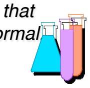
Solutions I

Concentrations

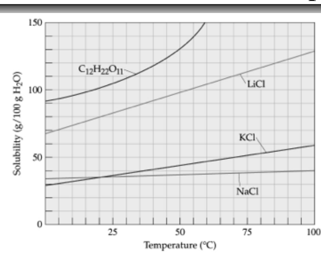
Dr. Ron Rusay

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



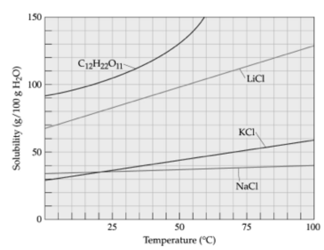
Relative Solution Concentrations:
Saturated
Unsaturated
Supersaturated

Dilute
Concentrated

A solution of 35g of potassium chloride in 100g H_2O @ 25°C is Saturated & Concentrated; @ 75°C it is Unsaturated but Concentrated.

QUESTION

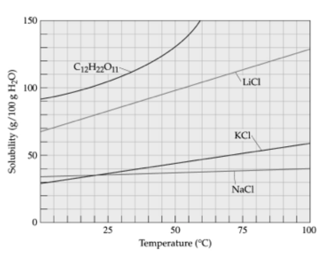
What describes a solution of 25.0g NaCl in 0.100L of H_2O @ 10°C?



A) Dilute
B) Concentrated
C) Saturated
D) Unsaturated

QUESTION

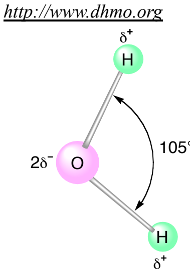
What describes a solution of 100.0g sucrose in 0.100L of H_2O @ 10°C?



A) Dilute
B) Concentrated
C) Saturated
D) Unsaturated

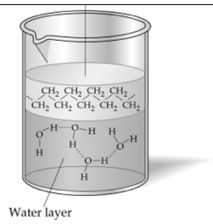
DHMO, dihydromonoxide : "The Universal" Solvent

http://www.dhmo.org



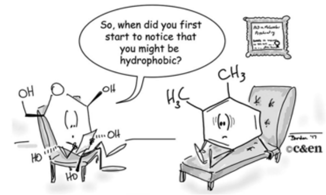
Water : “The Universal” Solvent

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



Gene[…]nd nonp[…]g. oil an[…]

Water : “The Universal” Solvent



Generally, likes dissolve likes, i.e. polar (water)-polar (solutes) *“hydrophilic”*
Water (polar) repels nonpolar solutes *“hydrophobic”*

QUESTION

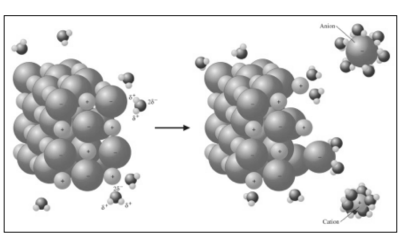
An unknown substance dissolves readily in water but not in benzene (a nonpolar solvent). Molecules of what type are present in the substance?

a) neither polar nor nonpolar
b) polar
c) either polar or nonpolar
d) nonpolar
e) none of these

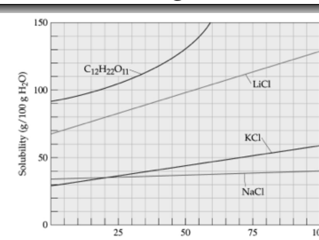
Aqueous Reactions & Solutions

- *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



Water dissolving an ionic solid



How can a salt solute be separated from a solution?
http://chemconnections.org/crystals/

Solution Concentrations

$$\text{molarity} = M = \frac{\text{moles solute}}{\text{liters solution}}$$

$$\%\text{ by mass} = \frac{\text{mass solute}}{\text{mass solution}} \times 100$$

$$\%\text{ by volume} = \frac{\text{volume solute}}{\text{volume solution}} \times 100$$

