Contents

1 Objectives

The objective of this experiment is to determine:

1. The heat capacity of pure components and the binary solutions of water and acetone
2. The enthalpy of mixing by measuring the heat of mixing using an adiabatic calorimeter
3. The partial molar enthalpies of components and the molar enthalpies at infinite dilution

2 Notes on the Procedure

1. Rinse the adiabatic flask with the chemical that will be added to it.
2. Fill the adiabatic flask with the calculated amount of chemical and a magnetic bead, then shut the flask with the stopper including the heating coil and the heat sensor.
3. Start the stirrer at 500rpm and wait for the steady temperature.

   Additionally for Binary Solutions:
   (a) Remove the stopper and place it in distilled water.
   (b) Fill the flask with the calculated amount of second component of the solution.
   (c) Close the flask with the stopper enclosing the heating coil and the temperature sensor after wiping the heating coil and the temperature sensor with a tissue paper.
   (d) Wait for a steady temperature.
4. Simultaneously start the voltmeter and the timer.
5. Note the time for an rise in temperature of 2 degree C.
6. Discard the solution safely in seperately.
7. Repeat the same procedure for other molar binary solutions.

3 Set-up

The apparatus required for the experiment is:

1. Adiabatic flask
2. Heating element
3. Temperature sensor connected to the temperature display
4. Magnetic bead and stirrer (kept constant at around 500 rpm)
5. Stopwatch or Timer
6. Voltage and Current regulator
7. Measuring Cylinders
8. Distilled Water
9. Analytical grade acetone
10. Beaker

4   Results

4.1   Raw Data

Mole fraction (x_a)	V_a (mL)	mass m (g)	moles (n)	T_i (°C)	T_{mi} (°C)	T_{mf} (°C)	ΔT_m $(T_{mi}\text{-}T_i)$ (°C)	V (volt)	I (A)	time (s)
0	0	149.5	8.31	29.3	29.3	31.3	0	16.3	2.7	79.2
0.2	75.7	133.80	5.14	29.3	34.8	36.9	5.5	16.5	2.72	77.47
0.4	109.7	126.52	3.72	29.2	32.1	34.2	2.9	16.3	2.72	68.32
0.6	128.9	122.41	2.92	29.3	29.4	31.5	0.1	16.3	2.72	60.03
0.8	141.3	119.76	2.39	29.3	27.4	29.5	-1.9	16.3	2.72	53.43
1	150	117.9	2.01	29.1	29.3	31.4	0	16.3	2.72	46.28

Table 1: Raw Data Table

The least count errors are:

1. Ammeter $\Delta I = 0.01$A
2. Voltmeter $\Delta V = 0.01$V
3. Stopwatch $\Delta t = 0.167$s
4. Mass $\Delta m = 0.1$g
5. $\Delta(\Delta T_m) = 0.1$ °C

Values used from literature:

1. Density of water = 997 kg/m^3
2. Density of acetone = 790 kg/m^3
3. Heat capacity of water at 20 °C = 4.186 J/g°C

4.2   Calculations for Volume and moles

Taking the mole fraction(x_a) to be 0.2
Let, subscript a denote acetone and subscript w denote water
Total volume $V_t = 150$ ml $= V_a + V_w$

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$$0.2 = \frac{n_a}{n_a + n_w} \text{ and } 0.8 = \frac{n_w}{n_a + n_w}$$

$$\implies 4 = \frac{n_w}{n_a}$$

$$\implies 4 = \frac{\rho_w * V_w * M_a}{\rho_a * V_a * M_w} = \frac{\rho_w * (150 - V_a) * M_a}{\rho_a * V_a * M_w}$$

$$\implies V_a * (\rho_w * M_a + 4 * \rho_a * M_w) = \rho_w * 150 * M_a$$

$$\implies V_a = 75.7 \text{ ml}$$

4.3 Calculations for pure component

4.3.1 Calculation for K

Let, Q be the heat required to raise the temperature of the solution by 2 °C (ΔT_1)
$Q = IVt = (m(C_p)_{water} + k)\Delta T_1$
$K = IVt/2 - m(C_p)_{water}$
$K = 1.1168 * 10^3 \pm 63.77$ J per °C

