

Temperature Dependence of Solubility of Gases in Water

- solubility is generally given in moles of solute that will dissolve in 1 Liter of solution
- generally lower solubility than ionic or polar covalent solids because most are nonpolar molecules
- for **all** gases, the solubility of the gas decreases as the temperature increases
 - ✓ the $\Delta H_{\text{solution}}$ is exothermic because you do not need to overcome solute-solute attractions

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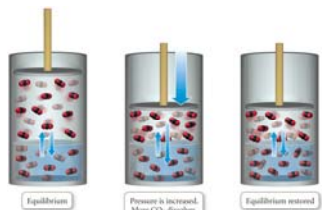
Temp	N ₂	O ₂	Ar	CO ₂	acetylene	NH ₃
0	0.00294	0.00695	0.00025	0.335	0.2	89.5
10	0.00231	0.00537		0.232	0.15	68.4
20	0.00190	0.00434		0.169	0.117	52.9
30	0.00162	0.00359		0.126	0.094	41.0
40	0.00139	0.00308		0.0973		31.6
50	0.00122	0.00266	9.95×10^{-5}	0.0761		23.5
60	0.00105	0.00227		0.0576		16.8
70	0.00085	0.00186				11.1
80	0.00066	0.00138				6.5
90	0.00038	0.00079				3.0

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Pressure Dependence of Solubility of Gases in Water

- the larger the partial pressure of a gas in contact with a liquid, the more soluble the gas is in the liquid



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Henry's Law

- the solubility of a gas (S_{gas}) is directly proportional to its partial pressure, (P_{gas})

$$S_{gas} = k_H P_{gas}$$

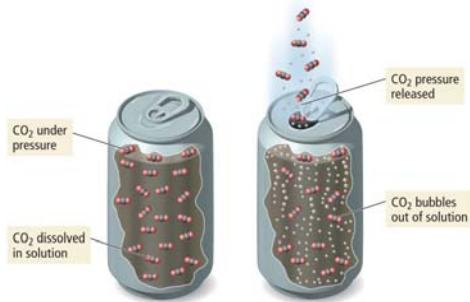
- k_H is called **Henry's Law Constant**

TABLE 12.4 Henry's Law Constants for Several Gases in Water at 25 °C

Gas	k_H (M/atm)
O ₂	1.3×10^{-3}
N ₂	6.1×10^{-4}
CO ₂	3.4×10^{-2}
NH ₃	5.8×10^1
He	3.7×10^{-4}

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Concentrations

- solutions have variable composition
- to describe a solution, need to describe components *and* relative amounts
- the terms **dilute** and **concentrated** can be used as qualitative descriptions of the amount of solute in solution
- concentration** = amount of solute in a given amount of solution
 - ✓ occasionally amount of solvent

Solution Concentration

Molarity

- moles of solute per 1 liter of solution
- used because it describes how many molecules of solute in each liter of solution
- if a sugar solution concentration is 2.0 M, 1 liter of solution contains 2.0 moles of sugar, 2 liters = 4.0 moles sugar, 0.5 liters = 1.0 mole sugar

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

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Molarity and Dissociation

- the molarity of the ionic compound allows you to determine the molarity of the dissolved ions
- $\text{CaCl}_2(aq) = \text{Ca}^{+2}(aq) + 2 \text{Cl}^{-1}(aq)$
- A 1.0 M $\text{CaCl}_2(aq)$ solution contains 1.0 moles of CaCl_2 in each liter of solution
 - ✓ 1 L = 1.0 moles CaCl_2 , 2 L = 2.0 moles CaCl_2
- Because each CaCl_2 dissociates to give one $\text{Ca}^{+2} = 1.0 \text{ M Ca}^{+2}$
 - ✓ 1 L = 1.0 moles Ca^{+2} , 2 L = 2.0 moles Ca^{+2}
- Because each CaCl_2 dissociates to give 2 $\text{Cl}^{-1} = 2.0 \text{ M Cl}^{-1}$
 - ✓ 1 L = 2.0 moles Cl^{-1} , 2 L = 4.0 moles Cl^{-1}

