Name:____

Chem 118 Laboratory
University of Massachusetts Boston

The Heat of Mixing

LEARNING GOALS

1. Appreciate the difference between chemical bonds and intermolecular bonds
2. Become familiar with the concepts of the change in enthalpy, change in entropy and the change in free energy (ΔH, ΔS and ΔG) and how they relate to the driving forces of reactions.
3. Continue to become familiar with using a spreadsheet to graph data.
4. Appreciate the true microscopic nature of polar liquids

OBJECTIVE

The objective of this experiment is to determine the heat released or absorbed when two solvents are mixed.

INTRODUCTION

There are two factors that can drive processes to occur. The first is the heat exchanged as a result of the process. This is referred to as the “change in enthalpy” and sometimes as “the heat of reaction”. If heat is released in the process ($\Delta H < 0$), it favors the spontaneity of the reaction. The second is the change in the state of order in the system. This is referred to as the “change in entropy”. A process that results in a more disordered state favors spontaneity ($\Delta S > 0$). These two factors can work together or fight it out in determining whether a process is indeed spontaneous. The ultimate determining factor is the change in free energy (ΔG) which is a function of the change in enthalpy (ΔH) and the change in entropy (ΔS). If ΔG is negative, the reaction occurs. If it is positive, the reaction does not occur. Thus, any spontaneous endothermic process has to be driven by a positive change in entropy.

$$\Delta G = \Delta H - T\Delta S$$

Intermolecular interaction in polar solvents, such as water and ethanol are based on hydrogen bonding. Pure water exists as spheres of 10-30 water molecules held together via hydrogen bonds. Pure ethanol is similar, but generally the clusters of ethanol are smaller. As we will soon verify, these two solvents are completely miscible in all proportions. What happens to the intermolecular bonding structure when these two solvents are mixed? Some water-water hydrogen bonds and ethanol-ethanol hydrogen bonds are broken and some water-ethanol hydrogen bonds are formed. The process of breaking bonds is endothermic (heat is absorbed by the molecules and the energy is used to break the bonds). The process of making bonds is exothermic (heat is released). By measuring the temperature change of the solutions upon mixing, one can assess whether a net number of hydrogen bonds were formed or broken upon mixing. Because molecules that are on the inside of the sphere are generally involved in more hydrogen bonding than those on the surface of the sphere, an exothermic mixing suggests that bigger clusters were formed and an endothermic mixing suggests that mixing has resulted in smaller solvent clusters.

PROCEDURE

Each group will perform a set of calorimetric experiments that will measure the temperature change that occurs when two solvents are mixed in an insulated Styrofoam cup. Data will be shared among groups and the data will be plotted. You will run the experiment with five different water/ethanol mole ratios and one water/acetonitrile mole ratio.

We are only limiting the water/acetonitrile trial to one trial because acetonitrile is not a particularly environmentally friendly solvent and we would like to limit the waste produced containing this solvent. For this reason, the acetonitrile/water mixtures will be disposed of in a separate waste container.

We will use nested Styrofoam coffee cups as the calorimeter in this experiment. Whichever solvent is largest in volume in the particular trial you are performing will be measured using a graduated cylinder and poured into the cup. A top of the cup will have a hole in it where you can stick a thermometer. Place the top on and record the initial temperature of the solvent. Measure the solvent to be added using a graduated cylinder designated for this solvent (so to prevent any prior mixing). With the thermometer in place, have one person carefully crack the top open enough to let another person quickly (but carefully) pour the solvent into the cup. The first person should quickly readjust the top on the cup after the solvent is added. Gently stir the mixture. The temperature of the solvent will change fairly rapidly upon mixing and should level out at a new temperature after a minute or so. Record the final temperature.

You will work in groups of three and your instructor will assign a group number to you. Trial # 6 should be preformed in the hood. There is a set-up in the hood already. You do not have to move your stuff.

Group 1	
1)	1.0 mL H_2O and 30.0 mL EtOH
2)	3.0 mL H_2O and 22.0 mL EtOH
3)	7.0 mL H_2O and 22.0 mL EtOH
4)	12.0 mL H_2O and 17.0 mL EtOH
5)	20.0 mL H_2O and 7.0 mL EtOH
6)	1.0 mL H_2O and 25.0 mL ACN

Group 2

1)	2.0 mL H_2O and 27.0 mL EtOH
2)	4.0 mL H_2O and 20.0 mL EtOH
3)	8.0 mL H_2O and 18.0 mL EtOH
4)	15.0 mL H_2O and 12.0 mL EtOH
5)	25.0 mL H_2O and 4.0 mL EtOH
6)	2.0 mL H_2O and 23.0 mL ACN

Group 3

1)	1.0 mL H_2O and 30.0 mL EtOH
2)	3.0 mL H_2O and 22.0 mL EtOH
3)	7.0 mL H_2O and 22.0 mL EtOH
4)	12.0 mL H_2O and 17.0 mL EtOH
5)	20.0 mL H_2O and 7.0 mL EtOH
6)	3.0 mL H_2O and 20.0 mL ACN

