GENERAL CHEMISTRY

LAB COMPONENT CHE101L

CONTENT: LAB 3

Dissolution Reactions: Heats of Dissociation

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EXPERIMENT 3

SESSION 1 (QUALITATIVE)

DISSOLUTION REACTIONS: HEATS OF DISSOCIATION

Heats (exothermic or endothermic) are associated with chemical reactions. Quantity of heat evolved or absorbed is directly proportional to the amount reacted. Consider the reactions below:

$$MgSO4(s) + H_2O\,(l) \longrightarrow Mg^{2+}(aq.) + SO_4^{2-}(aq.) \pm \text{heat}$$

$$NaNO_3(s) + H_2O\,(l) \longrightarrow Na^{+}(aq.) + NO_3^{-}(aq.) \pm \text{heat}$$

Heat could be generated or absorbed in this reaction. When heat is generated/released from a chemical reaction it is called exothermic reaction (you can feel it by touching the reaction container (warmer) and when heat is absorbed the reaction is called endothermic (colder). When reactions occur in a reaction vessel (*e.g.,* Beaker) in aqueous condition, formation and dissociation of chemical bonds occur simultaneously. Bond formation and dissociation involves heat energy of the system which is expressed by the term Q which is called enthalpy.

PROBLEM STATEMENT: **Is heat energy related to chemical reactions, how?**

This experiment is subdivided into two parts:

I. QUALITATIVE

II. QUANTITATIVE

PART I. QUALITATIVE

DATA COLLECTION:

Place about 30 mL of distilled water into a 50 mL beaker. Suspend a thermometer (having 0.1^{0}C division mark) into the beaker using thermometer clamp and ring stand. Please make sure that the thermometer is not touching the bottom of the beaker, as any movement of the beaker could break the thermometer. Record the temperature of water in the beaker in every 30 seconds for 180 seconds.

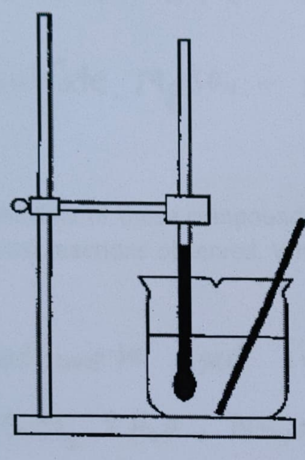


FIGURE 1: Experimental setup for dissolution reaction

Place a moderate amount (which would be 1 to 3 cm^3) of supplied anhydrous magnesium sulfate ($MgSO_4$) to the beaker. Mix vigorously with the glass rod for 2 minutes. Record your observations. **(2 points)**

We observed distilled water stability for 60 seconds, and the temperature of the water was 24'10°c, then we added $MgSO_4$. After 120 seconds, we noted the temperature increase to 34°c, indicating an exothermic reaction.

Repeat this procedure with each of the following compounds with two different amounts (roughly 1:2): (**2 points**)

a. Sodium Nitrate, $NaNO_3$ – 24·25°C – 23°C – Endothermic

b. Sodium Chloride, $NaCl$ – 24°C – 23°C – Endothermic

c. Hydrated Calcium Chloride, $CaCl_2.2H_2O$ – 24°C – 26°C – Exothermic

d. Ammonium Nitrate, NH_4NO_3 – 24°C – 22°C – Endothermic

e. Magnesium sulfate, $MgSO_4$ – 24·10°C – 34°C – Exothermic

DATA ANALYSIS:

Compare and contrast the behaviors of these compounds. Identify any generalizations that can be made about the chemical reactions observed. What conclusions can be drawn from the data? (4 points)

The compounds that we've used in the experiment are $NaNO_3$, $NaCl$, $CaCl_2 \cdot 2H_2O$, NH_4NO_3, $MgSO_4$. Among these compounds, all of them are soluble in water.

Here, $NaNO_3$, $NaCl$, NH_4NO_3 absorb energy and decrease the temperature when dissolved in water. So, $NaNO_3$, $NaCl$ and NH_4NO_3 are Endothermic.