4.3.2 Calculation of C_p of pure acetone

Let, Q be the heat required to raise the temperature of the solution by 2 °C (ΔT_1)
$Q = IVt = (mC_p + k)\Delta T_1$
Which gives $C_p = \dfrac{(IVt/2 - k)}{m} = $ -0.6638 $\pm$ 0.07678 J/(g°C)

4.4 Calculations for mixtures

Calculations for sample with $x_a = 0.2$

4.4.1 Finding the values of C_p and ΔH_m

Let, Q be the heat required to raise the temperature of the solution by 2 °C (ΔT_1)
$Q = IVt = (mC_p + k)\Delta T_1$

Which gives $C_p = \dfrac{(IVt/2 - k)}{m}$

$Q_m = -(mC_p + k)\Delta T = -IVT\dfrac{\Delta T}{2}$

H_m is given by $\dfrac{Q_m}{n_a}$

$H_m = -IVT\dfrac{\Delta T}{2n_a} = $ J per mole

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Molarity x_a	Heat Capacity C_p (J/g°C)	Error in C_p (J/g°C)	Heat of mixing Q_m (J)	Enthalpy of mixing ΔH_m (J/mole)	Error in H_m (J/mole)
0.2	4.6461	±0.5310	-9561.3	-1860.2	±354.00
0.4	3.2906	±0.3771	-4446.0	-1195.2	±247.38
0.6	1.8813	±0.2163	-134.7	-46.1	±54.07
0.8	0.6863	±0.0792	2278.0	953.2	±215.33

Table 2: Table for plotting ΔH_m VS x_a

4.5 Error calculations

Taking values for $x_a = 0.2$

Using the least counts from before,

$\Delta I = 0.01$ A

$\Delta V = 0.01$ V

$\Delta t = 0.167$ sec

$\Delta m = 0.1$ g

$\Delta(\Delta T) = 0.1$ K

$$\frac{\Delta k}{k} = \frac{\Delta I}{I} + \frac{\Delta V}{V} + \frac{\Delta t}{t} + \frac{\Delta(\Delta T)}{\Delta T} + \frac{\Delta m}{m}$$

$$\implies \frac{\Delta k}{k} = \frac{0.01}{2.72} + \frac{0.01}{16.5} + \frac{0.167}{79.2} + \frac{0.1}{2} + \frac{0.1}{149.5500} = 5.7\%$$

$$\frac{\Delta C_p}{C_p} = \frac{\Delta k}{k} + \frac{\Delta I}{I} + \frac{\Delta V}{V} + \frac{\Delta t}{t} + \frac{\Delta(\Delta T)}{\Delta T} + \frac{\Delta m}{m}$$

$$\implies \frac{\Delta C_p}{C_p} = 0.057 + \frac{0.01}{2.72} + \frac{0.01}{16.5} + \frac{0.167}{77.47} + \frac{0.1}{2} + \frac{0.1}{133.8} = 11.43\%$$

$$\frac{\Delta H_m}{H_m} = \frac{\Delta C_p}{C_p} + \frac{\Delta k}{k} + \frac{\Delta(\Delta T)}{\Delta T} + \frac{\Delta m}{m}$$

$$\implies \frac{\Delta H_m}{H_m} = 0.057 + 0.01143 + \frac{0.1}{5.5} + \frac{0.1}{133.8} = 19.03\%$$

