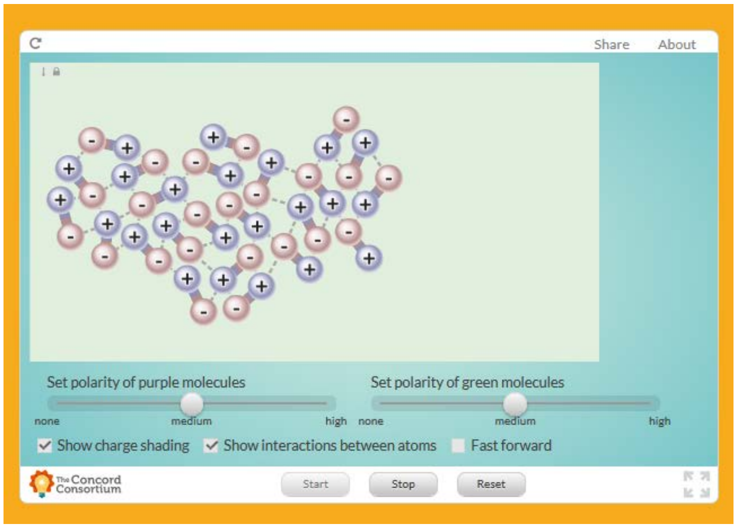
After some time water is able to dissolve the solid salt and ions are produced.

Water is a polar solvent with oxygen has the highest electronegativity compared with hydrogen. Oxygen has partial negative charge and hydrogen has partial positive charge.

The patial positive charged hydrogen will be attracted to the negative ion of the solute and oxygen partially negative charged will be attracted to the positive ion of the solute.

Molecular Workbench Simulation activitity can illustrate this type of attractions.

http://mw.concord.org/nextgen/#interactives/chemistry/solubility/dissolving-chemistry-experimental



Explore how molecules of different polarity interact when mixed.

Select the polarity of two different molecules and simulate what happens when these two molecules of different (or the same) polarities are mixed. Speed up the simulation to reach an outcome faster, or keep it slow to observe the interactions between atoms. Then draw conclusions about how polarity impacts how different substances dissolve.

Questions:

1. Are molecules with same polarities attracted to each other or repelled each other? Explain your answer.

2. Are molecules with different polarities attracted to each other or repelled each other? Explain your answer.

III. Classification of Solutions

Solutions can be classified according to:

1. Polarity of the solute and the solvent
2. Electrolyte and nonelectrolyte solute
3. Particles size of the solute
4. Maximum solubility of the solute
5. Osmotic pressure

1. Polarity of the solute and the solvent

Both of the solute and solvent should have the same polarity to mix and form a homogenous mixture.

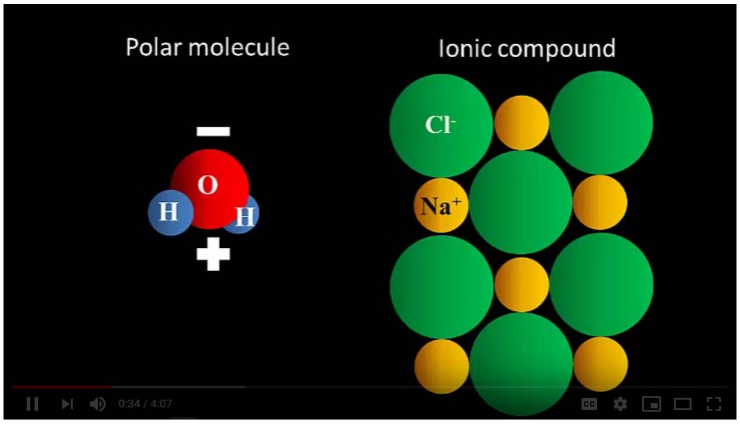
In the tables below, two solvents with different polarities are used; namely cyclohexane as none polar solvent and water as a polar solvent. The solubility of these solvents are tested with different solutes: sugar, potassium permanganate and sodium nitrate as polar solutes and oil and iodine as none polar solutes.

One can predict a solution formation if the polarities of the solute and solvent are the same.

This principle is known as: **“Like Dissolves Like”**

A You Tube illustrate the principle of Like Dissolves Like:

https://www.youtube.com/watch?v=0ThbvPk-j2A



Like Dissolves Like.mp4

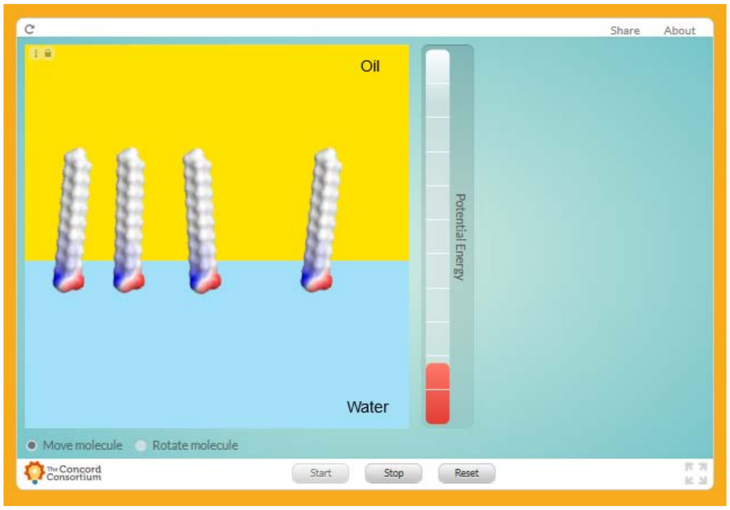
One therefore can distinguish between polar solution from none polar solution.

Solvent	Solute	Solution is Formed?	Reason
Water	Sodium nitrate	Yes	Both solute and solvent have same polarities
Water	Potassium permanganate	Yes	Both solute and solvent have same polarities
Water	Sugar	Yes	Both solute and solvent have same polarities
Water	Iodine	No	Both solute and solvent have different polarities
Water	Oil	No	Both solute and solvent have different polarities

Solvent	Solute	Solution is Formed?	Reason
Cyclohexane	Sodium nitrate	No	Both solute and solvent have different polarities
Cyclohexane	Potassium permanganate	No	Both solute and solvent have different polarities
Cyclohexane	Sugar	No	Both solute and solvent have different polarities
Cyclohexane	Iodine	Yes	Both solute and solvent have same polarities
Cyclohexane	Oil	Yes	Both solute and solvent have same polarities

Molecular Workbench activity illustrates the distribution of large fatty acids molecules with polar part is attracted and soluble in water and none polar part is attracted and soluble in oil.

http://mw.concord.org/nextgen/#interactives/chemistry/solubility/polar-nonpolar-interface-chemistry



Molecule movement in a mixture of oil and water.

Observe how molecules with hydrophilic molecules (which likes to be dissolved in water: polar) and hydrophobic molecules (which dislike to be dissolved in water: nonpolar) are moving between the two regions of the mixture of oil and water, and pay attention to changes in potential energy over time. Move and rotate the molecules to see how they interact with their surrounding environment.

Questions:

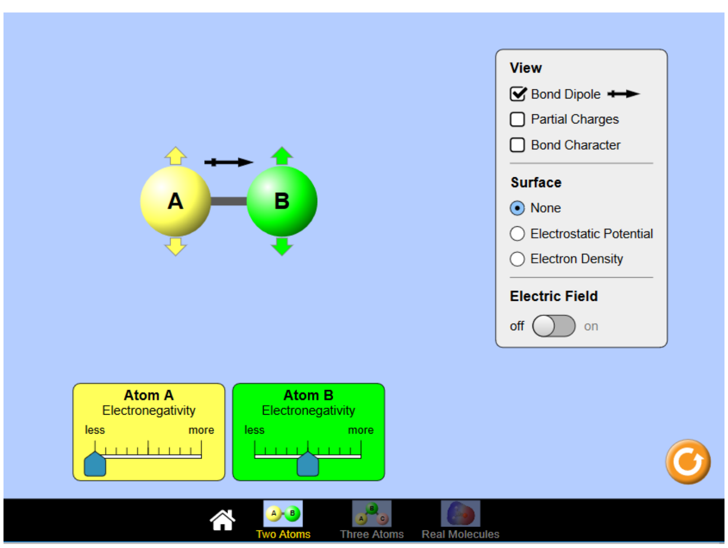
1. Explain the alignments of the fatty acids polar part in water with the corresponding potential energy.

2. Explain the alignments of the fatty acids none polar part in oil with the corresponding potential energy.

3. When the fatty acid molecules are rotated, do the polar part and none polar part exchange their regions (i.e. oil region versus water oil)? Why and why not? Explain.

Molecule polarity is illustrated in a Phet simulation activity below:

https://phet.colorado.edu/sims/html/molecule-polarity/latest/molecule-polarity_en.html



In the simulation above, the students can explore:

Predict how changing electronegativity will affect the bond polarity.

Explain the relationship between the bond dipoles and the molecular dipole.

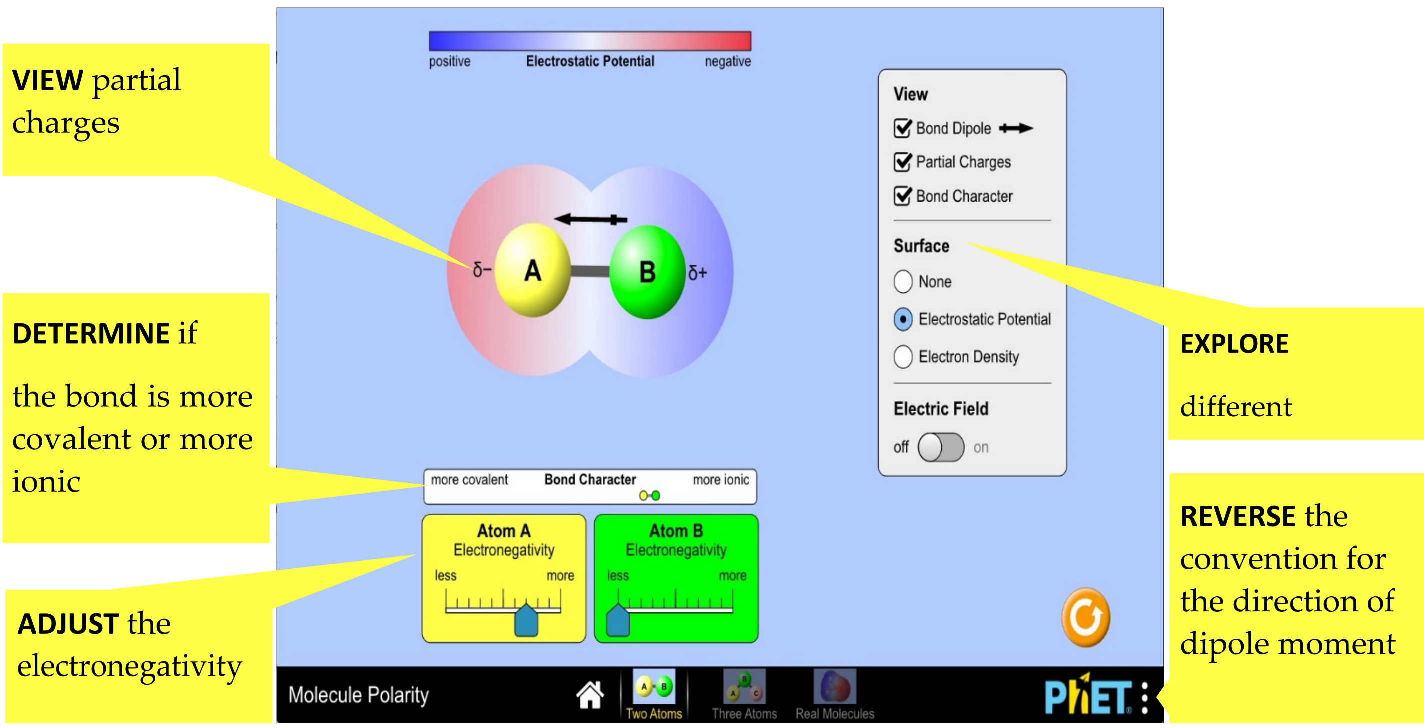
Determine if a non-polar molecule can contain polar bonds.

Describe how the ABC bond angle effects the molecular dipole.

Compare the behavior of non-polar and polar molecules in an external electric field.

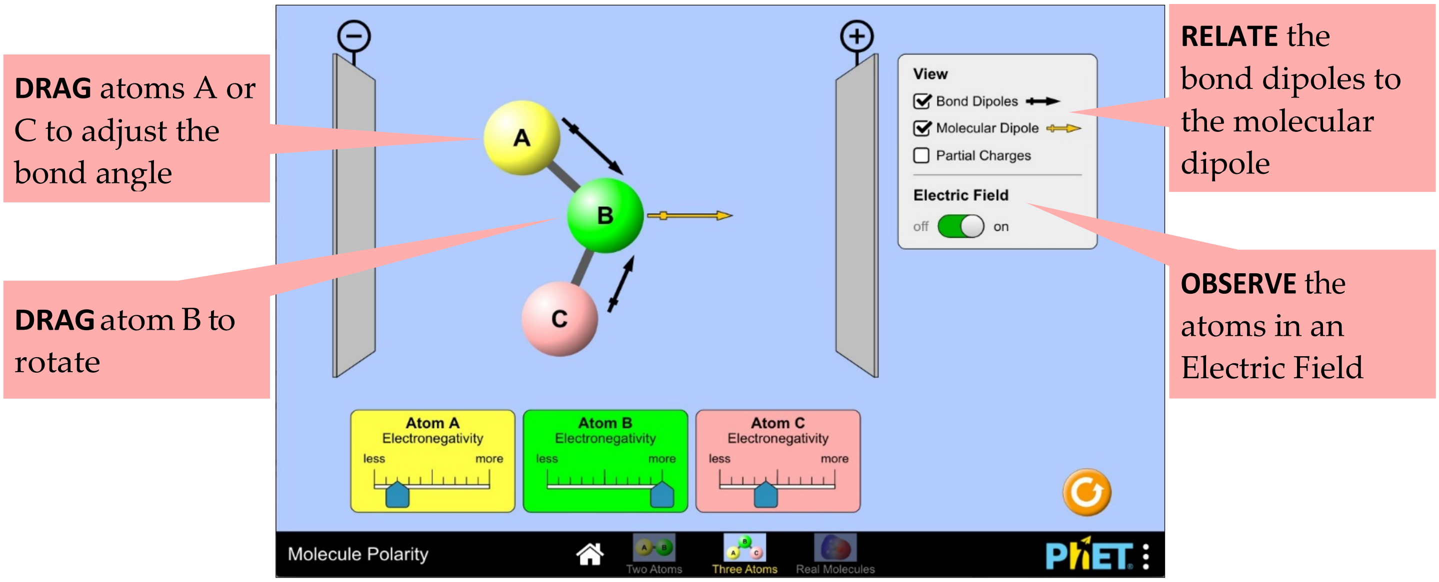
Two Atoms Screen

Change the electronegativity of the atoms, view the resulting electrostatic potential or electron density, and predict the bond polarity.



