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SOLUTION CHEMISTRY

It's all about the concentration

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Common units of concentration

% by mass – $\frac{g\ solute}{100\ g\ solution}$

% by volume $\frac{mL\ solute}{100\ mL\ solution}$

% by mass-volume $\frac{g\ solute}{100\ mL\ solution}$

Molarity – $\frac{moles\ solute}{L\ solution}$

Molality – $\frac{moles\ solute}{kg\ solvent}$

Normality $\frac{equivalent\ moles\ solute}{L\ solution}$

ppt – $\frac{g\ solute}{1000\ g\ solution}$

ppm – $\frac{g\ solute}{1{,}000{,}000\ g\ solution}$

ppb – $\frac{g\ solute}{1{,}000{,}000{,}000\ g\ solution}$

lb/million gallons - $\frac{lb\ solute}{1{,}000{,}000\ gal\ solution}$

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Some conversion problems:

Convert 136 μg NaCl/mL pond water to lb NaCl/million gallons pond water

.

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Some conversion problems:

136 µg NaCl …. ? lb NaCl
mL pond water million gallons pond water

What do we need to know?

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Some conversion problems:

136 µg NaCl …. ? lb NaCl
mL pond water million gallons pond water

What do we need to know?

- How many µg in a lb?
- How many mL in a million gallons?

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Some conversion problems:

136 µg NaCl …. ? lb NaCl
ml pond water million gallons pond water

453.6 g = 1 pound
1 µg = 10^{-6} g
1 mL = 10^{-3} L
1.057 L = 1 quart
4 quarts = 1 gallon

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Some conversion problems:

$$\frac{136\ \mu g\ NaCl}{mL\ pond\ water} * \frac{10^{-6}\ g}{1\ \mu g} * \frac{1\ lb}{453.6\ g} = \frac{2.998x10^{-7}\ lb}{mL\ pond\ water}$$

$$\frac{2.998x10^{-7}\ lb}{mL\ pond\ water} * \frac{1\ mL}{10^{-3}\ L} * \frac{1.057\ L}{1\ qt} = \frac{3.17\ x10^{-4}\ lb}{qt}$$

$$\frac{3.17\ x10^{-4}\ lb}{qt} * \frac{4qt}{1\ gal} * \frac{10^{6}\ gal}{million\ gal} = \frac{1.26x10^{3}\ lb}{million\ gal}$$

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Some conversion problems:

Convert 36% by mass of HCl to Molarity.

How do we start?

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Some conversion problems:

Convert 36% by mass of HCl to Molarity.

How do we start?

Units! Units! Units!

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Some conversion problems:

Convert 36% by mass of HCl solution to Molarity.

36 g HCl .... Moles HCl
100 g solution 1 L solution

What do we need to know?

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Some conversion problems:

Convert 36% by mass of HCl solution to Molarity.

36 g HCl .... Moles HCl
100 g solution 1 L solution

What do we need to know?

- Molar mass of HCl
- Density of HCl solution

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Some conversion problems:

Convert 36% by mass of HCl solution to Molarity.

36 g HCl .... Moles HCl
100 g solution 1 L solution

What do we need to know?

- Molar mass of HCl (36.46 g/mol – from Periodic table)
- Density of HCl solution (from where???)

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Density – your critical judgment

For a solution, sometimes you know the density, sometimes you don't.

There are tables, but they are not all inclusive.

You might, for example, find in a table that:
Density (30% HCl) = 1.12 g/mL
Density (40% HCl) = 1.23 g/mL
Density (36% HCl) = ???

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Interpolate or Assume

Density (30% HCl) = 1.12 g/mL
Density (40% HCl) = 1.23 g/mL
Density (36% HCl) = ???

You could assume that 36% is closest to 40% and use 1.23 g/mL. This is legitimate, although not 100% accurate. Results may vary, depending on how good the assumption is.

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Interpolate or Assume

Density (30% HCl) = 1.12 g/mL Density (40% HCl) = 1.23 g/mL
Density (36% HCl) = ???