On the other hand, $MgSO_4$ and $CaCl_2 \cdot 2H_2O$ ~~Hea~~ release heat and rise the temperature when dissolved in water. Thus $MgSO_4$ and $CaCl_2 \cdot 2H_2O$ are Exothermic.

Session 2(Quantitative)

Part II. Quantitative

Data Collection:

a. Accurately weigh a 3 to 5 gm sample of $MgSO_4$ on the analytical balance. Record the exact mass here. For 4 different trials below measure four different weight samples (e.g., 1,2, 4 & 5 grams respectively).

b. Suspend the thermometer into a polystyrene cup/coffee cup. Make sure of the thermometer is not touching the bottom of the cup. Measure 20 mL of distilled water by a volumetric cylinder into the cup and stir for 240 second. Record the temperature in every 20 seconds. After 240 seconds add $MgSO_4$ with vigorous mixing while continuing to record data for 5 minutes.

c. Determine the temperature change, ΔT, for the reaction. This can be done from the difference of the highest temperature minus the slope of the line go through the points from first 240 seconds of data.

d. Draw a temperature vs. time graph. Draw the best curve through the points and point out what is happing in each part of the curve.

e. Repeat the whole procedure with $NaNO_3$.

Data Table 1:

Trails

(I) Mass of $MgSO_4$_0.5 gm			(II) Mass of $MgSO_4$_1.0 gm	
Time (s)	Temp(°C)		Time(s)	Temp(°C)
20	25		20	25
40	25		40	25.10
60	25		60	25.5
80	27		80	29
100	27		100	31
120	26.75		120	31.10
140	26.5		140	31.10
160	26.25		160	31
180	26		180	37
200	26		200	31
220	25.9		220	31
240	25.75		240	30.9
260	25.5		260	30.5
280	25.5		280	30.5
300	25.5		300	30.25

(III) Mass of $MgSO_4$_1.5 gm			(IV) Mass of $MgSO_4$_2.0 gm	
Time (s)	Temp(^oC)		Time(s)	Temp(^oC)
20	23		20	24.5
40	23		40	24.5
60	23		60	24.5
80	29.5		80	30
100	32		100	33
120	32		120	33.5
140	32		140	34
160	32		160	34
180	31.5		180	34
200	31.5		200	33.8
220	31.5		220	33.8
240	31		240	33.8
260	31		260	33.5
280	31		280	33.5
300	30.75		300	33.25

DATA TABLE 2: **TRAILS**

(I) Mass of $NaNO_3$_0.5 gm			(II) Mass of $NaNO_3$_1.00 gm	
Time (s)	Temp(^oC)		Time(s)	Temp(^oC)
20	24.75		20	23
40	24.75		40	23
60	24.75		60	23
80	24.5		80	22.5
100	24.25		100	22
120	24.25		120	22
140	24.1		140	22
160	24.1		160	22
180	24.1		180	22
200	24		200	21.75
220	24		220	21.75
240	24		240	21.75
260	24		260	21.5
280	24		280	21.5
300	24.1		300	21.5

(III) Mass of $NaNO_3$ _1.5 gm			(IV) Mass of $NaNO_3$ _2.0 gm	
Time (s)	Temp(^{0}C)		Time(s)	Temp(^{0}C)
20	25·25		20	24·25
40	25·10		40	24·1
60	25·10		60	24
80	25		80	23·75
100	24·5		100	23
120	24·1		120	23
140	24·1		140	23
160	24		160	23
180	24		180	23
200	23·9		200	23·25
220	23·9		220	23·5
240	23·9		240	22
260	23·75		260	22·5
280	23·75		280	22
300	23·75		300	21·5

DATA ANALYSIS

1. What do you understand form both data sets you recorded and from the other trials? **(4 points)**

For $MgSO_4$: From the data tables of $MgSO_4$, we can say that $MgSO_4$ dissolves in water & increase temperature for certain time period and then it started to decrease. Thus it's an Exothermic reaction.

$$MgSO_4(s) + H_2O(l) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq), \quad \Delta H = -ve \text{ (Exothermic reaction)}$$

If we add more substance then we can see the more temperature to rise.