[Proof = % by volume x 2]

$$\text{parts per million} = \text{ppm} = \frac{\text{mass solute}}{\text{mass solution}} \times 10^6$$

$$\text{parts per billion} = \text{ppb} = \frac{\text{mass solute}}{\text{mass solution}} \times 10^9$$

$$\text{molality} = m = \frac{\text{moles solute}}{\text{kilograms solvent}}$$

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

Solution Concentrations

Molarity (M) = moles solute / Liter$_{solution}$

- *What is the molarity of a solution of 0.50 mol $NiCl_2$ in 200.0 mL of solution?*

M_{NiCl2} = [0.50 mol $_{NiCl2}$ / 200.0 mL] x [1000 mL / L]

= 0.25 mol $_{NiCl2}$ / L

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

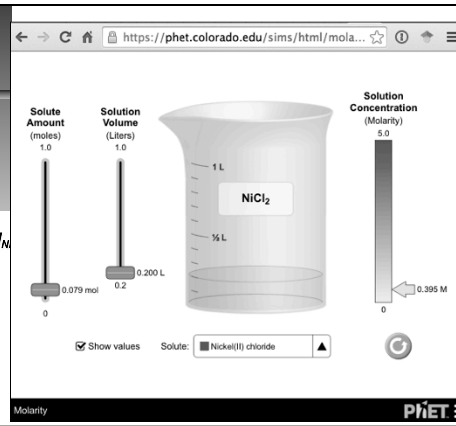
Solution Concentrations

Molarity (M) = moles solute / Liter$_{solution}$

- *What is the molarity of a solution of 10.00 g $NiCl_2$ in 200.0 mL of solution?*

M_{NiCl2} = [10.00g $_{NiCl2}$ / 200.0mL][1mol$_{NiCl2}$ / 129.5 g $_{NiCl2}$][1000mL / L]

= 0.386 mol$_{NiCl2}$ / L



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

QUESTION

40.0-g of HF [MM = 20.0 g/mol] was dissolved in water to give 2.0 x 10^2 mL of HF(aq), a weak acid solution. The concentration of the solution is:

a) 0.5 M
b) 1.0 M
c) 2.0 M
d) 5.0 M
e) 10. M

Solution Concentrations

- *Mass percent, eg. Glucose, Saline and Ringer's lactate solutions*

Mass % = Mass solute / [Mass solute + Mass solvent] x100

- *What is the mass % of 65.0 g of glucose dissolved in 135 g of water?*

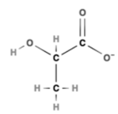
Mass % = 65.0 g / [65.0 + 135]g x 100
= 32.5 %

Solution Concentrations

Molarity (M) = moles solute / Liter (Solution)

Ringer's lactate solution

Na^{1+} = 0.130 mol/ L
Cl^{1-} = 0.109 mol/ L
Lactate anion $(C_3H_5O_3)^{1-}$ = 0.028 mol/ L
K^{1+} = 0.004 mol / L
Ca^{2+} = 0.0015 mol/ L



After blood loss due to trauma, surgery, or burn, it is used for fluid resuscitation usually @ rate equal to 20 to 30 ml/kg body weight/hour.

Solution Concentrations

Molarity (M) = moles solute / $Liter_{solution}$

mol = (mol solute / $Liter_{solution}$) **x** $\mathbf{Liter}_{solution}$

- *An important relationship is* $\mathbf{M \times V_{solution} = mol}$
  It is used directly in mass calculations of chemical reactions and in the dilutions of solutions.

Seven Solutions Post Lab Questions
http://chemconnections.org/general/chem120/solutions-mixes.108.html

QUESTION

Solutions: molarity & volume → mass

How many grams of NaCl are contained in 350. mL of a 0.250 M solution of sodium chloride?

A) 41.7 g
B) 5.11 g
C) 14.6 g
D) 87.5 g
E) None of these

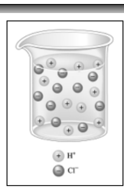
ANSWER

B) 5.11 g

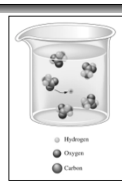
Seven Solutions Post Lab Questions
http://chemconnections.org/general/chem120/solutions-mixes.108.html

Volume (L) times concentration (mol/L) gives moles. Moles are then converted to grams.