Three Atoms Screen

Explore the relationship between the bond dipoles and the molecular dipole, and observe the molecule in an electric field.



Simulation conclusions:

The electronegativity slider ranges from 2 to 4, but the value is never displayed. The resulting electronegativity difference between two bonded atoms varies from 0 to 2.

Bond dipoles are parallel to the bond axis, and their length is linearly proportional to the difference in electronegativity. Note that this is a simplification; in reality, the dipole is not influenced solely by electronegativity.

The molecular dipole is the vector sum of the bond dipoles. In the Two Atoms screen, the molecular dipole is not shown, as it is equivalent to the bond dipole. In the Three Atoms screen, manipulating electronegativity results in an understanding of summing vector magnitudes, while manipulating bond angles results in an understanding of summing vector angles.

The magnitude of an atom's partial charge is linearly proportional to the electronegativity difference between the bonded pair. If an atom has a higher electronegativity than the atom at the other end of the bond, then the partial charge's sign is negative; otherwise it is positive. For atoms that participate in more than one bond (e.g., atom B in the "Three Atoms" screen), net partial charge is the sum of the partial charges contributed by each bond.

The electrostatic potential and electron density are linearly proportional to the electronegativity difference set by the sliders. These surfaces are not implemented for the triatomic molecule in the Three Atoms screen, because the manipulation of bond angles results in undefinable surfaces.

The Three Atoms screen allows for students to change the bond angle between the outer atoms C). The AB and BC bonds are treated independently, and the model does not allow for these atoms to repel each other. To explore how atoms would repel one another when the bond angles are changed.

Questions:

1. Explain how the polarity of a molecule is related to the electronegativity of the atoms within the molecule. Use your knowledge gained from the previous chapters.

2. Explain how is the solubility of a solution is affected with the polarity and electronegativity

2. Electrolyte and nonelectrolyte solute

Solutes that are soluble in water and can dissociate in water and produce ions are called electrolytes such as sodium chloride (kitchen salt). Electrolytes can conduct electricity because they can produce ions when dissolved in water. Solutes are soluble in water and cannot dissociate in water and cannot produce ions are called nonelectrolytes such as sugar. Nonelectrolytes cannot produce ions and hence cannot conduct electricity.

Electrolytes can be divided into weak electrolytes and strong electrolytes.

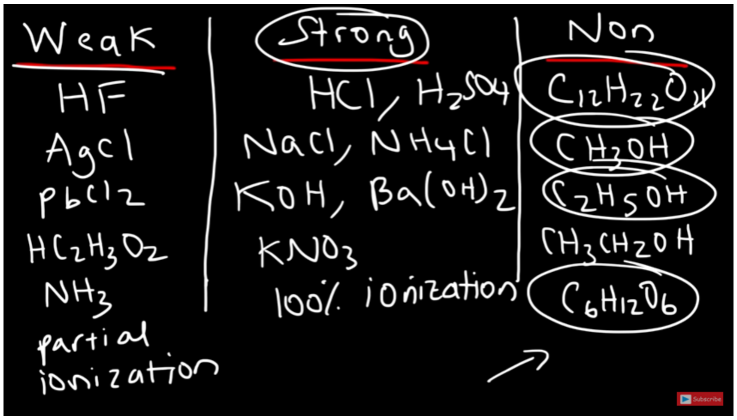
Weak electrolytes are solutes that dissolved and dissociate partially in water and conduct electricity to limited extent while strong electrolytes dissociate completely in water and conduct electricity to greater extent.

The table below illustrates the different types of electrolytes.

Electrolyte Type	Dissociation in water	Ions are formed?	Examples	Electricity Conduction
Weak Electrolytes	partially	limited number of ions +large amount of undissociated molecules	weak acids and bases and all metal ions other than group 1A and 2A. HF, HNO_2, H_3PO_4 $Al(OH)_3$, $Fe(OH)_2$	partial, weak conduction
Strong Electrolytes	completely	only ions	strong acids and bases and groups 1A and 2A metal ions are forming strong electrolytes: HCl, HNO_3, HBr, H_2SO_4 NaOH, KOH, $Mg(OH)_2$	complete, strong conduction
None Electrolytes	No	No	Sugar $C_6H_{12}O_6$ Ethanol C_2H_5OH Honey	No

A You Tube explains how to identify electrolytes (weak and strong) and nonelectrolytes:

https://www.youtube.com/watch?v=2U2DBWWo6nc



Identifying Strong Electrolytes Weak Electrolytes and Nonelectrolytes.mp4

3. Particles size of the solute

According to the particles size of the solutes, one can differentiate between three types of mixtures: homogeneous mixture (normal solution), heterogeneous mixture (colloid) and another heterogeneous mixture called suspension.

Normal solutions have solutes with smaller particles size and the particles not be seen by the naked eyes or any other optical tools such as microscopes. The size of particles is below 1.00 nm (nano meter) and the particles cannot be seen by naked eyes. Normal solutions are considered as homogenous mixtures.

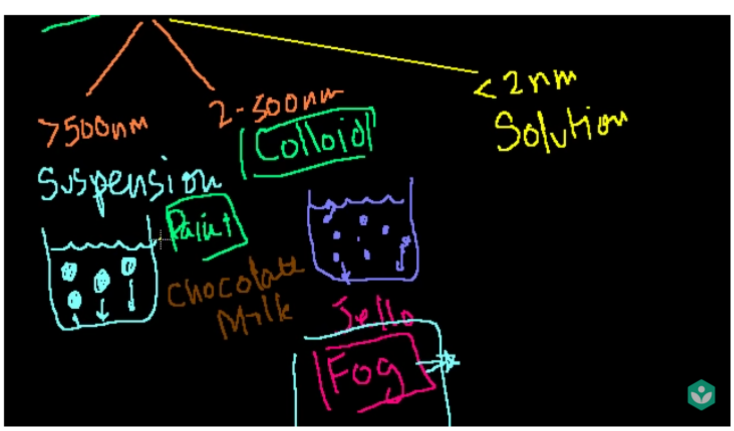
Colloids have solutes with larger particles size. The size of particles is between 1.00 nm – 100.0 nm and therefore the particles can be seen by optical tools such as microscopes but not by naked eyes. The particles can be seen by a Tyndall Effect by which a colloidal solution is exposed to a light source. The light is scattered and reflected due to the particles size of the solutes and the particles of solute can be exposed and seen then by naked eyes. Colloids are considered as heterogeneous mixtures.

Furthermore, colloidal solutions are not stable and cannot pass through membranes or semi membranes.

The suspensions have solutes with the largest particles sizes. The size of particles is great than 100.0 nm and therefore they can be seen by naked eyes. Suspensions tend to settle out

A YouTube video illustrate the difference between the three solutions.

https://www.youtube.com/watch?v=3ROWXs3jtQU



Suspensions Colloids and Solutions Chemistry.mp4

The table below can summarize the differences between solutions, colloids and suspensions

	Mixtures Appearance	Particles size	Tyndall Effect	Settling Out	Semi Membranes Separation	Examples
Solutions	transparent	Less than 1.00 nm	No	No	No	Sugar dissolved in water
Colloids	Cloudy, homogeneous	1.00 nm – 100.0 nm	Yes	No	No	Foam, Smoke, Clouds
Suspensions	Cloudy, heterogeneous	Greater than 100.0 nm	No, if particles settle out	Yes	Yes	Char Coal suspension in water

4. Maximum solubility of the solute

There are three types of solutions according the maximum solubility of the solute in the solvent:

1. Unsaturated solution

The solute amount in the solution is less than the maximum amount. An example of unsaturated solution is sodium chloride in water. Maximum solubility of sodium chloride in water at room temperature of 25 ^{O}C is 357 mg/mL. If sodium chloride amount is less than 357 mg/mL (less the maximum solubility of solute in solution), then the solution is considered to be unsaturated solution and it is homogeneous. Most of the solutions used in the chemistry laboratory are unsaturated. They tend to be very stable and very often are called stock solutions.

2. Saturated solution

The solute amount in the solution is equal to the maximum solubility of 357 mg/mL at room temperature. The solution is still homogeneous mixture and tend to be more viscos. Any addition of the solute after the saturation point is reached will lead to the extra incoming solute particles to settle out of the solution.

3. Supersaturated solution

The amount of the solute is large and it exceeds the maximum solubility amount of 357 mg/mL at room temperature. The solution tends to be heterogeneous and the solute particles tend to settle out.

A You Tube illustration can be seen below:

https://www.youtube.com/watch?v=JQRIlS9lNdg&list=RDJQRIlS9lNdg&start_radio=1

Solutions Tutorial- Unsaturated Saturated Supersaturated.mp4

The table below summarizes the three types of solutions

Solution	Amount of Solute	Appearance of the Solution	Mixture type
Unsaturated	Less than the maximum solubility of solution in solvent	Transparent	homogenous
Saturated	Equal the maximum solubility of solution in solvent	Thick, viscos	homogenous
Supersaturated	Very large, exceeds the maximum solubility of solution in solvent	Particles settle out	heterogeneous

Maximum Solubility calculations:

Example:

The maximum solubility of NaCl is 35.7 grams in 100.0 gram water at room temperature of 25 °C. If there is a solution made of 95.0 grams of NaCl in 200.0 grams water at room temperature 25 °C. Answer the following questions:

a. How many grams of NaCl will be dissolved
b. How many grams of NaCl will not be dissolved and remain in solution
c. Is this solution is saturated or supersaturated?

a. How many grams of NaCl will be dissolved?
   Grams of NaCl = [200.0 g H_2O] x [35.7 g NaCl / 100.0 g H_2O] = 71.4 g NaCl

b. How many grams of NaCl will not be dissolved and remain in solution
   Undissolved NaCl = 95.0 g NaCl - 71.4 g NaCl =23.6 g NaCl remaining

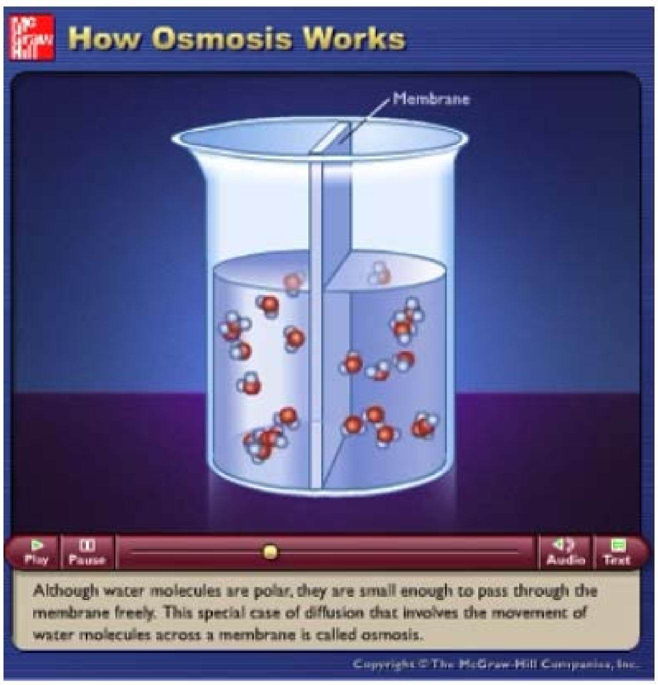
c. If 95.0 g NaCl is added to 200 grams at room temperature, 23.6 g NaCl will not dissolve and settle out at the bottom of the mixing container. The solution then is said to be supersaturated.

4. Osmotic pressure

Osmosis is the diffusion of a solvent such water with higher amount (less amount of solute) through a semi membrane into a solution with higher solute concentration and less solvent amount.

A You Tube video illustrates the osmosis concept.

https://www.youtube.com/watch?v=-g-VJymtAf4



How Osmosis Works.mp4

The solution is classified as isotonic, hypotonic and hypertonic according to the amount of the solvent outside and inside a cell. Red A blood cell has the concentration of glucose about 5% and sodium chloride amount 0.9% and rest is water

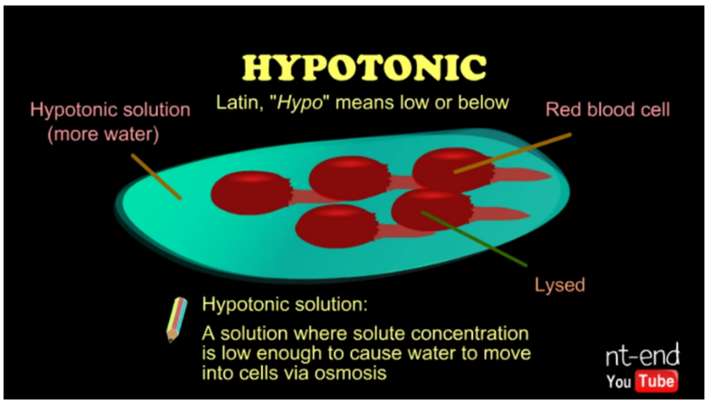
The table below exhibits the details difference between these three tonic solutions

Solution	Glucose 5%	Sodium Chloride 0.9% inside cell	Water inside cell	Sodium Chloride 0.9% outside cell	Water outside cell	Status of cell
Isotonic	No change	0.9%	No Change	0.9%	No change	Healthy, normal red cells sizes

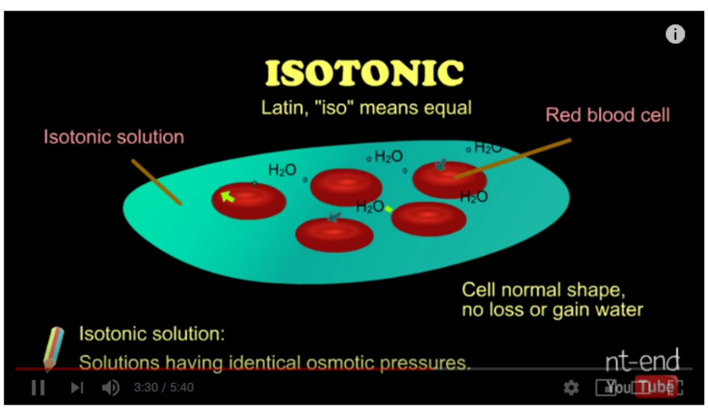
Hypotonic	No change	Higher than 0.9%	Lower amount	Less than 0.9%	Higher amount	Hemolysis, red cells are swollen
Hypertonic	No change	Lower than 0.9%	Higher amount	Higher than 0.9%	Lower amount	Crenation, red cells are shrunk

A You Tube video illustrates the different types of tonicity of the solutions according to its osmosis.