Group 4

1)	2.0 mL H_2O and 27.0 mL EtOH
2)	4.0 mL H_2O and 20.0 mL EtOH
3)	8.0 mL H_2O and 18.0 mL EtOH
4)	15.0 mL H_2O and 12.0 mL EtOH
5)	25.0 mL H_2O and 4.0 mL EtOH
6)	4.0 mL H_2O and 21.0 mL ACN

Group 5

1)	1.0 mL H_2O and 30.0 mL EtOH
2)	3.0 mL H_2O and 22.0 mL EtOH
3)	7.0 mL H_2O and 22.0 mL EtOH
4)	12.0 mL H_2O and 17.0 mL EtOH
5)	20.0 mL H_2O and 7.0 mL EtOH
6)	5.0 mL H_2O and 21.0 mL ACN

Group 6

1)	2.0 mL H_2O and 27.0 mL EtOH
2)	4.0 mL H_2O and 20.0 mL EtOH
3)	8.0 mL H_2O and 18.0 mL EtOH
4)	15.0 mL H_2O and 12.0 mL EtOH
5)	25.0 mL H_2O and 4.0 mL EtOH
6)	7.0 mL H_2O and 20.0 mL ACN

Group 7

1)	1.0 mL H_2O and 30.0 mL EtOH
2)	3.0 mL H_2O and 22.0 mL EtOH
3)	7.0 mL H_2O and 22.0 mL EtOH
4)	12.0 mL H_2O and 17.0 mL EtOH
5)	20.0 mL H_2O and 7.0 mL EtOH
6)	8.0 mL H_2O and 15.0 mL ACN

Group 8

1)	2.0 mL H_2O and 27.0 mL EtOH
2)	4.0 mL H_2O and 20.0 mL EtOH
3)	8.0 mL H_2O and 18.0 mL EtOH
4)	15.0 mL H_2O and 12.0 mL EtOH
5)	25.0 mL H_2O and 4.0 mL EtOH
6)	12.0 mL H_2O and 15.0 mL ACN

Group 9

1)	1.0 mL H_2O and 30.0 mL EtOH
2)	3.0 mL H_2O and 22.0 mL EtOH
3)	7.0 mL H_2O and 22.0 mL EtOH
4)	12.0 mL H_2O and 17.0 mL EtOH
5)	20.0 mL H_2O and 7.0 mL EtOH
6)	14.0 mL H_2O and 10.0 mL ACN

Group 10

1)	2.0 mL H_2O and 27.0 mL EtOH
2)	4.0 mL H_2O and 20.0 mL EtOH
3)	8.0 mL H_2O and 18.0 mL EtOH
4)	15.0 mL H_2O and 12.0 mL EtOH
5)	25.0 mL H_2O and 4.0 mL EtOH
6)	20.0 mL H_2O and 6.0 mL ACN

Name:
Section:
Partners:

DATA AND CALCULATIONS

Use the molecular masses and densities of the three solvents to calculate the mole fraction of water for each of your mixtures and enter the data in the table provided below. ie. mol fraction = {mol water/(mol water + mol ethanol)}

Solvent	Molecular Mass (g/mol)	Density (g/mL) @ 20°C
Water	18.02	1.000
ethanol	46.08	0.789
Acetonitrile	41.05	0.788

	Volume H_2O (mL)	**Volume EtOH or ACN (mL)**	**mol H_2O**	**mol EtOH or ACN**	**mol fraction H_20 (mol H_20/total mol)**	**T_i (˚C)**	**T_f (˚C)**	**$\Delta T = T_f - T_i$ (˚C)**
Trial 1								
Trial 2								
Trial 3								
Trial 4								
Trial 5								
Trial 6								

FOR THE LAB REPORT

Before leaving, your data will be entered into an Excel Spreadsheet and the Excel data file will be posted on Blackboard.

There will be no abstract for this lab. Your lab report will consist of data sheet (pg 5), two Excel plot (can be on the same graph) and answers to the question below. Your data sheet will be worth 18 points (1/2 pt for each entry in the last six columns).

Using the Excel, graph the class data of ΔT as function of mol fraction of water for both the water-ethanol mixtures and the water-acetonitrile mixtures. Carefully label your plots. Turn in your plots along with your answers to the following questions. Each plot is worth 10 pts and each question is worth 4 points. This adds to 62. So, a perfect score will be 62/60 pts).

1. Does a chemical reaction occur? What is the nature of hydrogen bonds?
2. Is the process of mixing ethanol and water exothermic or endothermic? Does this suggest presence of large clusters or small clusters in the mixture?
3. Is the process of mixing acetonitrile and water exothermic or endothermic? What can we say about the entropy change for this process (Remember: ΔG is negative because mixing occurred) and how does it relate to the size of the solvent clusters?
4. For the mixing process of ethanol and water, what mole fraction releases the maximum amount of heat? Interpret this data, relative to the intermolecular interactions between the solvents?
5. For the mixing process of acetonitrile and water, what mole fraction absorbs the maximum amount of heat? Interpret this data, relative to the intermolecular interactions between the solvents?
6. If you were to redo the Trial 1, doubling the volumes of each of the two solvents, predict the ΔT that would be measured. Explain your reasoning. Hint: Think about the molar heat capacity of the solution.