For $NaNO_3$: From the data tables of $NaNO_3$, we can say that $NaNO_3$ dissolves in water and decrease temperature for a certain time period and then it started increasing again. Thus it's an Endothermic.

$$NaNO_3(s) + H_2O(l) \longrightarrow Na^+(aq) + NO_3^-(aq), \quad \Delta = +ve \text{ (Endothermic Reaction)}$$

If we add more substance, then we can see the more temperature to fall.

2. Calculate the heat, Q & moles, n, of the reaction both data sets. Take help from the equitation $Q = C \times M \times \Delta T$. Assume $C = 4.18$ Joules/gram ^0C and M is the mass of water (take the water density as 1.00 grams/cm^3). **(4 points)**

For $MgSO_4$:

0·5 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (27-25) = 167{\cdot}2$ J

Mole, $n = \frac{0{\cdot}5}{120} = 0{\cdot}0041$ mole

1 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (31{\cdot}10 - 25{\cdot}5) = 468{\cdot}16$ J

Mole, $n = \frac{1}{120} = 0{\cdot}0083$ mole

1·5 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (32-23) = 752{\cdot}4$ J

Mole, $n = \frac{1{\cdot}5}{120} = 0{\cdot}0125$ mole

2gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (34 - 24{\cdot}5) = 794{\cdot}2$ J

Mole, $n = \frac{2}{120} = 0{\cdot}0167$ mole

For $NaNO_3$:

0·5 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (24{\cdot}75 - 24) = 62{\cdot}7$ J

Mole, $n = \frac{0{\cdot}5}{85} = 0{\cdot}0059$ mole

1 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (23 - 21{\cdot}5) = 125{\cdot}4$ J

Mole, $n = \frac{1}{85} = 0{\cdot}0118$ mole

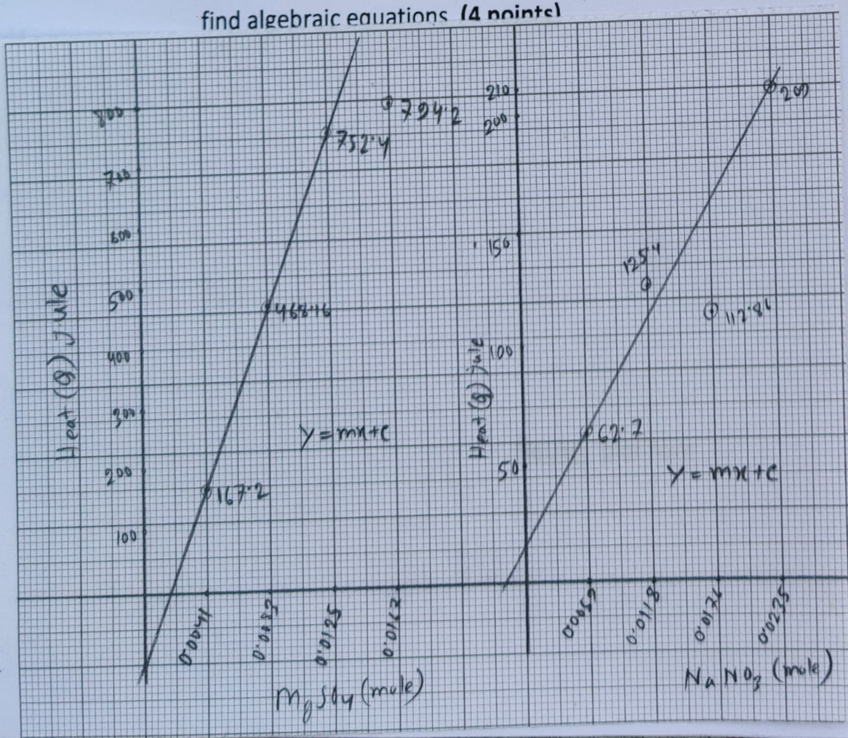
1·5 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (25{\cdot}10 - 23{\cdot}75) = 112{\cdot}86$ J