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



Hypotonic Isotonic Hypertonic.mp4



IV. Solubility

Solubility is a term used to express the dissolution of solute in the solvent. Both of the solute and the solvent have different phases, i.e. solute the solid and the solvent is liquid, or the solute is solid and the solvent is a gas etc.

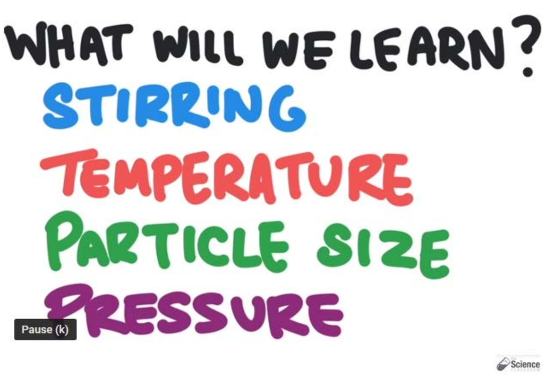
Miscibility on the other hand is used to express the dissolution of the solute and solvent with both solute and solvent have the same phases, i.e. solute is solid and solvent is solid or solute is liquid and the solvent is liquid or a solute is a gas and the solvent is a gas.

The solubility of inorganic ionic compounds in water is affected by the following factors:

1. Temperature:
   The higher the temperature the higher the rate of the dissolution of the solute in the solvent
2. Surface area:
   The higher the surface area of the solute, the higher the rate of the dissolution of the solute in the solvent. An example of this can be seen in the solubility of fine powder sodium chloride in water compared with the solubility of the coarse sodium chloride (rocky sodium chloride) in water. The fine powder sodium chloride has larger surface area and hence higher rate of dissolution in water.
3. Solute concentration:
   The higher the concentration of the solute the higher the rate of dissolution in the solvent.
4. Agitation, shaking and Stirring:
   Agitation, shaking and stirring are increasing the rate of the dissolution of the solute in the solvent.

   A You Tube video illustrates some of the factors affecting solubility:

   https://www.youtube.com/watch?v=qL5-lcc_TfY



Factors that Affect Solubility.mp4

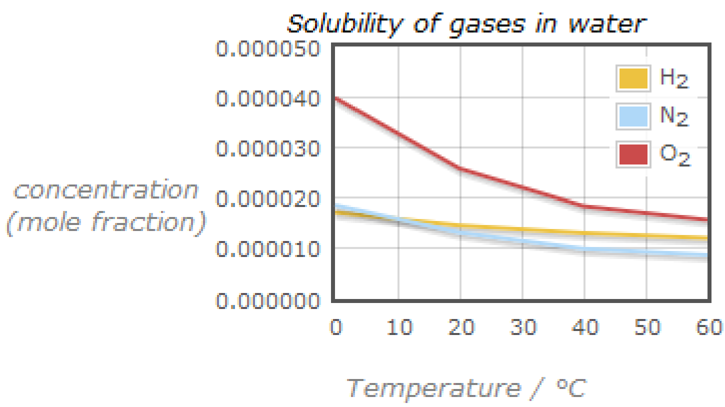
Temperature Effect:

The solubility of solids and in general liquids solutes fin a solvent is increased with increasing the temperature and a polar or none polar solution is obtained. This trend cannot be seen in case of gases solutes.

The solubility of gases in water decreases as the temperature increases. At higher temperatures the gases molecules acquire enough energy to escape the solution.

An example of such escape is the fuzzing CO_2 gas out a soda can when it is open to atmospheric the temperature and when the soda is warmed up to room temperature after it was refrigerated. This effect is illustrated below:

Reference: https://www.ausetute.com.au/henryslaw.html



The partial pressures of gases on the other hand have more effect on their solubility in water.

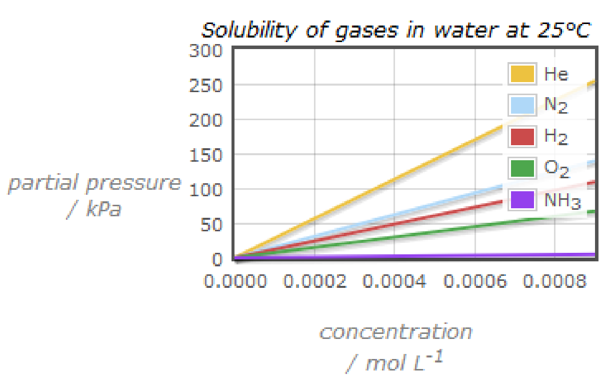
The solubility of gases in water increases as their partial pressures over the solution increases. At higher pressures more molecules of gases are available and can enter the solution and can be dissolved. This is known as Henry's law.

Henry's Law:

Henry's Law has the formula:

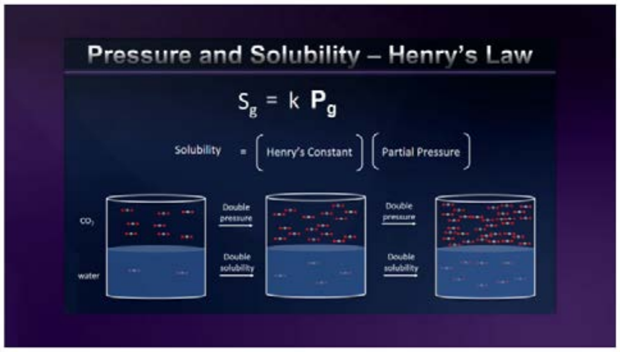
$P = K_H \times C$
Where:
P = partial pressure of a gas above the liquid in Pascal (P) or in kilopascal (kPa).
K_H = Henry's constant in [kPa / (mol/L)]
C = concentration of the solution in (mol/L)
The figure below illustrates the Henry's law of gases solubility in liquids:

Reference: https://www.ausetute.com.au/henryslaw.html



A You Tube video illustrates the Henry's law in some details:

https://www.youtube.com/watch?v=9JtTpPEesOk



Henrys Law and Gas Solubility Explained.mp4

Inorganic Compounds Solids Formation

Some solutes are not soluble in some solvents. The attractive forces within the solute ions in the crystal network are greater than that with the solvent and hence the solvent will not be able to penetrate through the crystal network of the solute and the solute remains in the solution undissolved.

The solubility table is one of the methods used to predict the possible solubility of ionic compounds in water. [Reference: http://mrsspencerslab.weebly.com/semester-2/double-replacement-reaction]

Rule	Important Exceptions
All nitrate (NO_3^-), nitrite (NO_2^-), chlorate (ClO_3^-) and perchlorate (ClO_4^-) salts are soluble.	Silver nitrite and potassium perchlorate are considered slightly soluble.
Essentially, all alkali metal (Li^+, Na^+, K^+, Rb^+, Cs^+) and ammonium (NH_4^+) salts are soluble.	Some Li^+ are insoluble.
Most halogen (Cl^-, Br^-, I^-) salts are soluble.	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+, Tl^+ (Pb^{2+} halogens are soluble in hot water.) $HgBr_2$ is slightly soluble.
Most acetate ($C_2H_3O_2^-$) salts are soluble.	Ag^+, Hg_2^{2+}
Most sulfate (SO_4^{2-}) salts are soluble.	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Pb^{2+}, Ag^+, Hg^{2+} (Some sources consider calcium sulfate and silver sulfate to be slightly soluble.)
Many sulfides (S^{2-}) are insoluble.	All alkali metal and alkaline earth (Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}) sulfides are soluble. Ammonium sulfide is soluble. (Some sources consider MgS, CaS and BaS to be slightly soluble.)
Most borates (BO_3^{2-}), carbonates (CO_3^{2-}), chromates (CrO_4^{2-}), phosphates (PO_4^{3-}), and sulfites (SO_3^{2-}) are slightly soluble.	$MgCrO_4$ is soluble, $MgSO_3$ is slightly soluble.
Most hydroxide (OH^-) salts are insoluble	Alkali metal hydroxides are soluble. Ba^{2+}, Sr^{2+}, Ca^{2+}, Tl^+ are considered slightly soluble.

Examples:

Ionic compounds (solutes)	Solubility in water (solvent)
KNO_3	soluble
NH_4Cl	soluble
$AgBr$	insoluble
$PbSO_4$	insoluble
$CaCO_3$	insoluble
$LiCO_3$	soluble
$Al(OH)_3$	soluble
FeS	insoluble
$Ba_3(PO_4)_2$	insoluble
$NaClO_3$	soluble

Types of Writing Ionic Chemical Equations

There are three types of Writing Ionic Chemical Equations:

1. Molecular Chemical Equation:

   In this type of writing chemical equation, all the ionic compounds are written intact and not taken apart in ions.

   Example:

   $2\ Na_3PO_4(aq) + 3\ Ca(NO_3)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ NaNO_3(aq)$

   In this example Na^+ and Ca^{2+} are exchanging their anions.

2. Complete Ionic Chemical Equation:

   In this type of writing chemical equation, all the ionic compounds with aqueous symbol are written as ions. All solids, liquids and gases are not taken apart.

   $2\ Na_3PO_4(aq) + 3\ Ca(NO_3)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ NaNO_3(aq)$

   All ions will be taken apart, except solids, liquids or gases:

$6\ Na^+(aq) + 2\ PO_4^{3-}(aq) + 3\ Ca^{2+}(aq) + 6\ NO_3^-(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ Na^+(aq) + 6\ NO_3^-(aq)$

3. Net Ionic Chemical Equation:

   In this type of writing ionic chemical equation, all spectator ions will be discarded.
   Spectator ions are ions appear on both sides of the chemical ionic equation and they are said to be chemically inactive and they do not participate in the actual chemical reaction.

   $6\ Na^+(aq) + 6\ NO_3^-(aq)$ are spectator ions and can be discarded.

$\cancel{6\ Na^+(aq)} + 2\ PO_4^{3-}(aq) + 3\ Ca^{2+}(aq) + \cancel{6\ NO_3^-(aq)} \rightarrow Ca_3(PO_4)_2(s) + \cancel{6\ Na^+(aq)} + \cancel{6\ NO_3^-(aq)}$

   The net ionic chemical equation is written as follows:

   $2\ PO_4^{3-}(aq) + 3\ Ca^{2+}(aq) \rightarrow Ca_3(PO_4)_2(s)$

Net ionic chemical equations are considered to be very important because they are expressing the actual chemical species that participate in the chemical reactions.

Example:

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

1. Molecular Chemical Equation:

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

2. Complete Ionic Chemical Equation:

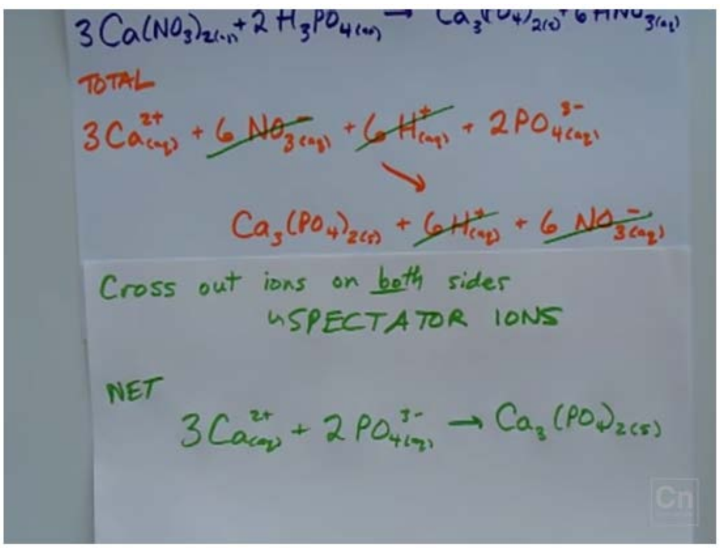
$Mg^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + 2Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq) + 2H_2O(l)$

3. Net Ionic Chemical Equation:

$2OH^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l)$

A You Tube video illustrates the writing of the net chemical equations:

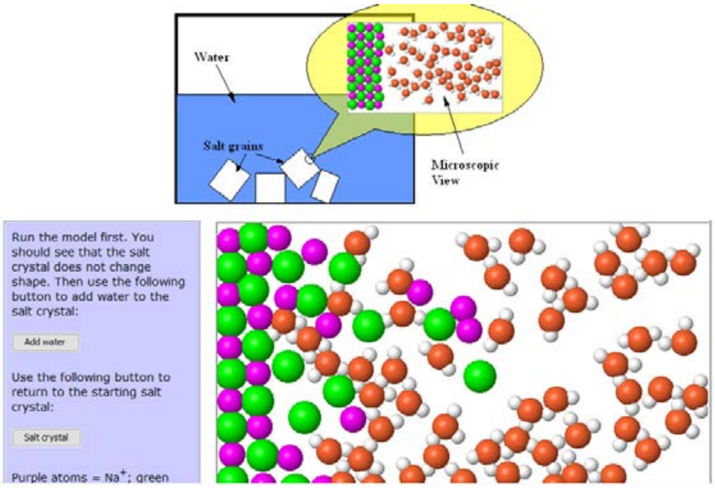
https://www.youtube.com/watch?v=EQIqcT9a7DY



How to Write Total and Net Ionic Equations (Easy).mp4

Molecular Workbench illustrates a simulation of dissolving salt in water. The simulation requires Java software to run:

http://mw.concord.org/modeler/showcase/simulation.html?s=http://mw2.concord.org/public/student/solution/dissolve.html



This simulation demonstrates that dissolution occurs because the electrostatic interactions between water and salt ions compete with the electrostatic interactions among the salt ions themselves and therefore cause the structure of ionic crystal to fall apart.