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Solution Concentration

Molality, m

- moles of solute per 1 kilogram of solvent
 - ✓ defined in terms of amount of solvent, not solution
 - like the others
- does not vary with temperature
 - ✓ because based on masses, not volumes

$$\text{molality, } m = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

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Percent

- parts of solute in every 100 parts solution
- mass percent = mass of solute in 100 parts solution by mass
 - ✓ if a solution is 0.9% by mass, then there are 0.9 grams of solute in every 100 grams of solution
 - or 0.9 kg solute in every 100 kg solution

$$\text{Mass Percent} = \frac{\text{Mass of Solute, g}}{\text{Mass of Solution, g}} \times 100\%$$

$$\text{Mass of Solute} + \text{Mass of Solvent} = \text{Mass of Solution}$$

Percent Concentration

$$\text{Percent} = \frac{\text{Part (solute)}}{\text{Whole (solution)}} \times 100\%$$

$$\text{Mass Percent} = \frac{\text{Mass of Solute, g}}{\text{Mass of Solution, g}} \times 100\%$$

$$\text{Mass of Solute} + \text{Mass of Solvent} = \text{Mass of Solution}$$

$$\text{Percent Mass/Volume} = \frac{\text{Mass of Solute, g}}{\text{Volume of Solution, mL}} \times 100\%$$

$$\text{Mass of Solute} + \text{Volume of Solvent} \neq \text{Volume of Solution}$$

$$\text{Volume Percent} = \frac{\text{Volume of Solute, mL}}{\text{Volume of Solution, mL}} \times 100\%$$

$$\text{Volume of Solute} + \text{Volume of Solvent} \neq \text{Volume of Solution}$$

Using Concentrations as Conversion Factors

- concentrations show the relationship between the amount of solute and the amount of solvent
 - ✓ 12% (m/m) sugar(aq) means 12 g sugar \equiv 100 g solution
 - or 12 kg sugar \equiv 100 kg solution; or 12 lbs. \equiv 100 lbs. solution
 - ✓ 5.5% (m/v) Ag in Hg means 5.5 g Ag \equiv 100 mL solution
 - ✓ 22% (v/v) alcohol(aq) means 22 mL EtOH \equiv 100 mL solution
- The concentration can then be used to convert the amount of solute into the amount of solution, or vice versa

Preparing a Solution

- need to know **amount** of solution and **concentration** of solution
- calculate the mass of solute needed
 - ✓ start with amount of solution
 - ✓ use concentration as a conversion factor
 - 5% by mass \Rightarrow 5 g solute = 100 g solution
 - ✓ “Dissolve the grams of solute in enough solvent to total the total amount of solution.”

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Solution Concentration PPM

- grams of solute per 1,000,000 g of solution
- mg of solute per 1 kg of solution
- 1 liter of water = 1 kg of water
 - ✓ for water solutions we often approximate the kg of the solution as the kg or L of water

$$\frac{\text{grams solute}}{\text{grams solution}} \times 10^6$$

$$\frac{\text{mg solute}}{\text{kg solution}} \quad \frac{\text{mg solute}}{\text{L solution}}$$

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Solution Concentrations Mole Fraction, X_A

- the **mole fraction** is the fraction of the moles of one component in the total moles of all the components of the solution
- total of all the mole fractions in a solution = 1
- unitless
- the **mole percentage** is the percentage of the moles of one component in the total moles of all the components of the solution
 - ✓ = mole fraction \times 100%

$$\text{mole fraction of } A = X_A = \frac{\text{moles of component } A}{\text{total moles in the solution}}$$

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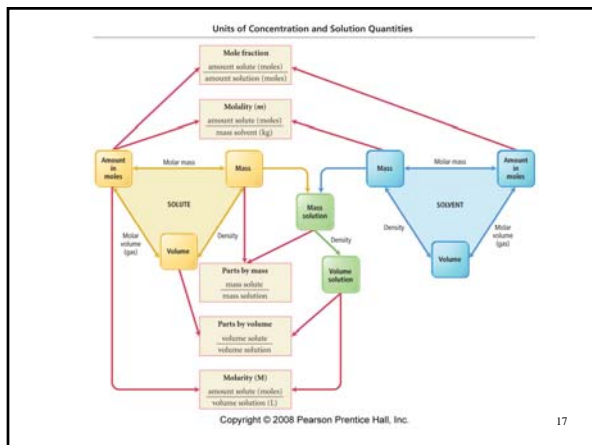
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Converting Concentration Units

- assume a convenient amount of solution
 - ✓ given % (m/m), assume 100 g solution
 - ✓ given % (m/v), assume 100 mL solution
 - ✓ given ppm, assume 1,000,000 g solution
 - ✓ given M, assume 1 liter of solution
 - ✓ given m, assume 1 kg of **solvent**
 - ✓ given X, assume you have a total of 1 mole of solutes in the solution
- determine amount of solution in non-given unit(s)
 - ✓ if assume amount of solution in grams, use density to convert to mL and then to L
 - ✓ if assume amount of solution in L or mL, use density to convert to grams
- determine the amount of solute in this amount of solution, in grams and moles
- determine the amount of solvent in this amount of solution, in grams and moles
- use definitions to calculate other units

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