Solutions Thermodynamics DCI

Name ______________________________	Section ______

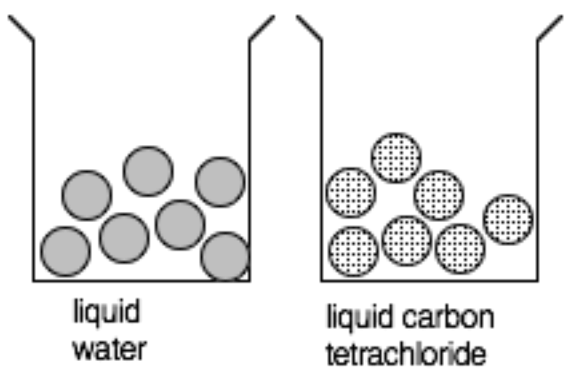
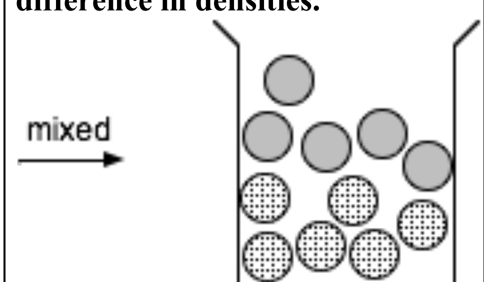
1. The three attractive interactions which are important in solution formation are; solute-solute interactions, solvent-solvent interactions, and solute-solvent interactions. Define each of these interactions and describe their importance in determining whether a particular solute-solvent pair will form a homogeneous mixture or a heterogeneous mixture.

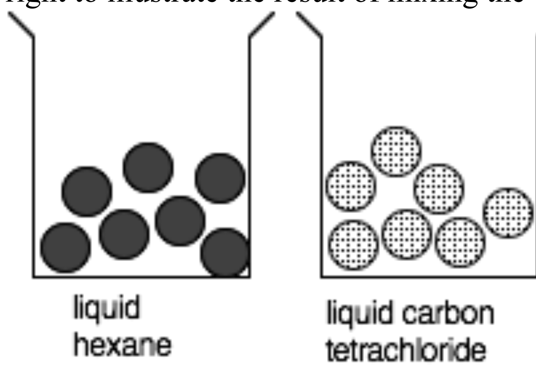
    Solute-solute interactions are the intermolecular attractions between solute particles.

    Solvent-solvent interactions are the intermolecular attractions between solvent particles.

    Solute-solvent interactions are the intermolecular attractions between a solute particle and a solvent particle.

    If the intermolecular attractions between solute particles are different compared to the intermolecular attractions between solvent particles it is unlikely dissolution will occur. Similar intermolecular attractions between solute particles and between solvent particles make it more likely a solution will form when the two are mixed.

Shown below are two beakers. One contains liquid water and the other contains liquid carbon tetrachloride. For simplicity a circle is used to represent the molecule. Complete the beaker on the right to illustrate the result of mixing the two liquids. 	**The two liquids form a heterogeneous mixture. The drawing should show the carbon tetrachloride on the bottom and the water on top, due to the difference in densities.** 

<table>
<tr>
<td>Shown below are two beakers. One contains liquid hexane and the other contains liquid carbon tetrachloride. For simplicity a circle is used to represent the molecule. Complete the beaker on the right to illustrate the result of mixing the two liquids.

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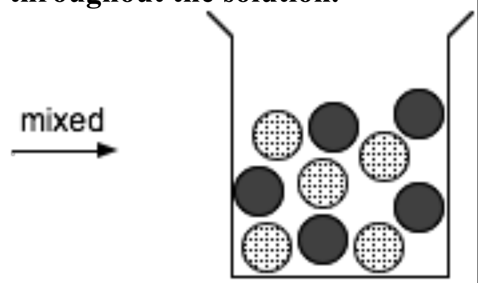
<td>The two liquids form a solution. The two components are uniformly distributed throughout the solution.

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2a. In terms of the attractive interaction explain how it is the formation of a solution can be exothermic or endothermic.

If energy is released in the solution process, then the solute-solvent intermolecular bonds which are formed release more energy than the energy required to separate the solute particles plus the energy required to separate the solvent particles the solution process will be exothermic.

$$|\Delta H_{solute/solvent}| > \Delta H_{solute/solute} + \Delta H_{solvent/solvent}$$

EXOTHERMIC SOLUTION PROCESS

If the energy released when the solute-solvent intermolecular bonds are formed is smaller than the energy required to separate the solute particles plus the energy required to separate the solvent particles the solution process will be exothermic.

$$|\Delta H_{solute/solvent}| < \Delta H_{solute/solute} + \Delta H_{solvent/solvent}$$

ENDOTHERMIC SOLUTION PROCESS

b. Describe the underlying thermodynamic property which favors the formation of a solution. Explain why some combinations of chemicals do not form homogeneous mixtures.

“Disorder” is the underlying thermodynamic drive which favors the formation of solutions. If the energy required to separate the solute particles and the solvent particles is too large the favorable disorder term may not be large enough to counteract the unfavorable enthalpy term. Whether a solution forms depends on the relative magnitude of the enthalpy term and the disorder term.