Try this simulation and make your notes regarding the dissolution of the salt in water and the effect of the electrostatic interactions and answer the questions below. To have better knowledge about the dissolution of the salt in water, your will need to use the buttons showing the electrostatic attractions as well as charges.

Questions:

Why is water able to penetrate the salt crystal network?

Describe the electrostatic attraction forces orientation in the solution i.e. positive and negative charges of the solvent water versus the positive and negative charges of solute sodium chloride.

V. Solution Concentrations

The concentration of a solution is referred to as the ratio of the solute amount to the amount of the solution (or a solvent in some specific cases).

The below is the table summarizing all types of concentrations formulas used in this chapter

Name of the Concentration	Formula	Unit of solute	Unit of solution (solvent)	Overall unit of the formula
(Mass/volume)%	={[mass of the solute]/[volume of the solution]} x100%	Grams (g)	Milliliters (mL)	[g/mL]%
(Mass/mass)% or mass%	=[mass of the solute]/[mass of the solution]x100% Note that: Mass of solution = mass of solute + mass of solvent	Grams (g)	Grams (g)	[g/g]%
(Volume/volume)% or volume%	=[volume of the solute]/[volume of the solution]x100% Note that: Volume of the solution = volume in solute + volume of the solvent	Milliliters (mL)	Milliliters (mL)	[mL/mL]%
(Molarity)	= [moles of the solute]/[liter of solution]	Moles (mol)	Liter (L)	[mol/L] Also can be expressed as M or molar
(Molality)	= [moles of the solute]/[Kilogram of solvent	Moles (mol)	Kilogram (kg)	[mol/kg] Also can be expressed as m or molal
Equivalent molarity of the electrolytes	= [milliequivalents/Liter of solution]	Milliequivalents (mEq)	Liter (L)	[mEq/L]
Dilution	$C_1xV_1 = C_2xV_2$ or sometimes is given in: $M_1xV_1=M_2xV_2$ Where C_1 and M_1 are the concentration and the molarity of the stock solution respectively. C_2 and $M_2$are the concentration and molarity of the diluted solution respectively V_1 is the volume of the stock solution and V_2 is the volume of diluted solution	Moles (mol)	Liter (L)	[mol/L] Also can be expressed as M or molar

Let us now go over some workout problems in some details covering all the formulas.

1. (Mass/volume)%

a. What is the mass/volume percent by of a solution formed by mixing 25.0 grams of sodium chloride NaCl with 455 mL of water?

Solution:

(Mass/volume)% = {[mass of the solute]/[volume of the solution]} x100%

= {[25.0 g NaCl] / [455 mL solution]} x100% = 5.494505494505495% (answer from calculator and it should be rounded off to the correct significant figures which is 3.

Final answer after the significant figures rule consideration is 5.50% (g/mL %)

b. Calculate amount of grams of solute potassium nitrate aqueous solution which is 38.5% (mass/mL%) if the solution made with 1.00 Liter of water.

Solution:

Let us set up the formula and replacing it with the given data:

(Mass/volume)% = {[mass of the solute]/[volume of the solution]} x100%

First the volume should be converted from Liter into milli Liter (mL)

[38.5 g/mL]% = { [X] / [1000 mL] } x 100%

Cross x Multiply

[38.5 g/mL] / [100] = [X] / [1000 mL]

X = 385 g potassium nitrate KNO_3

Verifying the answer:

(Mass/volume)% = {[mass of the solute]/[volume of the solution]} x100%

= [385 g / 1000 mL] x100% = (38.5 g/mL)%

Conclusion the answer is correct.

2. (Mass/mass)% or mass%

a. A solution is formed by adding 48 g of Lithium sulfate to 250 g of water. What is the percent by mass of Lithium sulfate?

(Mass/mass)% or mass% = [mass of the solute]/[mass of the solution]x100%

Note that:

Mass of solution = mass of solute + mass of solvent

(Mass/mass)% = {[48 g of Lithium sulfate] /[48 g of Lithium sulfate + 250 g water]} x 100%

= 16.10738255033557% from calculator and it should be rounded off to the correct significant figures

Final answer = 16% [g/g]%

b. What is the mass of solvent (water) in grams for a solution made of 10.5% mass percent of each component in the mixture formed by adding 2.00 g of Aluminum nitrate in water?

(Mass/mass)% or mass% =[mass of the solute]/[mass of the solution]x100%

Note that:

Mass of solution = mass of solute + mass of solvent

Mass of the whole solution is not known and it will be referred to as X

[10.5 / 100] = [2.00 g Aluminum nitrate] / [X]

Cross / Multiply:

[0.105] * [X] = 2.00

X = [2.00 /0.105] = 19.04761904761905 = 19.0

X = amount of water in grams = 19.0 – 2.00 = 17.0 grams water

Verifying the answer:

[Mass/mass]% = [2.00 /(2.00 + 17.0)] x 100% = 10.52631578947368% = 10.5%

The answer is correct.

3. (Volume/volume)% or volume%

a. What is the percent by volume of a solution formed by added 25 L of ethanol to 155 L of water?

(Volume/volume)% or volume% = [volume of the solute]/[volume of the solution]x100%

Note that:

Volume of the solution = volume in solute + volume of the solvent

(Volume/volume)% = [25 L] /[25L + 155 L] x 100 % = [25 L] / [180 L] = 13.88888888888 %. The answer is from calculator and it should be rounded off to the correct significant figures

Final answer is 14 % (two significant figures).

b. A 5.50% volume percent solution is made by adding certain amount of volume of a solute acetone to 255 mL water as solvent. Calculate the amount of the acetone in mL added.

(Volume/volume)% or volume% = [volume of the solute]/[volume of the solution]x100%

Note that:

Volume of the solution = volume in solute + volume of the solvent

Amount of the solute is unknown and it will be referred to as X

5.50% = [X] / [X + 255 mL]

0.0550 = [X] / [X + 255 mL]

0.0550 [X + 255 mL] = [X]

0.0550 X + (0.0550*255) = [X]

Solving for X

0.0550*255 = X – 0.0550 X = 0.945 X

X = 14.8 mL (3 significant figures)

Verifying the answer:

Volume/volume)% = { [14.8 mL] / [14.8 mL + 255 mL] } x 100% = 5.485544848035582 % rounded to 3 significant figures = 5.50 %. The answer is correct.

4. Molarity

Molarity = [moles of the solute]/[liter of solution]

a. Calculate the molarity of solution made by dissolving 35.0 grams of sodium chloride solid in 97890. mL distilled water.

Molarity = [moles of the solute]/[liter of solution]

First one has to calculate the number of moles of sodium chloride with given mass of 35.0 grams. Therefore, one has to use the molar mass of sodium chloride in calculating number of moles with given number of grams.

Molar mass of sodium chloride = NaCl using the atomic masses of Na and Cl, the molar mass is:

23.0 g/mole + 35.5 g/mol = 58.5 g/mol

Number of moles of sodium chloride = (35.0 g) / (58.5 g/mol) = 0.598 moles NaCl

Second one has to convert the mL into Liters by dividing by 1000 =(97890. mL) / (1L / 1000 mL) = 97.890 L

Molarity = [0.598 moles NaCl] / [97.890 L} = 0.006108897742363877 mol/L. This the calculator's answer and it will be rounded off to the correct significant figures (3 significant figures).

Molarity = 0.00611 mol/L or 0.00611 M or 0.00611 molar.

b. A solution of a molarity of 2.675 M is prepared by dissolving 8.50 gram of magnesium nitrate in certain amount of distilled water as a solvent. Calculate the amount of the distilled water.

First one has to calculate the number of moles of magnesium nitrate with given mass of 8.50 grams.

Therefore, one has to use the molar mass of magnesium nitrate in calculating number of moles with given number of grams.

Molar mass of magnesium nitrate = $Mg(NO_3)_2$ using the atomic masses of Mg and 2 (NO_3), the molar mass is: 24.3 g/mol + 2x (14.0 g/mol) + 2 (3 x 16.0 g/mol) =148.3 g/mol

Number of moles of magnesium nitrate = [8.50 g $Mg(NO_3)_2$] / [148.3 g $Mg(NO_3)_2$ / mol $Mg(NO_3)_2$]

Number of moles of magnesium nitrate = 0.0573 moles

2.675 M = 2.675 mol /L = [0.0573 mol] / [X]

X = amount of the solution or solvent in Liters

Solving for X, one can obtain:

2.675 X = 0.0573

X = 0.0573 / 2.675 = 0.02142056074766355 Liters. The correct rounded off answer has to have three significant figures. The final correct answer is 0.0214 Liters

Verifying the answer: = [0.0573 mol] / [0.0214 Liters] = 2.6775700934579439 = 2.678 mol/L

The answer is correct. Note that the verified answer is not exactly the given molarity of 2.675 mol/L. This is because of the in between rounding off and rounding off the atomic masses.

c. 10.00×10^{26} molecules of acetone dissolved to make 3500. mL of water of solvent. Calculate the molarity of acetone solution.

First one has to calculate the number of moles of acetone with given number of molecules.

Number of moles of acetone = [10.00×10^{26} molecules of acetone] x [1 mole acetone/6.022×10^{23} molecules of acetone]

One has to use the Avogadro's number of 6.022×10^{23} to calculate number of moles:

1 mole of acetone = 6.022×10^{23} molecules of acetone

Moles of acetone = 1660.577881102624 moles

The volume of solution is 3500. mL = 3.500 L (volume is converted into Liters)

Molarity = [1660.577881102624 moles] / [3.500 L] = 474.4508231721783 mol/L = 474.5 M or 474.5 mol/L or 474.5 molar.

The answer is rounded to the correct 4 significant figures.

5. Molality = [moles of the solute]/[Kilogram of solvent

a. What is the molality of a solution made of 9.384 grams of aluminum nitrate has been dissolved in 5500.0 g water

First the number of moles of aluminum nitrate is calculated using the molar mass of aluminum nitrate.
Molar mass of aluminum nitrate= $Al(NO_3)_3$ = Al + 3N + 9O = 27.0 g/mol + (3 x 14.0) g/mol + (9 x 16.0 g/mol) = 213.0 g/mol
Number of moles = [9.384 grams of aluminum nitrate] / [mol aluminum nitrate /(= 213.0 g/mol)] = 0.04405633802816902 moles aluminum nitrate.

Second to convert 5500.0 g water into kilo grams water by diving by 1000 = 5.500 kg water

Molality = [0.04405633802816902 moles aluminum nitrate] / [5.500 kg water] = 0.008010243277848913 mol/kg.
The answer should be rounded off to the correct significant figures of 4.
The final correct answer is 0.008010 mol/kg or m or molal.

b. What mass of water is required to dissolve 45.0 grams calcium chloride to prepare a 2.50 m solution?

First the number of moles of calcium chloride is calculated using the molar mass of calcium chloride.
Molar mass of calcium chloride $CaCl_2$ = Ca + 2 Cl = 40.0 g/mol + 2x 35.5 g/mol = 111.0 g/mol
Number of moles $CaCl_2$ = [45.0 g calcium chloride] / [111.0 g/mol] = 0.4054054054054054 moles = 0.405 moles $CaCl_2$

Second the molality formula is used:

2.50 m = [2.50 CaCl2 mol / kg water] = [0.405 moles $CaCl_2$] / X
Where X is the amount of water

Solving for X yields:
X = 0.405 / 2.50 = 0.162 kg water

Verifying:

Molality = [0.405 moles $CaCl_2$] / [0.162 kg water] = 2.50 m

6. Equivalent molarity of the electrolytes

Milliequivalents (mEq) calculations are covered in greater details in the link below:

https://www.researchgate.net/file.PostFileLoader.html?id=546acea8d4c1182b638b473a&assetKey=AS:273639646138393@1442252184176

Milliequivalents calculations cover the three topics:

a. Converting milliequivalents to weight
b. Converting weight to milliequivalents
c. Converting milligrams% into milliequivalents

Each electrolyte such as Na^+ is measured in equivalent (Eq).For example 1 mole of an ionic compound of NaCl dissolved in water will produce 1 mole of Na^+ 1 mole of and Cl^-. Each Na^+ and Cl^- which equal to 1 equivalent each.

The table below illustrates the relationship between the electrolytes charge and number of the equivalents.

ion	Ion charge	Ion Oxidation number	Number of Equivalents per 1 mole
Li^+, Na^+, $K^+NH_4^+$	1+	+1	1 Eq
Mg^{2+}, Ca^{2+}, Ba^{2+}	2+	+2	2 Eq
Al^{3+}, Cr^{3+}, Fe^{3+}	3+	+3	3 Eq
Br^-, I^-, F^-	1-	-1	1 Eq
CO_3^{2-}, SO_4^{2-}	2-	-2	2 Eq
PO_4^{3-}	3-	+3	3 Eq

a. Converting milliequivalents to weight

What is the concentration of a solution contains 8.50 mEq/L of NaCl?

First the molar mass of NaCl should be calculated. NaCl molar mass is calculated in the above examples and it equals 58.5 g/mol

Second use the general formula for the calculation of the milligram/L from mEq/L:

Mg/L = [(mEq/L) x (atomic mass or molar mass)] / [number of the equivalent)

Mg/L = [(8.50 mEq/L) x (58.5 g /mol)] / [1 Eq/ 1 mol] = 497.25 mg / L

Final answer is 497 mg / L (3 significant figures).

b. Converting weight to milliequivalents

How many mEq of NaCl are in 10.5 g of NaCl?