Mole, $n = \frac{1{\cdot}5}{85} = 0{\cdot}0176$ mole

2 gm : Heat, $Q = C \times M \times \Delta T = 4{\cdot}18 \times 20 \times (24 - 21{\cdot}5) = 209$ J

Mole, $n = \frac{2}{85} = 0{\cdot}0235$ mole

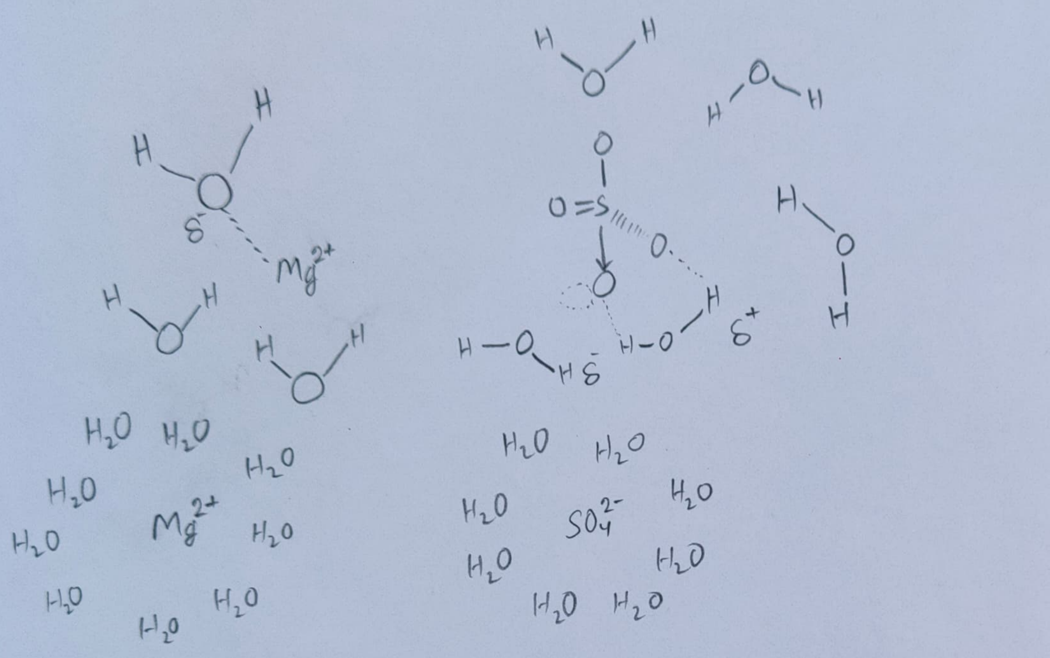
3. Plot the collected data as moles, n vs. Q both sets of data. Number of moles can be calculated as n = (mass of sample in gram) / (molecular weight in grams/mole). Try to find algebraic equations. **(4 points)**



MENTAL MODEL: Use the chemical equation given above to represent the dissolution reaction in this experiment. Draw a picture(s) which describes what is happening in atomic or in molecular level for either $MgSO_4$ or $NaNO_3$ system. How heat release or absorbed can be described from these pictures? **(5 points)**

The formula for $MgSO_4$ dissolution:

$$MgSO_4 (s) + H_2O (l) \longrightarrow Mg^{2+} (aq) + SO_4^{2-} (aq) + H_2O (l)$$



The dissolution of $MgSO_4$ in water is an exothermic process, meaning that it releases heat. This heat release is due to the strong attractions between the ions in $MgSO_4$ and the water molecules. When $MgSO_4$ is dissolved in water, the ions dissociate and break apart, and water molecules surround and stabilize them. This process of hydration releases a significant amount of energy in form of heat.