Solution Concentrations:
Solute vs. Ion Concentrations



HCl
1.0M 100% Ionized



Acetic Acid $(HC_2H_3O_2)$ **< 100% Ionized**

[H+] = [Cl-] = 1.0M

[H+] = $[C_2H_3O_2^-]$ ***< 1.0M***

Preparation of Solutions

Solution Formation
from a Solid

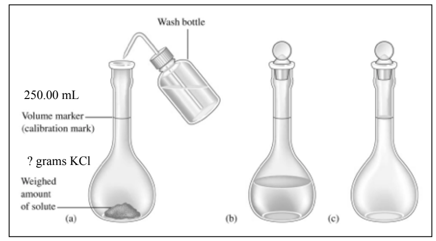
Solutions II

(Solutions/ Molarity)

Applications / Calculations

Dr. Ron Rusay

Preparing a Standard Solution of a Targeted Molarity, M (mol/L)



Preparation of Solutions used in chemistry

Molarity (M) = Moles solute / Liter (Solution)

QUESTION

A 51.24-g sample of $Ba(OH)_2$ [MM= 171.3 g/mol] is dissolved in enough water to make 1.20 liters of solution. What is the molarity of the solution?

a) 0.300 M

b) 3.33 M

c) 0.278 M

d) 2.49 x 10^{-1} mol/L

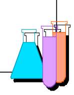
e) 42.7 g/mL

Solution Concentration

- *The following formula can be used in dilution calculations:*

  $$M_1V_1 = M_2V_2$$

- *A concentrated stock solution is much easier to prepare and then dilute rather than preparing a dilute solution directly. Concentrated sulfuric acid is 18.0M. What volume would be needed to prepare 250.mL of a 1.50M solution?*
- $V_1 = M_2V_2 / M_1$
- V_1 = 1.50 M x 250. mL / 18.0 M
- V_1 = 20.8 mL



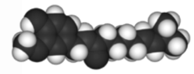
QUESTION

What volume of 18.0 M sulfuric acid must be used to prepare 15.5 L of 0.195 M H_2SO_4?

A) 168 mL
B) 0.336 L
C) 92.3 mL
D) 226 mL
E) None of these

Solution Dilution

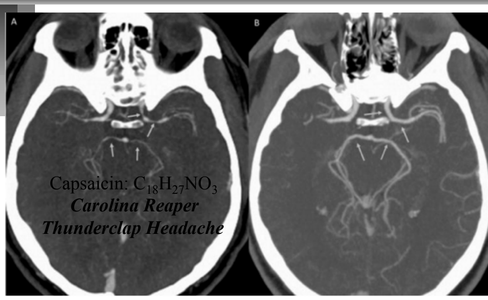
Solution Applications
Scoville Units / Capsaicin



Capsaicin: $C_{18}H_{27}NO_3$
Carolina Reaper
"Thunderclap Headache"

http://en.wikipedia.org/wiki/Scoville_scale
https://www.youtube.com/watch?v=hrF3jVppfr4

Reversible Cerebral Vasoconstriction Syndrome (RVS)



https://www.youtube.com/watch?v=hrF3jVppfr4

QUESTION

What happens to the number of moles of $C_{12}H_{22}O_{11}$ (sucrose) when 100.0 mL of a 0.20 M solution is diluted to a final concentration of 0.10 M?

A) The number of moles of $C_{12}H_{22}O_{11}$ decreases.

B) The number of moles of $C_{12}H_{22}O_{11}$ increases.

C) The number of moles of $C_{12}H_{22}O_{11}$ does not change.

D) There is insufficient information to answer the question.

Solution Applications

A solution of barium chloride was prepared by dissolving 26.0287 g in water to make 500.00 mL of solution. What is the concentration of the barium chloride solution? ***M_{BaCl2} = ?***

M_{BaCl2} =

= [26.0287g$_{BaCl2}$ / 500.00mL][1mol $_{BaCl2}$ / 208.23g$_{BaCl2}$] [1000mL / L]

= 0.25000 mol / L

Solution Applications

10.00 mL of this solution was diluted to make exactly 250.00 mL of solution which was then used to react with a solution of potassium sulfate. What is the concentration of the diluted solution. ***M_2 = ?***

$M_{BaCl2} = M_1$

$M_2 = M_1V_1 / V_2$

M_2 = 0.25000 M x 10.00 mL / 250.00 mL

M_2 = 0.010000 M

QUESTION

A 51.24-g sample of $Ba(OH)_2$ is dissolved in enough water to make 1.20 liters of solution. How many mL of this solution must be diluted with water in order to make 1.00 liter of 0.100 molar $Ba(OH)_2$?