First the molar mass of NaCl should be calculated. NaCl molar mass is calculated in the above examples and it equals 58.5 g/mol

Second use the setup that relates mEq to mass of electrolytes using molar mass:

mEq = {[10.5 g of NaCl] / [58.5 g NaCl/mol]} * [Eq /1 mol] * [1000 mEq/ 1Eq] = 179 mEq

c. Converting milligrams% into milliequivalents

Convert the expression 15.0 mg% of Ba^{2+} to mEq/L

Ba^{2+} atomic mass = 137.3 g/mol

Ba has 2+ ion and hence 2 Eq

Equivalent mass of Ba^{2+} = [137.3 g/mol] / [2 Eq/mol] = 68.65 g/Eq = 68.7 g per Eq

1mEq Ba^{2+} = [68.7 g] / [1 g/1000 mg] = 0.0687 mg

15.0 mg% = [15.0 mg Ba^{2+}] / [100 mL solvent] = [15.0 mg/ 100 mL]*[1000 mL/1L] = 150. mg/L

0.0687 mg/ 1 mEq = 150. mg/ X mEq

Solving for X = 150. / 0.0687 = 2183.406113537118 mEq/L rounded off to 2180 mEq/L (3 significant figures) or expressed in scientific notation 2.18 X 10^3 mEq/L

7. Dilution

$C_1xV_1 = C_2xV_2$ or sometimes is given in:
$M_1xV_1=M_2xV_2$
Where C_1 and M_1 are the concentration and the molarity of the stock solution respectively. C_2 and $M_2$are the concentration and molarity of the diluted solution respectively
V_1 is the volume of the stock solution and V_2 is the volume of diluted solution
The stock solution is considered as the most concentrated solution.

Examples:

a. If 75.5 mL of water are added to 875.0 mL of a 0.125 M HNO_3 solution, what will be the new molarity of the diluted solution?
$C_1xV_1 = C_2xV_2$
Total volume = V_2 = 75.5 + 875.0 = 950.5 mL
0.125 M x 875.0 mL = C_2 x 950.5 mL
C_2 = [0.125 M x 875.0 mL] / [950.5 mL] = 0.115 M

b. If 500.0 mL are added to 0.150 M HCl solution until the final volume is 650.0 mL, what will be the molarity of the diluted solution?
$C_1xV_1 = C_2xV_2$
Total volume = V_2 = 650.0 mL
0.150 M x 500.0 mL = C_2 x 650.0 mL
C_2 = [0. 0.150 M x 500.0 mL] / [650.0 mL] = 0.115 M

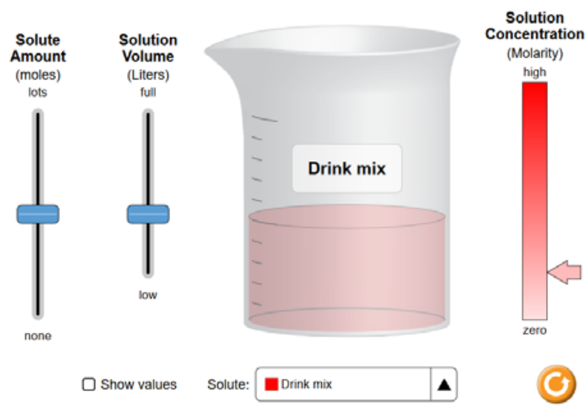
c. How much water should be added to 985 mL of a 6.55 M NaOH solution to make a 1.00 M solution?
$C_1xV_1 = C_2xV_2$
Total volume = V_2 = X + 985 mL
X = volume of water
6.55 M x 985 mL = 1.00 M x V_2
V_2 = [6.55 M x 985 mL] / [1.00 M] = 6451.75 mL
X + 985 mL = 6451.75 mL
X = 5466.75 mL = 5470 mL rounded off to 3 significant figures

d. 450.5 mL of a 2.660 M KNO_3 solution. If one boils the water until the volume of the solution is half of its amount, what will be the molarity of the solution after the boiling?
$C_1xV_1 = C_2xV_2$
Total volume = V_2 = 450.5/2 mL = 225.3 mL
450.5 mL x 2.660 M KNO_3 = C_2 x 225.3 mL
C_2 = [450.5 x 2.660] / [225.3] = 5.319 M [Boiling the stock solution had led to higher concentration of the new boiled solution]

After going over couple examples of the concentrations, let us look at some available simulation activities for the concentrations of the solution.

A Phet molarity simulation activity is given below:

https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html



In this simulation, the students will use the information below:

Solution volume is the combined volume of solute and water.

By design, not all solutions will reach saturation. The number of moles that can be added is limited to the range of 0.2-1.0 moles so that students can explore some solutions for the full concentration range (0-5 M).

Drink mix is assume to have the same solubility as sucrose.

Solubility of each solution listed was calculated at 25^0 C, except for $AuCl_3$ and Drink mix, which were based on data taken at 20^0 C.

Activity:

Determine the qualitative relationships between molarity, moles, and liters before completing quantitative problems or data collection.

The simulation demonstrates saturation but does not explain why different solutes have different solubilities. The Drink Mix example provides a real-world link to the concept of concentration to help the students make connections to the chemical examples. Determine the saturation molarity in mol/L for all salts (solutes) in the simulation.

Questions:

1. Which one of the salts (solutes) used has the largest saturation concentration

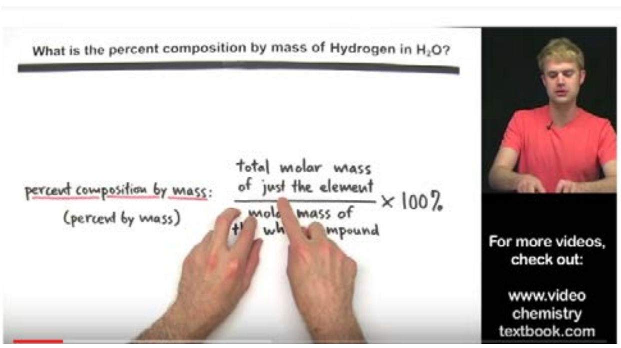
2. Which one of the salts (solutes) used has the smallest saturation concentration

3. Arrange the salts (solutes) in increasing order of saturation concentration. Explain the difference in the saturation concentrations among the salts (solutes).

Several You Tube videos discussing the concentration of solution:

(Mass) %

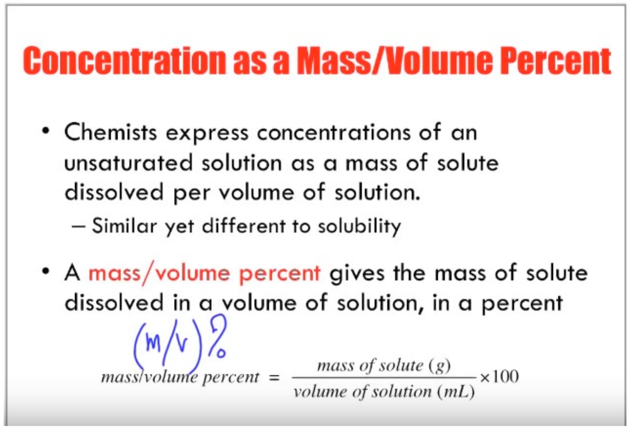
https://www.youtube.com/watch?v=lywmGCfIUIA



Percent Composition By Mass.mp4

(Mass/volume) %:

https://www.youtube.com/watch?v=dl6G_p6gsJc

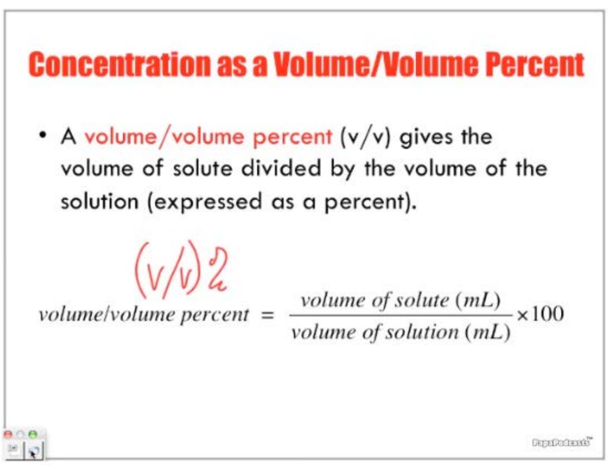


Concentration of Solutions Introduction MassVolume % (mv)%.mp4

(Volume/volume) %

https://www.youtube.com/watch?v=RCbhk3yyM88

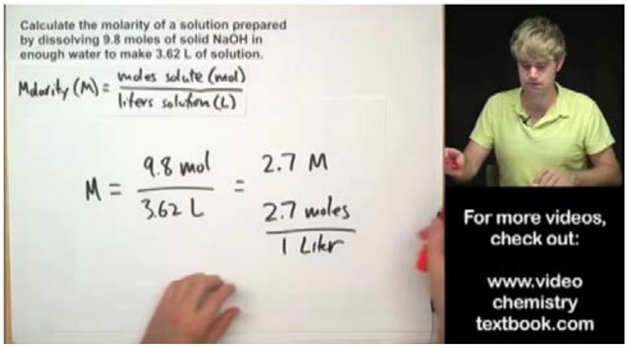
Concentration of Solutions VolumeVolume % (vv).mp4



Concentration of Solutions VolumeVolume % (vv).mp4

Molarity:

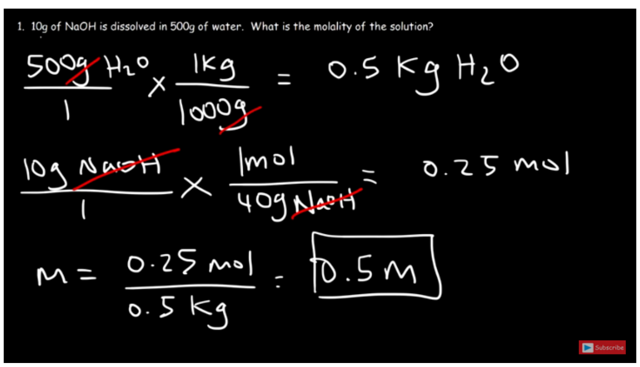
https://www.youtube.com/watch?v=SXf9rDnVFao



Molarity Practice Problems.mp4

Molality:

https://www.youtube.com/watch?v=uj1u7Nx9JUc



How To Calculate Molality Given Mass Percent Molarity Density and Volume Percent - Chemistry.mp4

Dilution:

https://www.youtube.com/watch?v=v6dnEp58mVk

When diluting a more concentrated solution:

-the volume increases
-the number of moles stays the same

(Initial Concentration)(Initial Volume) = (Final Concentration)(Final Volume)

$$M_1V_1 = M_2V_2$$

Initial and final concentrations must have the same units.
Initial and final volumes must have the same units.

Dilution Problems - Chemistry Tutorial.mp4

VI. Concentrations Calculations in Chemical Reactions

Concentrations and moles calculations in chemical reactions are known as stoichiometry. In most cases, one reactant is used in excess and the other reactant is used in limiting amount. The concentration of the product or the yield of the product is calculated based on the limited reactant amount because it is consumed completely during the chemical reaction.

In the example below, the molarity and the volume of the reactant are used to determine the molarity of the other reactant molarity and/or volume:

Example:

$2\ Na_3PO_4(aq) + 3\ Ca(NO_3)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ NaNO_3(aq)$

If 355.0 mL of 0.380 M Na_3PO_4 are required to react with 0.135 M $Ca(NO_3)_2$ to produce $Ca_3(PO_4)_2$.

Calculate the amount of the volume $Ca(NO_3)_2$ needed for this reaction.

Solution:

Step 1: number of moles of a given reactant using its molarity and volume:

Number of moles of Na_3PO_4:

355.0 mL are converted into Liters and multiplied with molarity 0.380 mol/L = 0.3550 L X 0.380 mol/L = 0.1349 moles Na_3PO_4

Step 2: using the mole ratio of both reactants from the chemical equation above, one can calculate number of moles of the other reactant:

Mole ratio = 2 moles Na_3PO_4 / 3 moles $Ca(NO_3)_2$ or 3 moles $Ca(NO_3)_2$ / 2 moles Na_3PO_4

Moles of $Ca(NO_3)_2$ = [3 moles $Ca(NO_3)_2$ / 2 moles Na_3PO_4] x [0.1349 moles Na_3PO_4] = 0.20235 moles

Step 3: amount of the volume of $Ca(NO_3)_2$ can be calculated using its molarity and number of moles:

Amount of $Ca(NO_3)_2$ needed = [0.20235 moles $Ca(NO_3)_2$] / [0.135 mol / L $Ca(NO_3)_2$ = 1.50 L (3 significant figures)

Example:

How many liters of 0.188 M hydrochloric acid HCl would be required to react completely with 2.85 grams of sodium hydroxide NaOH according to the reaction below?

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

Step 1: number of moles of NaOH is calculated with the help of the molar mass of NaOH:

Molar mass of NaOH = Na + O + H = 23.0 + 16.0 + 1.0 = 40.0 g/mol

NaOH number of moles = [(2.85 g) / (40.0 g/mol)] = 0.07125 mol

Step 2: using the mol ratio from the chemical equation:

Mole ratio = 1 mol HCl / 1 mol NaOH = 1:1

HCl moles = NaOH moles = 0.07125 mol

Step 3: with the help of molarity of HCl and its number of moles, its volume can be calculated

Volume of HCl = [0.07125 mol HCl / (0.188 mol/L)] = 0.379 L

VII. Colligative Properties of Solutions

The colligative properties of the solution are physical properties that depend on the amount of solute particles in the solution.

Adding solute particles to the pure solvent will lead to a decrease in the freezing point and an increase in the boiling point of the solvent. Also adding the solute particles to pure solvent will lead to a decrease in the vapor pressure of the solvent.

Let us look at each colligative property by itself:

a. Freezing point depression (decrease):

When a nonvolatile solute is added to a pure solvent, the pure solvent freezing point is lowered because of the solute particles are preventing the pure solvent molecules to organize and hence less temperature is needed before the solvent molecules become organized to freeze.

Antifreeze ethylene glycol is added to car radiator to lower the freezing point of the radiator water solution. Ethylene glycol has higher boiling point of water.