3a. Define the following terms;

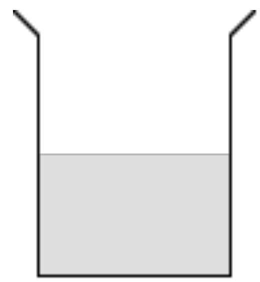
solubility **is the extent to which a solute will dissolve in a solvent. It is also the amount of solid which will dissolve in a given amount of solvent.**

unsaturated solution **s a solution which can dissolve more solute.**

saturated solution **is a solution with the dissolved solute in equilibrium with the undissolved solute.**

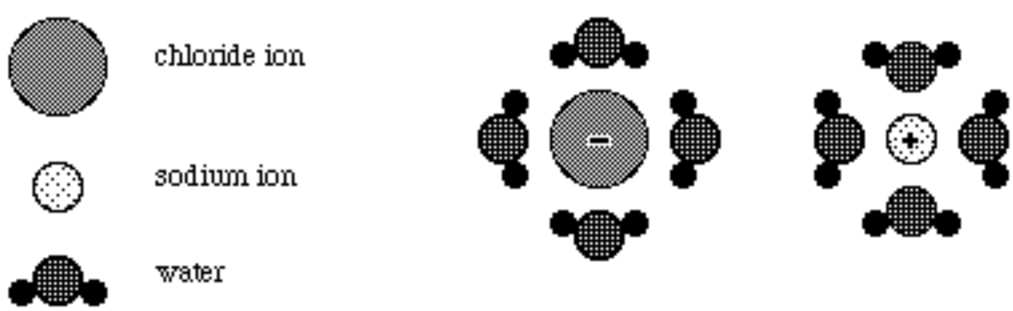
supersaturated solution **is a solution holding more dissolved solute than would be in equilibrium with the undissolved solute.**

b. Given that the beaker to the right contains an aqueous solution of NaCl, describe a simple test to determine whether the solution is unsaturated, saturated or supersaturated. What would you expect to happen during the test if the solution were unsaturated? saturated? supersaturated?



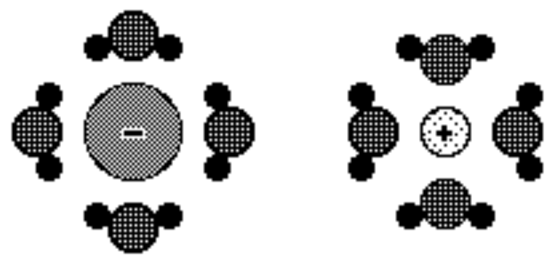
Adding a crystal of sodium chloride is all that is necessary to determine whether the solution is unsaturated, saturated or supersaturated. If the solution is unsaturated, the crystal of NaCl will dissolve. If the solution is saturated, the crystal will fall to the bottom of the beaker and will not dissolve. If the solution is supersaturated, the addition of the crystal will cause the extra NaCl to precipitate out of the solution.

4a. Given the representations below, sketch the orientations of a chloride ion and a several water molecules and a sodium ion and several water molecules to illustrate the ion-dipole interaction.



b) Briefly describe ion-dipole intermolecular attractive forces which occur when an ionic solid dissolves in water. Indicate what causes the attractive force and describe how the strength depends on the charge and the size of the ion.

The intermolecular attractive forces which occur when an ionic solid dissolves in water are electrostatic in nature. The attraction results from the charge on the ion and the partial charge of the permanent dipole which is present on a water molecule. The strength of the attraction between an ion and water increases as the charge on the ion increases and decreases as the size of the ion increases.



In the drawing above the positive end of the water dipole is oriented towards the anion and the negative end of the dipole in the water molecule is oriented towards the cation.

5. Define the term *lattice energy* and explain its importance in the enthalpy of solution.

Lattice energy is the energy released when gas phase ions come together to form a solid lattice.

$$\mathbf{M^+}_{(g)} + \mathbf{X^-}_{(g)} \rightarrow \mathbf{MX}_{(s)}$$

Lattice energy is directly proportional to the charge on the ions and inversely proportional to the size of the ions.

$$\text{Lattice energy} = \frac{kQ_{cation}Q_{anion}}{d}$$

Lattice energy is a measure of the strength of the attractive forces holding the crystal together. If it requires more energy to overcome the lattice energy compared to the energy released when solute-solvent interactions (ion-dipole) are formed the enthalpy of solution will be positive. If it requires less energy to overcome the lattice energy compared to the energy released when solute-solvent interactions (ion-dipole) are formed the enthalpy of solution will be negative.

6. Explain how pressure, temperature and molar mass affect the solubility of a gas in a liquid.

Pressure will only affect the solubility of a gas in a liquid. Increasing the external pressure increases the solubility of a gas in a liquid. Changes in pressure will not affect the solubility of a solid or a liquid in a liquid.

Temperature affects on the solubility of a solute (whether it is a solid, liquid or a gas) depends on whether the formation of the solution is exothermic or endothermic. If the solution process is exothermic, increasing the temperature of the solution will decrease the solubility of the solute in the solvent. If the solution process is endothermic, increasing the temperature of the solution will increase the solubility of the solute in the solvent.

For nonpolar gases dissolving in water the solubility of the gas increases with increasing molar mass. The larger the molar mass of the gas, the more important are the London dispersion forces. The higher the London dispersion forces the higher the solubility of the gas. (It should be remembered the solubility of nonpolar gases is very low in relative terms.) The solubility of polar molecules is very high. In fact in many instances polar gases such as ammonia and hydrogen chloride are miscible in water.