You could assume that density changes linearly with concentration (it doesn't, but it is pseudo-linear for small changes). In that case, you would "linearly interpolate" the density.

$$\frac{1.23\text{ g/mL} - 1.12\text{ g/mL}}{40\%\text{ HCl}-30\%\text{HCl}} = 0.011\ \frac{\text{g/mL}}{\%} = 0.011\ \frac{\text{g}}{\text{mL\%}}$$

1.12 g/mL + 0.011 g/mL% * 6% = 1.186 g/mL = 1.19 g/mL

This is legitimate, although still not 100% accurate, but probably better than the previous assumption.

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If I don't have Density tables…

For dilute solutions, you can get pretty close by assuming the density of the solution is the same as the density of pure water.

For concentrated solutions (like 36%), this is probably not a good assumption, but it is better than nothing!

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Solving the problem (finally)

Convert 36% by mass of HCl solution to Molarity.

$\frac{36\ g\ HCl}{100\ g\ solution}$ …….. $\frac{Moles\ HCl}{1\ L\ solution}$

What do we need to know?

- Molar mass of HCl (36.46 g/mol – from Periodic table)
- Density of HCl solution (1.19 g/mL – by assuming linear change)

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Solving the problem (finally)

$$\frac{36\ g\ HCl}{100\ g\ sol}\frac{1\ mol\ HCl}{36.46\ g}\frac{1.19\ g}{1\ mL}\frac{1000\ mL}{1\ L} = 11.7\frac{mol}{L\ sol} = 11.7\ M\ HCl$$

(if you don't specify solvent, usually assumed to be water)

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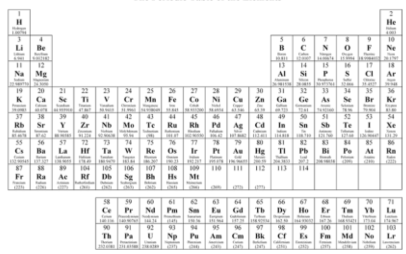

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lb/million gallons - $\frac{lb\ solute}{1{,}000{,}000\ gal\ solution}$

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All are important, but…

Moles! Moles! Moles!

Molarity – $\frac{mol\ solute}{L\ solution}$ (most common)

Molality – $\frac{mol\ solute}{kg\ solvent}$ (not very common)

Normality – $\frac{equivalent\ mol\ solute}{L\ solution}$ (specialized usage)

What's "equivalent moles"?

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Normality vs. Molarity

Molarity = moles solute/L solution
- generic, just the moles folks

Normality = equivalent moles of solute/L solution
- specific, it takes into account the actual chemistry of the solute.

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Acids

What's an acid?

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Acids

What's an acid?

Within the Bronsted-Lowry theory of acids/bases, an acid is a proton (H^+) donor and a base is a proton acceptor.

Can you think of examples of acids or bases?

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Some acids and bases

NaOH – base
$Mg(OH)_2$ – base

HCl – acid (hydrochloric acid)
HF – acid (hydrofluoric acid)
H_2SO_4 – acid (sulfuric acid)

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Acid – what's it good for?

????

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Acid – what's it good for?

Protons

If we define an acid as a proton donor, the proton is what makes it what it is.

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Consider two solutions:

1 M HCl

1 M H_2SO_4

How are they the same? How are they different?

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Consider two solutions:

1 M HCl	1 M H_2SO_4
1 mole molecules/L	1 mole molecules/L

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Consider two solutions:

1 M HCl	1 M H_2SO_4
1 mole molecules/L H+ Cl^- in solution	1 mole molecules/L H^+ and SO_4^{2-} in solution
$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$	$H_2SO_{4\,(aq)} \rightarrow 2\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$
$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$	$H_2SO_{4\,(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

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Consider two solutions:

1 M HCl	1 M H_2SO_4
1 mole molecules/L	1 mole molecules/L
H+ Cl^- in solution	H^+ and SO_4^{2-} in solution
$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$	$H_2SO_{4\,(aq)} \rightarrow 2\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$
$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$	$H_2SO_{4\,(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$
$\frac{1\,mol\,H^+}{L\,solution}$	$\frac{2\,mol\,H^+}{L\,solution}$

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Consider two solutions:

1 M HCl	1 M H_2SO_4
1 mole molecules/L	1 mole molecules/L
$\frac{1\,mol\,H^+}{L\,solution}$	$\frac{2\,mol\,H^+}{L\,solution}$

They are both acids, they are defined by their ability to donate protons. The protons are the “equivalents” for an acid.

1 N HCl	2 N H_2SO_4