Change in Freezing point:

The addition of the solute particles will lower the freezing point. This change can be calculated using the formula below:

$\Delta T_F = T_F(\text{pure solvent}) - T_F(\text{solution}) = (i) \times K_F \times \text{molality}$

Where:

T_F(pure solvent) = Freezing point of the pure solvent

T_F(solution) = Freezing point of the solution

I = Number of the particles present and it is called the van't Hoff factor

K_F = Molal freezing point constant in (kg ^{o}C)/mol

m = molality in mol solute / kg solvent = [(mass /molar mass) solute] / kg solvent

(molar mass) = [(i) x K_F x mass solute] / [(ΔT_F) x (kg solvent)]

The molal freezing point constant K_F is given in a table out of the reference:

http://www.kbcc.cuny.edu/academicDepartments/PHYSCI/PL/chm11/Documents/FreezingPoint.pdf

Material	mp (°C)	K_F $\left(\frac{kg\,°C}{mol}\right)$	Material	mp (°C)	K_F $\left(\frac{kg\,°C}{mol}\right)$
acetone	-94.9	4.04	lauric acid	45	3.9
acetic acid	16.7	3.90	naphthalene	80.5	6.94
ammonia	-77.7	0.957	phenol	40.5	7.40
aniline	-6.3	5.87	sulfuric acid	10	1.86
benzene	5.5	5.12	water	0.0	1.86
cyclohexane	6.6	20.0	o-xylene	-25	4.3

Where mp is the melting point which is equal the freezing point of the material.

The value of I depends on the status of the dissociation of compound in water. For example, nonelectrolytes do not dissociate and hence I = 1

1 mole of sugar $C_6H_{12}O_6(s)$ + $H_2O(l)$ → 1 mole of sugar $C_6H_{12}O_6(aq)$ [I = 1 mole of particles]

1 mole of NaCl(s) + $H_2O(l)$ → 1 mole $Na^+(aq)$ + 1 mole $Cl^-(aq)$ [I = 2 moles of particles]

1 mole of $Ca_3(PO_4)_2(s)$ → 3 $Ca^{2+}(aq)$ + 2 $PO_4^{3-}(aq)$ [I = 5 moles of particles]

Example:

80.50 grams of naphthalene are dissolved in 5546.5 grams of benzene. What will be the change in the freezing point of benzene? K_F of benzene from the table above is 5.12 (kg °C)/mol. Freezing point of benzene is 5.5 °C.

Solution:

Solute = naphthalene $C_{10}H_8$ with the molar mass of 128.2 g / mol

Solvent = benzene

Step 1: the molality should be calculated.

Moles of naphthalene = (80.50 g) / (128.2 g / mol) = 0.6279 moles

molality = 0.6279 moles / 5.5465 kg = 0.1132 m = 0.1132 mol / kg

Step 2: Freezing point depression formula is used.

$\Delta T_F = T_F(\text{pure solvent}) - T_F(\text{solution}) = (i) \times K_F \times \text{molality}$

$\Delta T_F = 5.5\ °C - T_F(\text{solution}) = 1 \times [5.12\ (kg\ °C)/mol] \times [0.1132\ mol / kg]$

1 mol naphthalene $C_{10}H_8(s)$ + benzene(l) → 1 mol naphthalene $C_{10}H_8(l)$ [I = 1 mole of particles]

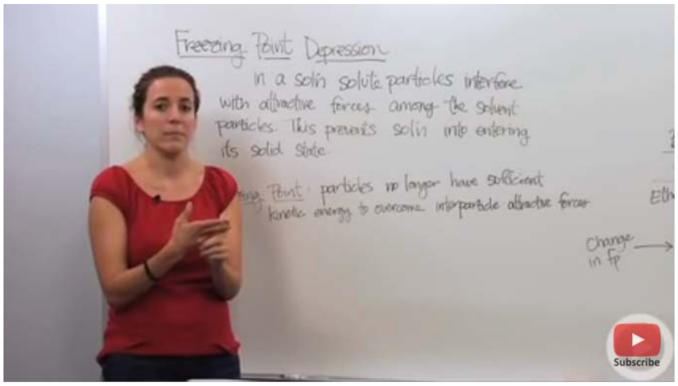
$5.5\ °C - T_F(\text{solution}) = 1 \times [5.12\ (kg\ °C)/mol] \times [0.1132\ mol / kg]$

$5.5\ °C - T_F(\text{solution}) = 0.580\ ^0C$

$T_F(\text{solution}) = 5.5\ °C - 0.580\ ^0C = 4.9\ °C$

A You Tube video illustrates the Freezing Point Lowering calculations:

https://www.youtube.com/watch?v=06Buf6N2Yp4&feature=youtu.be&t=13



Freezing Point Depression.mp4

b. Boiling point elevation (increase):

When a nonvolatile solute is added to a pure solvent, the pure solvent boiling point is increase. This is because the addition of a nonvolatile solute to a pure solvent will lower of vapor pressure of the pure solvent. The vapor pressure of pure solvent should reach atmospheric pressure before it begins to boil and since the vapor pressure is lowered by this addition, a higher temperature needed than the boiling point of original pure solvent boiling point to bring the solution to boiling.

Change in Boiling Point:

The addition of the solute particles will increase the boiling point. This change can be calculated using the formula below:

$\Delta T_B = T_B(\text{solution}) - T_B(\text{pure solvent}) = (i) \times K_B \times \text{molality}$

Where:

T_B(pure solvent) = Boiling point of the pure solvent

T_B(solution) = Boiling point of the solution

I = Number of the particles present and it is called the van't Hoff factor

K_B = Molal boiling point constant in (kg °C)/mol

m = molality in mol / kg

The molal boiling point constant K_B is given in a table out of the reference:

https://chem.libretexts.org/Textbook_Maps/General_Chemistry/Map%3A_General_Chemistry_(Petrucci_et_al.)/13%3A_Solutions_and_their_Physical_Properties/13.08%3A_Freezing-Point_Depression_and_Boiling-Point_Elevation_of_Nonelectrolyte_Solutions

Material	Boiling Point (°C)	K_B (Kg °C/mol)
acetic acid	117.90	3.22
benzene	80.09	2.64
d-(+)-camphor	207.4	4.91
carbon disulfide	46.2	2.42
carbon tetrachloride	76.8	5.26
chloroform	61.17	3.80
nitrobenzene	210.8	5.24
water	100.00	0.51

Example:

25.50 grams of acetic acid CH_3COOH are dissolved in 2550.0 grams water H_2O. What will be the boiling point of the resulting solution?

Solution:

Solute = acetic acid CH_3COOH, molar mass = 60.00 g/mol and K_B = 0.51 (Kg °C/mol)

Solvent water H_2O

Step 1: the molality should be calculated.

Amount of solvent should converted into kilograms = 2550.0 gram = 2.5500 kg

Moles of acetic acids = (25.50 g) / (60.00 g/mol) = 0.4250 moles

molality = 0.425 moles acetic acid / 2.5500 kg water = 0.1667 mol/kg

Step 2: Boiling point elevation formula is used.

$\Delta T_B = T_B(\text{solution}) - T_B(\text{pure solvent}) = (i) \times K_B \times \text{molality}$

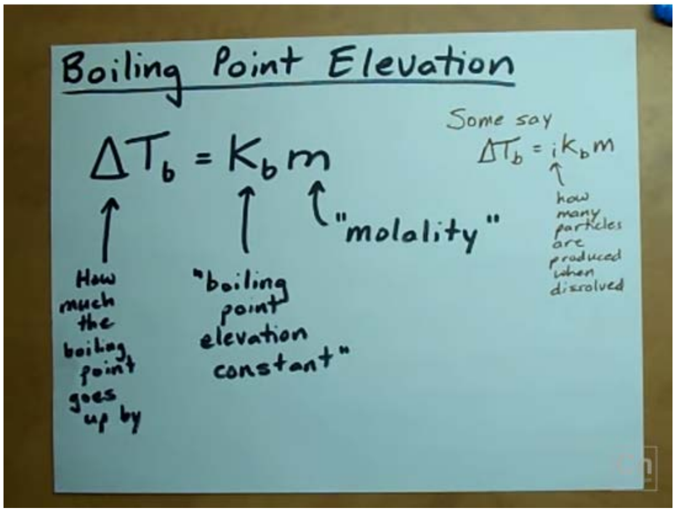
$CH_3COOH(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CH_3COO^-(aq)$ [1 mole acetic acid will have 2 moles of particles and hence I = 2]

$\Delta T_B = T_B(\text{solution}) - 100.0\ ^oC = (2) \times (0.51\ kg\ ^oC/mol) \times (0.1667\ mol/kg) = 0.17\ ^oC$

$T_B(\text{solution}) = \Delta T_B + 100.0\ ^oC = 0.17\ ^oC + 100.0\ ^oC = 100.17\ ^oC = 100.2\ ^oC$

A You Tube video illustrates the Boiling Point Elevation calculations:

https://www.youtube.com/watch?v=QX4efwPcGt4



Find the Boiling Point (Elevation).mp4

VIII. Dialysis

Dialysis is a method of separating larger particles such as colloids from small particles such as sodium chloride via a semipermeable membrane.

This method has several medical and chemical applications, kidney dialysis to name a few.

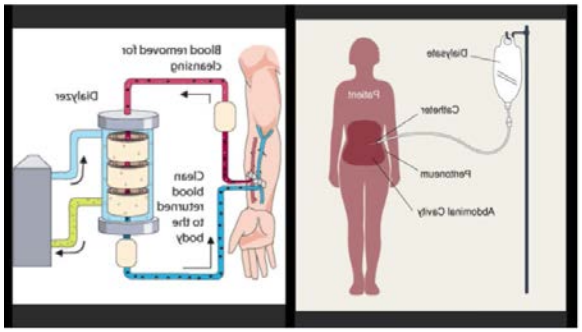
The kidney is very important organ in our body which has the duty to remove harmful particles from the blood stream and also to regulate the blood ionic concentration at the same time keep the important needed particles in the blood.

Kidney dialysis

When the kidney is malfunctioned, dialysis must be performed to remove all harmful and unwanted large molecules using kidney dialysis machine which is using semipermeable membrane.

A You Tube illustrates the kidney dialysis.

https://www.youtube.com/watch?v=fKlY2SKi_dk



How Does Dialysis Work.mp4

End of Chapter Questions:

I. Solutions Are Around Us.

Check the appropriate categories for mixtures listed below. All substances will have a check in more than one column.

Substance	**Heterogeneous Matter**	**Homogeneous Matter**	**None**
lead metal			
table salt ($NaCl$)			
Kool-Aid drink			
vegetable soup			
oxygen gas			
distilled water			
Concrete			
pure gold			
brass metal			
flat 7-Up soda			
raw egg (cracked open)			
Air			
pure iron			
iron rust (Fe_2O_3)			
dirt			
baking soda ($NaHCO_3$)			

State if the mixture below homogeneous or heterogeneous, if it is neither/nor select neither/nor:

1. Carbonated soft drink (w bubbles)
2. Chocolate chip ice cream
3. Italian salad dressing
4. Corn syrup
5. Soil
6. Aluminum foil
7. Black coffee
8. Sugar water
9. air (with smog)
10. paint
11. rubbing alcohol
12. full fat milk
13. beach sand
14. pure air
15. chunky spaghetti sauce

II. Solutions Definition

Fill in your answers with **soluble** or **insoluble** in the following table below:

Solute:	Solvent: H_2O	Solvent: CCl_4	Solvent: Alcohol
NaCl			
I_2			
CH_3CH_2OH (Ethyl Alcohol)			
C_6H_6 (Benzene)			
Br_2			
KNO_3			
$Ca(OH)_2$			
C_7H_8 (Toluene)			
CH_3OH (Methyl Alcohol)			
HCl			
NaOH			
$C_3H_5(OH)_3$ (Glycerol)			
CH_3COOH (Acetic Acid)			
$Mg(ClO_3)_2$			
NH_4OH			
H_2SO_4			
NH_4NO_3			
C_6H_{12} (Cyclohexane)			
$LiClO_4$			
$KMnO_4$			

III. Classification of Solutions

Fill in your answers in the table below:

Compound Formula	Compound Name	Ionic or Covalent?	Electrolyte? Strong or Weak?	Nonelectrolyte?
	Glucose			
KNO_2				
	Calcium Hydroxide			
P_4				
Ethanol				
	phosphoric acid			
	tin(II) phosphate			
$Fe(OH)_3$				
	Ammonium phosphate			
$PbCO_3$				
	Aluminum nitrate			
S_8				

Select the correct choice:

1. Sugar dissolved in water is an example of which solute-solvent combination?

   a) gas-liquid
   b) solid-liquid
   c) liquid-liquid
   d) liquid-solid

2. Which mixture is made up of the smallest particles?

   a) milk
   b) shaving cream
   c) salt water
   d) muddy water

3. Which mixture contains visible particles that settle out unless the mixture is stirred?

   a) a colloid
   b) a solution
   c) a homogeneous mixture
   d) a suspension

4. A metal solution is a(n)

   a) colloid.
   b) suspension.
   b) alloy.
   d) emulsion.

5. A substance whose water solution is a good conductor of electricity is a(n)

   a) nonelectrolyte.
   b) nonpolar substance.
   c) electrolyte.
   d) solute.

6. Which of the following is an electrolyte?
   a) sodium chloride
   b) pure water
   c) sugar
   d) glass

7. Which of the following does *not* increase the rate of dissolving a solid in water?
   a) raising the temperature of the water
   b) stirring the solution
   c) using larger pieces of solid
   d) crushing the solid

8. Increasing the surface area of the solute
   a) increases the rate of dissolution.
   b) decreases the rate of dissolution.
   c) has no effect on the rate of dissolution.
   d) can increase, decrease, or have no effect on the rate of dissolution.

9. Which of the following will dissolve most rapidly?
   a) sugar cubes in cold water
   b) sugar cubes in hot water
   c. powdered sugar in cold water
   d. powdered sugar in hot water

10. In a solution at equilibrium,
   a) no dissolution occurs.
   b) the rate of dissolution is less than the rate of crystallization.
   c) the rate of dissolution is greater than the rate of crystallization.
   d) the rate of dissolution and the rate of crystallization are equal.

11. "Like dissolves like" is a very general rule used for predicting whether
   a) one substance will form a solution with another.
   b) one substance will react with another.
   c) a reaction will reach equilibrium.
   d) a mixture will contain two or three phases.