4.6 Plotting ΔH_m vs. x_a

In this section, the plot of the molar enthalpy of mixing vs. the mole fraction of acetone is show along with a data table. The code used to plot the graph is give here.
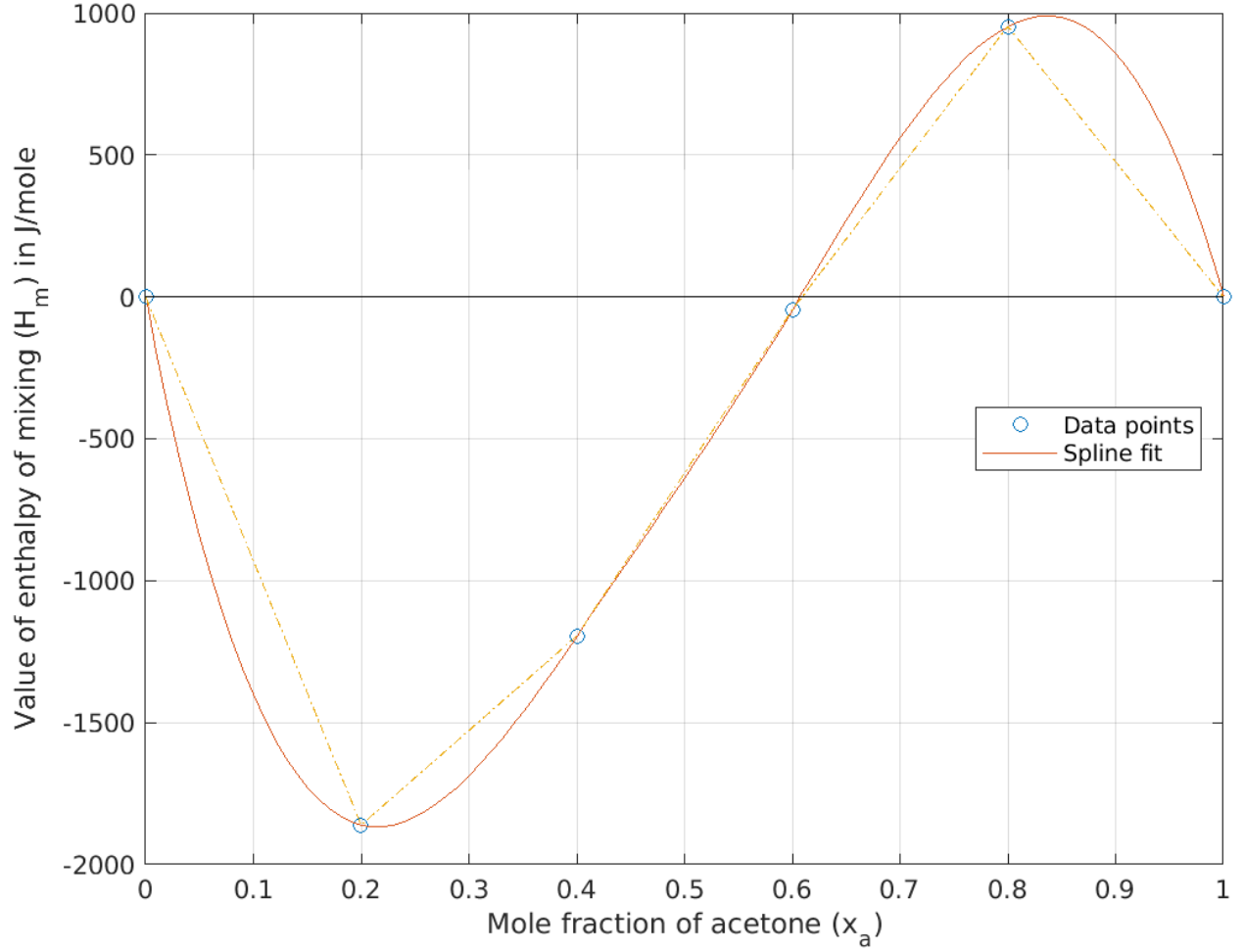
Figure 1: H_m vs. x_a

4.7 Calculation of partial molar enthalpies

Taking the values of $H_m|_{x_1=0.5}$, $dH_m/dx_1|_{x_1=0}$, $dH_m/dx_1|_{x_1=1}$ and $dH_m/dx_1|_{x_1=1}$ from the plot.

For $x_1 = 0.5$,

$H_{1p} = H_m + x_2 * dH_m/dx_1|_{x_1=0}$

$H_{1p} = -638.5561 + 0.5 * 5680.8 = 2.2018$ KJ per mole

$H_{2p} = H_m - x_1 * dH_m/dx_1|_{x_1=0}$

$H_{2p} = -638.5561 - 0.5 * 5680.8 = -3.479$ KJ per mole

For infinite dilutions,

$H_{1\infty} = dH_m/dx_1|_{x_1=0}$ (as $H_m = 0$ and $x_2 = 1$)

$H_{1\infty} = -1.9149 * 10^4$ J per mole

$H_{2\infty} = -dH_m/dx_1|_{x_1=1}$ (as $H_m = 0$ and $x_1 = 1$)

$H_{2\infty} = 1.2812 * 10^4$ J per mole

5   Discussion