a) 400. mL
b) 333 mL
c) 278 mL
d) 1.20×10^3 mL
e) 285 mL

(Chem 120 Prep)

Solution Applications

20.00 mL of a $M_2 = 0.010000$ M barium chloride solution required 15.50 mL of the potassium sulfate solution to react completely. $M_{K2SO4} = ?$

$BaCl_2(aq) + K_2SO_4(aq) \rightarrow\ ?\ +\ ?$

$BaCl_2(aq) + K_2SO_4\ (aq) \rightarrow 2\ KCl(aq) + BaSO_4\ (s)$

$?M_{K2SO4} = [M_{BaCl2} \times V_{BaCl2} / V_{K2SO4}]\ [?\ mol_{K2SO4} / ?\ mol_{BaCl2}]$

$$?M_{K2SO4} = \frac{0.010000\ mol_{BaCl2} \times 0.02000\ L_{BaCl2} \times 1\ mol_{K2SO4}}{L_{BaCl2} \times 0.01550\ L_{K2SO4} \times 1\ mol_{BaCl2}}$$

$?M_{K2SO4} = 0.01290\ mol_{K2SO4} / L_{K2SO4} = 0.01290\ M_{K2SO4}$

(Chem 120 Prep)

Solution Applications

How many grams of potassium chloride are produced?

$BaCl_2(aq) + K_2SO_4(aq) \rightarrow\ ?\ +\ ?$

1 $BaCl_2(aq) + K_2SO_4\ (aq) \rightarrow 2\ KCl(aq) + BaSO_4\ (s)$

$?g_{KCl} = 0.010000\ mol_{BaCl2} / L_{BaCl2} \times 0.02000\ L_{BaCl2} \times 2\ mol_{KCl} / 1\ mol_{BaCl2} \times 74.55\ g_{KCl} / mol_{KCl}$

$= 0.02982\ g_{KCl}$

(Chem 120 Prep)

Solution Applications

If **20.00** mL of a **0.10** M solution of barium chloride was reacted with **15.00** mL of a **0.20** M solution of potassium sulfate, what would be the theoretical yield of barium sulfate?

$BaCl_2(aq) + K_2SO_4\ (aq) \rightarrow 2\ KCl(aq) + BaSO_4\ (s)$

Which is the Limiting Reagent?

$Mol_{BaCl2} = M_{BaCl2} \times V_{BaCl2}$	$Mol_{K2SO4} = M_{K2SO4} \times V_{K2SO4}$
$= \frac{0.10\ mol_{BaCl2} / L_{BaCl2} \times 0.02000\ L_{BaCl2}}{1\ mol_{BaCl2}}$	$= \frac{0.20\ mol_{K2SO4} / L_{K2SO4} \times 0.01500\ L_{K2SO4}}{1\ mol_{K2SO4}}$
$= 2.0 \times 10^{-3}$	$= 3.0 \times 10^{-3}$
2.0×10^{-3}	$< 3.0 \times 10^{-3}$
$2.0 \times$	10^{-3} mol *is limiting*

(Chem 120 Prep)

Solution Applications

If **20.00** mL of a **0.10** M solution of barium chloride was reacted with **15.00** mL of a **0.20** M solution of potassium sulfate, what would be the theoretical yield of barium sulfate?

$BaCl_2(aq) + K_2SO_4\ (aq) \rightarrow 2\ KCl(aq) + BaSO_4\ (s)$

Must use the limiting reagent:

$$= \frac{0.10\ mol_{BaCl2} \times 0.02000\ L_{BaCl2} \times 1\ mol_{BaSO4} \times 233.39\ g_{BaSO4}}{L_{BaCl2} \qquad 1\ mol_{BaCl2} \qquad mol_{BaSO4}}$$

$= 0.47$ g

QUESTION

What mass of NaOH is required to react exactly with 25.0 mL of 1.2 M H_2SO_4?

A) 1.2 g
B) 1.8 g
C) 2.4 g
D) 3.5 g
E) None of these

ANSWER

C) 2.4 g

-

Remember that the reaction is $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$, so there are two moles of NaOH used per one mole of H_2SO_4.