12. Which of the following is an example of a polar solvent?
   a) carbon tetrachloride
   b) water
   c) benzene
   d) gasoline

13. What is an electrolyte?
   a) compound that dissolves by breaking into ions and conducting electricity in solution.
   b) substance that has covalent bonds
   c) substance that does not conduct electricity but dissolves in water
   d) substance that shares electrons

14. Why does an open soda go flat?
    a) because there is greater surface area for the gas to react with the air
    b) because the pressure on the dissolved gas is released.
    c) because there is greater entropy.
    d) because the temperature of the gas is decreased.

IV. Solubility

Determine the correct net ionic equation in the following multiple choices:

15. Which of the following net ionic equations best represents the reaction that takes place in aqueous solution when dilute ammonia and manganese (II) nitrate solution are mixed?

a. $Mn^{2+} + 2NH_3 + 2H_2O \leftrightarrow Mn(OH)_2 + 2NH_4^+$

b. $Mn(NO_3)_2 + 2OH \leftrightarrow Mn(OH)_2 + 2NO_3^-$

c. $Mn(NO_3)_2 + 2NH_3 + 2H_2O \leftrightarrow Mn(OH)_2 + 2NH_4NO_3$

d. $Mn^{2+} + 2OH^- \leftrightarrow Mn(OH)_2$

e. $NO_3^- + NH_4^+ \leftrightarrow NH_4NO_3$

16. Which of the following net ionic equations best represents the reaction that takes place in aqueous solution, when sulfuric acid and sodium hydroxide solutions are mixed?

    a. $H_2SO_4 + 2NaOH \leftrightarrow Na_2SO_4 + 2H_2O$

    b. $H_2SO_4 + 2OH^- \leftrightarrow SO_4^{2-} + 2H_2O$

    c. $H^+ + NaOH \leftrightarrow Na^+ + H_2O$

    d. $H^+ + OH^- \leftrightarrow H_2O$

    e. No reaction

17. The net ionic equation for the reaction, if any, which occurs when aqueous solutions of manganese(II) chloride and sodium carbonate are mixed is:

    a. $MnCl_2 + CO_3^{2-} \leftrightarrow MnCO_3 + 2Cl^-$

    b. $MnCl_2 + 2Na^+ \leftrightarrow 2NaCl + Mn^{2+}$

    c. $MnCl_2 + Na_2CO_3 \leftrightarrow MnCO_3 + 2NaCl$

    d. $Mn^{2+} + 2Cl^- + 2Na^+ + CO_3^{2-} \leftrightarrow$ no reaction

    e. $Mn^{2+} + CO_3^{2-} \leftrightarrow MnCO_3$

18. The net ionic equation for the reaction, if any, when aqueous solutions of $CuCl_2$ and Na_2S are mixed is:

    a. $Cu^{2+} + S^{2-} \leftrightarrow CuS$

    b. $Cu + S \leftrightarrow CuS$

c. $CuCl_2 + S^{2-} \leftarrow\rightarrow CuS + 2Cl^-$

d. $Na_2S + Cu^{2+} \leftarrow\rightarrow CuS + 2Na^+$

e. $Na_2S + CuCl_2 \leftarrow\rightarrow CuS + 2NaCl$

19. Which net ionic equation best represents the reaction (if a reaction occurs) between $NaC_2H_3O_2$ and HCl:

a. $Na^+ + Cl^- \leftarrow\rightarrow NaCl$

b. $C_2H_3O_2^- + H^+ \leftarrow\rightarrow HC_2H_3O_2$

c. $NaC_2H_3O_2 + H^+ \leftarrow\rightarrow HC_2H_3O_2 + Na^+$

d. $C_2H_3O_2^- + HCl \leftarrow\rightarrow CCl^- + 2H_2 + CO_2$

e. No reaction will occur.

20. A mixture that has uniform composition throughout is called

a) saturated solution
b) super saturated solution
c) solution
d) solvent

21. At a particular temperature solution which cannot dissolve more solute is called

a) saturated solution
b) unsaturated solution
c) aqueous solution
d) supersaturated solution

22. Molecular solutions do not conduct electricity because they contain:

a) molecules only
b) cations and anions
c) molecules and anions
d) molecules and cations

23. To determine the solubility of a solute in water, a solution must be prepared that is:

a) saturated
b) unsaturated
c) concentrated
d) supersaturated

24. From the list of salts below, how many are considered soluble at 25°C?

$CuCl_2$ $CaSO_4$ PbS Ag_3PO_4

a) none
b) one
c) two
d) three

25. The intermolecular forces between particles in a liquid can involve all of the following except

a) London dispersion forces.
b) dipole-dipole attractions.
c) hydrogen bonding.
d) gravitational forces.

26. The intermolecular forces between particles are:
a) weaker in solids than in liquids.
b) stronger in gases than in solids.
c) equal in strength in gases and in liquids.
d) stronger in liquids than in gases.

27. Solubility of gases increases with decrease of:
a) mass
b) volume
c) temperature
d) pressure

28. Solubility depends upon
a) temperature
b) solute
c) solvent
d) all of above

29. When a large amount of solute dissolves in a given amount of solvent it forms:
a) dilute solution
b) saturated solution
c) aqueous solution
d) concentrated solution

30. Maximum amount of solute which can dissolve in 100g of solvent at room temperature is called:
a) Solubility
b) Capacity
c) Eligibility
d) Tendency

31. Solution which can hold no more solute is called
a) dilute solution
b) saturated solution
c) aqueous solution
d) concentrated solution

32. One of following substances that belongs to colloid system is:
a) milk
b) water
c) vinegar
d) blood

33. Dispersed phase and dispersing medium of smoke are:
a) solid in liquid
b) liquid in solid
c) solid in gas
d) gas in solid

34. These following things are colloid properties, except
a) composed of 2 phase

b) stable
c) homogeneous
d) can be filtered

35. The Tyndall effect is used to distinguish between
    a) liquids and gases
    b) solutions and colloids
    c) solvents and solutes
    d) electrolytes and nonelectrolytes

36. Stirring increases the rate of dissolution because it
    a) lowers the temperature
    b) raises the temperature
    c) brings fresh solvent into contact with the solute
    d) decreases the surface area of the solute

37. Which mixture contains particles that are in a dispersed phase and do not settle out?
    a) a colloid
    b) a homogeneous mixture
    c) a solution
    d) a suspension

38. Increasing the surface area of the solute
    a) can increase, decrease, or have no effect on the rate of dissolution
    b) decreases the rate of dissolution
    c) increases the rate of dissolution
    d) has no effect on the rate of dissolution

39. A heterogeneous mixture always contains
    a) only one substance
    b) more than two substances
    c) two or more substances that are not visibly distinguishable
    d) two or more substances that are visibly distinguishable

40. Which is not an example of a colloid?
    a) Smoke
    b) butter
    c) sugar water
    d) paint

41. In solutions particles are:
    a) Invisible
    b) visible by naked eye
    c) visible by ordinary microscope
    d) visible by electron microscope

42. Describe each of the following as (a) colloid, (b) suspension, (c) solution, or (d) none of these:
    Milk
    Gold
    orange juice with pulp
    Kool-aid (ready to drink)
    sugar water solution
    distilled water
    tap water

43. Match the following choices with the statements below. You might have to use more than one choice:

a) Homogeneous mixture
b) Heterogeneous mixture
c) Solution
d) Colloid
e) Suspension
f) Pure Substance
g) Element
h) Compound

Statement 1: A liquid sample of matter in a beaker is slightly cloudy. Upon passing a laser through the beaker you notice that the red beam is easily visible as it passes through the sample. You also notice solute particles settling out of the sample at the bottom of the container. Which of the following best describe this sample of matter?

Statement 2: A liquid sample of matter in a beaker is totally clear and colorless. Upon passing a laser through the beaker you notice that the red beam is not visible at all as it passes through the sample. Also, there are no solute particles settling out of the sample. Which of the following best describe this sample of matter?

Statement 3: A white solid (X) which is known to be a pure substance is heated in the air resulting in a white solid Y and a gas Z. What is the Y?

44. When tiny particles of a substance are dispersed through medium then mixture is called
    a) alloys
    b) amalgams
    c) suspension
    d) colloid

45. Particle size in suspension is
    a) less than 10^3 nm
    b) 10^2 nm
    c) greater than 10^3
    d) 10 nm

46. Colloids can
    a) scatter light

b) not scatter light
c) absorb heat
d) evolve heat

47. Large particles settle out on standing
a) suspension
b) colloid
c) solution

48. Medium size particles settles out on standing, scatters light
a) suspension
b) colloid
c) solution

49. Very small particles does not settle out on standing
a) suspension
b) colloid
c) solution

50. Chocolate milk
a) suspension
b) colloid
c) solution

51. Fog
a) suspension
b) colloid
c) solution

52. Smoke
a) suspension
b) colloid
c) solution

53. Muddy water
a) suspension
b) colloid
c) solution

54. Orange juice
a) suspension
b) colloid
c) solution

55. Whipped cream
    a) suspension
    b) colloid
    c) solution

56. Sugar water
    a) suspension
    b) colloid
    c) solution

57. 3% hydrogen peroxide
    a) suspension
    b) colloid
    c) solution

58. Salt water
    a) suspension
    b) colloid
    c) solution

59. Oil and vinegar salad dressing
    a) suspension
    b) colloid
    c) solution

60. Marshmallow
    a) suspension
    b) colloid
    c) solution

61. When the cell presents with the same concentration on the inside and outside with no shifting of fluids this is called?
    a) hypotonic
    b) hypertonic
    c) isotonic
    d) osmosis

62. Which of the following is not a hypertonic fluid?
    a) hypotonic
    b) hypertonic
    c) isotonic
    d) osmosis

63. What type of fluid would a patient with severe hyponatremia most likely be started on?

a) hypotonic
b) hypertonic
c) isotonic
d) osmosis

64. When administering a hypertonic solution the nurse should closely watch for?
   a) signs of dehydration hypertonic
   b) pulmonary Edema osmosis
   c) fluid volume deficient
   d) increased Lactate level

65. A patient with cerebral edema would most likely be order what type of solution?
   a) 3% Saline
   b) .0.9% Normal Saline
   c) lactated Ringer's
   d) 0.225% Normal Saline

66. _______ solutions cause cell dehydration and help increase fluid in the extracellular space
   a) hypotonic
   b) osmosis
   c) Isotonic
   d) Hypertonic

67. D5W solutions are sometimes considered a hypotonic solution as well as an isotonic solution because after the body metabolizes the dextrose the solution acts as a hypotonic solution.
   a) True
   b) False

68. Which solution below is NOT a hypertonic solution?
   a) 5% Dextrose in 0.9% Saline
   b) 5% Saline
   c) 5% Dextrose in Lactated Ringer's
   d) 0.33% saline

69. Which patient below would NOT be a candidate for a hypotonic solution?

a) patient with increased intracranial pressure
b) patient with Diabetic Ketoacidosis
c) patient experiencing Hyperosmolar Hyperglycemia
d) all of the options are correct

70. Which condition below could lead to cell lysis, if not properly monitored?*
a) isotonicity
b) hypertonicity
c) hypotonicity
d) none of the options are correct

71. __ Isotonic fluids cause shifting of water from the extracellular space to the intracellular space
a) True
b) False

72. A patient is being admitted with dehydration due to nausea and vomiting. Which fluid would you expect the patient to be started on?
a) 5% dextrose in 0.9% Saline
b) 0.33% saline
c) 0.225% saline
d) 0.9% normal Saline

73. The doctor orders an isotonic fluid for a patient. Which of the following is not an isotonic fluid?*
a) 0.9% normal saline
b) lactated ringer's
c) 0.45% saline
d) 5% dextrose in 0.225% saline

74. The cell shrivels and possibly die: Hypotonic
a) True
b) False

75. Water entering the cell: Hypotonic
a) True
b) False

76. If water molecules move into and out of the cell at an equal rate, the solution is this. → Isotonic
    a) True
    b) False

77. Solution that has more solutes than a cell: Hypertonic
    a) True
    b) False

V. Solution Concentrations

78. The molar mass of carbon is 12 g /mol. How many moles are there in 3g of carbon?
    a) 0.25 mol
    b) 0.4 mol
    c) 4 mol
    d) 36 mol

79. The concentration of a solution is expressed as the number of moles in which of the following volumes?
    a) 1 L
    b) 1 mL
    c) 1 kL
    d) 1 dL

80. 25 mL is equivalent to how many Liters (L)?
    a) 0.025
    b) 0.25
    c) 2.5
    d) 0.0025

81. What is the concentration in percent mass/volume of 150. mL of solution containing 30.0 g of solute?
    a) 25.0%
    b) 20.0%
    c) 50.5%
    d) 60.5%

82. What is the concentration by % m/v if 67 g are dissolved to make 1.2 L of solution?
    a) 5.6%
    b) 12%
    c) 45%
    d) 92%

83. What volume of a 40.0 % m/v solution contains 70.0 g of solute? (175 mL)

a) 169 mL
b) 124 mL
c) 155 mL
d) 175 mL

84. What amount of solute is dissolved to make 0.500 L of a 20.0 % m/v solution?
    a) 178 g
    b) 124 g
    c) 100. g
    d) 254 g

85. What amount of a 75 % m/v solution will be made if 50 g of solute are dissolved?
    a) 185 mL
    b) 66.7 mL
    c) 143 mL
    d) 127 mL

86. What is the concentration in % m/v if 0.55 kg of solute is dissolved to make 1.5 L of solution?
    a) 52.8%
    b) 33.3%
    c) 36.7%
    d) 78.9%

87. 5.0 grams of sugar are dissolved in 150 g of water. What is the mass percent of sugar in the solution?
    a) 59%
    b) 3.2%
    c) 4.5%
    d) 6.2%

88. A 200.- gram solution of alcohol contains 180. mL of water. What is the mass percent of alcohol? (Remember water's density.)
    a) 10.0%
    b) 6.19%
    c) 8.05%
    d) 6.22%

89. How many grams of NaBr are needed to make 50 g of a 5.0% solution?
    a) 5.2 g
    b) 3.5 g
    c) 4.2 g
    d) 2.5 g

90. How many grams of LiOH are needed to make 25 g of a 4.0 % solution?
    a) 2.8 g
    b) 1.0 g
    c) 3.8 g
    d) 5.5 g

91. What mass of NaF must be mixed with 25 mL of water to create a 3.5% by mass solution?
    a) 0.84 g
    b) 0.55 g
    c) 0.91 g
    d) 0.87 g

92. An 800. g solution of Kool-Aid contains 780. g of water. What is the mass percent of solute in this solution?
    a) 3.66 g
    b) 2.50 g
    c) 4.75 g
    d) 2.98 g

93. What is the mass percent of a solution created by adding 10.0 g of olive oil to 90.0 g of vegetable oil?
    a) 20.0%
    b) 30.0%
    c) 10.0%
    d) 40.0%

94. If a 4000. g solution of salt water contains 40. g of salt, what is its mass percent?
    a) 1.0%
    b) 2.0%
    c) 3.0%
    d) 4.0%

95. Determine the volume/volume percent solution made by combining 25.0 mL of ethanol with enough water to produce 200. mL of the solution.
    a) 10.5 %
    b) 12.5 %
    c) 9.56%
    d) 11.7%

96. A solution is prepared by dissolving 90.0 mL of hydrogen peroxide in enough water to make 3000. mL of solution. Identify the concentration of the hydrogen peroxide solution.
    a) 5.00 %
    b) 3.00 %
    c) 4.00 %
    d) 2.00 %

97. How would you prepare 250. mL of 70 % (v/v) of rubbing alcohol ?

a) You would add enough water to 165 mL of rubbing alcohol to make a total of 250. mL of solution.
b) You would add enough water to 185 mL of rubbing alcohol to make a total of 250. mL of solution.
c) You would add enough water to 175 mL of rubbing alcohol to make a total of 250. mL of solution.
d) You would add enough water to 195 mL of rubbing alcohol to make a total of 250. mL of solution.

98. If 2.0 moles of salt is dissolved to form 1.0 liter of solution, calculate the molarity of the solution.
    a) 1.0 M solution
    b) 1.5 M solution
    c) 2.0 M solution
    d) 2.5 M solution

99. Calculate the molarity of a sugar solution if 4 liters of the solution contains 8 moles of sugar?
    a) 0.5 M
    b) 8 M
    c) 2 M
    d) 80 M

100. What is the molarity of a solution containing 5.00 moles of solute in 250. milliliters of solution?
    a) 20.0 M
    b) 15.0 M
    c) 0.104 M
    d) 1.25 M

101. How many moles of NaOH are needed to dissolve in water to make 4.0 liters of a 2.0 M solution?
    a) 0.50 M
    b) 2.0 M
    c) 8.0 mol
    d) 0.50 mol

102. How many moles of Na are needed to make 4.5 liters of a 1.5 M Na solution?
    a) 6.75 mol
    b) 0.33 M
    c) 0.33 mol
    d) 3.0 M

103. Molarity of a solution can be defined as the:
    a) atomic mass of an element
    b) moles of solution per liter of solute

c) moles of solute per liter of solution
d) mass of solvent per liter of solution

104. To calculate the Molarity of a solution when the solute is given in grams and the volume of the solution is given in milliliters, you must first:
a) Convert grams to moles, but leave the volume of solution in milliliters
b) Convert volume of solution in milliliters to liters, but leave grams to moles
c) Convert grams to moles, and convert volume of solution in milliliters to liters
d) None of the above

105. The molarity of an aqueous solution of $CaCl_2$ is defined as the
a) moles of $CaCl_2$ per milliliter of solution
b) grams of $CaCl_2$ per liter of water
c) grams of $CaCl_2$ per milliliter of solution
d) moles of $CaCl_2$ per liter of solution

106. How many grams of NaCl are contained in 350. mL of a 0.250 M solution of sodium chloride?
a) 41.7 g
b) 14.6 g
c) 5.11 g
d) 87.5 g
e) None of these

107. The molarity of Cl^- available in 110. mL of a solution containing 5.55 g of $CaCl_2$ is:
a) 0.00550 M
b) 0.668 M
c) 50.5 M
d) 0.455 M
e) 0.909 M

108. A 51.24 g sample of $Ba(OH)_2$ is dissolved in enough water to make 1.20 liters of solution. How many mL is this solution must be diluted with water in order to make 1.00 liter of 0.100 M $Ba(OH)_2$?
a) 400 mL
b) 333 mL
c) 278 mL
d) 1.20×10^3 mL
e) none of these

109. How many grams of NaOH are contained in 5.0×10^2 mL of a 0.80 M sodium hydroxide solution?

a) 16 g
b) 80. g
c) 20. g
d) 64 g
e) None of the above

110. 25.0 mL of 0.20 M K_2SO_4 is added to 50.0 mL of 0.40 M KOH. Calculate the concentration of K^+ ions in solution.
a) 0.20 M
b) 0.33 M
c) 0.40 M
d) 0.60 M
e) 0.66 M

111. What is the molarity of a solution that contains 122 g of MgSO4 in 3.50 L of solution?

a) 0.281 M
b) 0.550 M
c) 0.630 M
d) 0.290

112. How many moles of KI are present in 0.85 L of a 0.55 M KI solution?
a) 0.935 mol
b) 0.4675 mol
c) 3.10 mol
d) 1.55 mol

113. You are given 100.0 ml of a 2.00 M solution of KOH. What would be the molarity of the solution if it is diluted to a volume of 1000. ml?
a) 2.00 M
b) 0.002 M
c) 0.200 M
d) 0.0200 M

114. How many milliliters of 2.00 M NaCl solution are required to make 1 liter of 0.400 M NaCl solution?
a) 5,000 mL
b) 800. mL
c) 200. mL

d) 0.200

115. Determine the number of grams of $NaHCO_3$ that are in one liter of a 2.100 M solution

a) 2.5.50 g
b) 176.4 g
c) 205.0 g
d) 155.0 g

116. Determine the number of grams of $NaNO_3$ that are present in 500.0 mL of a 1.0 M solution.

a) 122.0 g
b) 33.55 g
c) 345.0 g
d) 42.50 g

117. Determine the number of grams of CCl_4 in 450.0 mL of a 3.200 M solution.

a) 45.50 g
b) 874.0 g
c) 221.8 g
d) 345.0 g

118. You need to make 300. mL of a 0.400 M solution of sodium chloride. The only available solution is 1.0 M. Determine how to make the needed dilution.

a) 125 mL 1.0 M solution + 180 mL water
b) 120 mL 1.0 M solution + 180 mL water
c) 130 mL 1.0 M solution + 180 mL water
d) 140 mL 1.0 M solution + 180 mL water

119. You have to make 500. mL of a 0.500 M $BaCl_2$. You have 2.00 M barium chloride solution available. Determine how to make the needed dilution

a) 135 mL 2.0M solution + 375 mL of water
b) 145 mL 2.0M solution + 375 mL of water
c) 155 mL 2.0M solution + 375 mL of water
d) 125 mL 2.0M solution + 375 mL of water

120. You need to make 10.0 L of 1.20 M KNO_3 . What molarity would the potassium nitrate solution need to be if you were to use only 2.50 L of it?

a) 4.80 M
b) 5.50 M
c) 3.55 M
d) 2.86 M

121. If 45 mL of water are added to 250 mL of a 0.75 M K_2SO_4 solution, what will be the molarity of the diluted solution be?

a) 0.89 M
b) 0.64 M
c) 0.15 M
d) 0.35 M

122. If water is added to 175 mL of a 0.45 M KOH solution until the volume is 250 mL, what will be the molarity of the diluted solution be?

a) 0.25 M
b) 0.45 M
c) 0.32 M
d) 0.15 M

123. How much 0.075 M NaCl solution can be made by diluting 450 mL of 9.0 M NaCl?

a) 45 L
b) 54 L
c) 43 L
d) 34 L

124. If 550. mL of a 3.50 M KCl solution are set aside and allowed to evaporate until the volume of the solution is 275 mL, what wil the molarity of the solution be?

a) 7.00 L
b) 6.00 L
c) 5.00 L
d) 4.00 L

125. How much water would need to be added to 750 mL of a 2.8 M HCl solution to make a1.0 M solution?

a) 2.5 L
b) 1.1 L
c) 2.1 L
d) 3.5 L

VI. Concentrations Calculations in Chemical Reactions

126. How many liters of 0.100 M HCl would be required to react completely with 5.00 grams of calcium hydroxide?

$Ca(OH)_2(s) + 2\ HCl(aq)$à → $CaCl_2(aq) + 2\ H_2O(l)$

a) 0.125 L
b) 0.135 L
c) 0.115 L
d) 0.105 L

127. If I combined 15.0 grams of calcium hydroxide with 75.0 mL of 0.500 M HCl, how many grams of calcium chloride would be formed?

a) 1.50 g
b) 3.15 g
c) 4.50 g
d) 2.08 g

128. How many grams of the excess reagent will be left over after the reaction

Ca(OH)2(s) + 2 HCl(aq)à CaCl2(aq) + 2 H2O(l)

If I combined 15.0 grams of calcium hydroxide with 75.0 mL of 0.500 M HCl, how many grams of calcium chloride would be formed?

a) 12.5 grams of $Ca(OH)_2$
b) 11.8 grams of $Ca(OH)_2$
c) 13.6 grams of $Ca(OH)_2$
d) 10.7 grams of $Ca(OH)_2$

129. What volume (mL) of 0.500 M $Cr_2(SO_4)_3$ solution is needed to react completely with 300. mL of 0.400 M $BaCl_2$?

a) 75.0 mL
b) 85.0 mL
c) 90.0 mL
d) 89.0 mL

130. 50.0 mL of 0.10 M silver nitrate is added to 50.0 mL of 0.20 M calcium chloride. A white precipitate forms. After the reaction is complete, calculate the concentration of Cl^- ions remaining in solution.

a) 0.15 M
b) 0.25 M
c) 0.35 M
d) 0.45 M

131. A 0.307 g sample of an unknown triprotic acid is titrated to the equivalence point using 35.2 mL of 0.106 M NaOH. Calculate the molar mass of the acid.

$H_3A + 3\ NaOH \rightarrow Na_3A + 3\ H_2O$

a) 227 g/mol

b) 237 g/mol
c) 247 g/mol
d) 257 g/mol

132. Given: $2\ MnO_4^- + 5\ H_2O_2 + 6\ H^+ \rightarrow 2\ Mn^{2+} + 8\ H_2O + 5\ O_2$
What volume of a 0.150 M $KMnO_4$ solution would be needed to titrate 75.0 mL of a 0.150 M H_2O_2 solution?
a) 40.0 mL
b) 30.0 mL
c) 20.0 mL
d) 10.0 mL

VII. Colligative Properties of Solutions

133. How much will the freezing point be lowered if enough sugar is dissolved in water to make a 0.50 molal solution?

a) – 0.65 °C
b) – 0.75 °C
c) – 0.85 °C
d) – 0.93 °C

134. What is the freezing point of a solution of a nonelectrolyte dissolved in water if the concentration of the solution 0.24 *m*?
a) – 0.446 *m*
b) – 0.355 *m*
c) – 0.565 *m*
d) – 0.250 *m*

135. What is the freezing point of a solution that contains 68.4 g of sucrose, $C_{12}H_{22}O_{11}$, dissolved in 1.00 x 10^2 g of water?
a) – 5.12 °C
b) – 2.88 °C
c) – 4.59 °C
d) – 3.72 °C

136. Suppose that 98.0 g of a nonelectrolyte is dissolved in 1.00 kg of water. The freezing point of this solution is found to be –0.465°C. What is the molecular mass of the solute?
a) 392 g/mol
b) 493 g/mol
c) 654 g/mol
d) 585 g/mol

137. A researcher places 53.2 g of an unknown nonelectrolyte in 505 g napthalene. The nonelectrolyte lowers napthalene's freezing point by 8.8°C. What is the molar mass of the unknown substance?

a) 52.3 g/mol
b) 65.2 g/mol
c) 70.0 g/mol
d) 81.4 g/mol

138. The boiling point of carbon tetrachloride is 76.8ºC. A given solution contains 8.10 g of a nonvolatile electrolyte in 300 g of CCl_4. It boils at 78.4ºC. What is the gram molecular mass of the solute?
a) 80.5 g/mol
b) 60.5 g/mol
c) 84.9 g/mol
d) 70.5 g/mol

139. The molal boiling point constant for ethyl alcohol is 1.22 ºC/molal. Its boiling point is 78.4ºC. A solution of 14.2 g of a nonvolatile nonelectrolyte in 264 g of the alcohol boils at 79.8ºC. What is the gram molecular mass of the solute?
a) 35.5 g/mol
b) 46.7 g/mol
c) 66.5 g/mol
d) 55.9 g/mol

140. Suppose that 130. g of a nonelectrolyte is dissolved in 0.500 kg of benzene. The boiling point of this solution is 80.61ºC. What is the molecular mass of the solute?
a) 129 g/mol
b) 250.g/mol
c) 155 g/mol
d) 355 g/mol

141. A water solution containing an unknown quantity of a nonelectrolyte solute is found to have a freezing point of – 0.23ºC. What is the molal concentration of the solution?
a) 0.124 molal
b) 0.125 molal
c) 0.285 molal
d) 0.375 molal

142. What is the boiling point of a solution of ethyl alcohol, C_2H_5OH, which contains 20.0 g of the solute dissolved in 250. g of water?
a) 101 ºC
b) 255 ºC
c) 319 ºC
d) 465 ºC

143. A solution contains 4.50 g of a nonelectrolyte dissolved in 225 g of water and has a freezing point of –0.310. º C. What is the gram formula mass (molar mass) of the solute?
a) 130. g/mol
b) 140. g/mol
c) 120. g/mol

d) 150. g/mol

144. How many grams of ethylene glycol, $C_2H_4(OH)_2$, must a researcher add to 500. g of water to yield a solution that will freeze at –7.44°C?

a) 124 g/mol
b) 355 g/mol
c) 981 g/mol
d) 632 g/mol

145. What is the expected boiling point of water for a solution that contains 150.0 g of sodium chloride dissolved in 1.000 kg of water?

a) 198.2 ºC
b) 234.5 ºC
c) 345.6 ºC
d) 102.6 ºC