Introduction:

Energy is always present in our life, from the way our body use all the energy obtained from sugars by glycolysis and the chain of electrons *(Nelson & Cox, 2017)*to the use of gasoline in our cars through the combustion of this compound. Remember the energy is the capacity of a body to do a work and can be found in different forms such as kinetic, potential, solar, etc.

Energy is normally transferred form a system to other, system is the part of the universe we are focused on.*(Martin Silberberg, 2017*) There are certain system that allow the transference of energy and matter; the open ones, other which only allow the transference of energy; closed ones, and the last genre does not allow the transference of nothing.

The energy of the universe is constant. this means that the internal energy E of a system can be defined most precisely as the sum of the kinetic and potential energies of all the "particles" in the system. The internal energy of a system can be changed by a flow of work, heat, or both:

$$[A]\Delta E = q + w$$

ΔE= Change in the internal energy of the system.

q= Heat.

w= Work.

Energy can be converted from one form into another, but all of the energy present before a change occurs always is kept after the change is completed. This observation is expressed in the law of conservation of energy: during a chemical or physical change, energy can be neither created nor destroyed, although it can be changed in form. (*rice university, 2015*)

Mechanical pressure-volume work is the form of work most used in chemistry,

$$[B]w = -p\Delta V$$

w= Work.

p= Heat.

ΔV= Volume difference.

When we substitute w in [1] from [2] we obtain=

$$[C]\Delta E = q - p\Delta V$$

Solving for q we get:

$$[D]\Delta E + p\Delta V = q$$

This equation may not say too much to us just like this, but when we compare it with Enthalpy equation, which is the sum of change in internal energy and the product of the constant pressure and the difference in volume

$$[E]H = U + pV$$

Thus.

$$[F]\Delta H = \Delta U + p\Delta V$$

H= Enthalpy

U= Internal energy

V= Volume

Δ=Difference

We can see that [D] and [F] can be equalized to get

$$[G]\Delta H = \Delta U + p\Delta V = q$$

In order to go further we must know that the specify heat capacity is the amount required to elevate the temperature of one gram of substance by one Kelvin

$$[I]c = \frac{q}{m\Delta T}$$

Knowing from daily life than the more heat we applied to an object, the hotter it will get; the temperatures is directly proportional to the heat(Zumdahl & Zumdahl, 2007)

$$\Delta q \; \alpha \; \Delta T$$

Solving [I] for q we obtain

$$[J]\; q = cm\Delta T$$

To cool 100mL drinkable water by 5°C, within 5 minutes, it requires an endothermic reaction that can absorb the heat from the water and decrease the temperature to ideal. Each substance has different specific heat capacity (c), which is the energy that is needed to change one unit of temperature of a substance per unit of mass. It can be found by experiment data or approximated by calculation using the standard heat of formation.

For this product, water's specific heat capacity is used, which is 4.18 J/g°C. Theoretically, the total amount of energy that is absorbed by the environment for decrease 5 degree Celsius, is determined by the heat capacity formula,

$$q=mc\Delta T, \qquad (1)$$

which defines the energy in Joules required for temperature change in degree Celsius of a given mass in gram. They are directly proportional to each other.

Chemicals on the chosen list are ammonium nitrate and ammonium chloride, they both absorb heat when they dissolve into water. It is because the ionic bond between ionic lattice are broken and new bond associate with water are formed, the energy difference between these two processes are either release or absorb.

The amount of energy is released or absorbed when a solid is dissolved and form a solution is called enthalpy of solution. It is equal to the sum of lattice energy and hydration energy of ions. Lattice energy is the energy that is needed by one mole of solid salt to break the ionic bonds into its gaseous states. Hydration energy is the amount of energy that releases when one mole of gaseous ions is solvated and form bonds with water, so it is always negative. The enthalpy of solution has an equation as below:

$$H_{solution} = H_{lattice\ energy} + H_{hydration}$$

Under the safety concern, ammonium nitrate is a toxic substance. Lethal dose is 2217mg/kg. It is also a combustion adjuvant, so it will accelerate combustions and is used in explosives. Therefore, ammonium nitrate can cause explosion and fire in the transport process, and it is risky if human accidentally intake. In the comparison, the relatively low-cost material ammonium chloride is safer and better cooling substance for a drink can. Thus, the ammonium chloride is chosen.

To measure the amount of ammonium chloride needed to decrease 5 degree Celsius, 100 ml water will be placed in a can which is surrounded by 100 ml water, and this system is heat isolated by a foam cup to make up a simple calorimeter. The ammonium chloride is then needed to decrease 5 degree Celsius for the total amount of 200ml water, because the heat is transferring inside and outside the can. The ammonium chloride is dissolving in the calorimeter but outside the can. The temperature in the can will be detected by the electronic thermometer. According to the conservation law of energy, the heat released by the water is equal to the heat absorbed by the dissolving process of ammonium chloride:

$$Q_{released} = Q_{absorb}$$

$$m_{H_2O}\Delta T \mathrm{C}_{H_2O} = H_{solution} n_{NH_4Cl} \qquad (2)$$

The density(p_{H_2O}) of water is 1.00g/ml; the molar mass(M_{NH_4Cl}) of ammonium chloride is 53.5g/mol; $H_{lattice\ energy}\ of\ ammonium\ chloride\ is\ 705KJ/mol$; $H_{hydration}$ of the gaseous ammonium ion is -307KJ/mol; $H_{hydration}$ of the gaseous chloride ion is -381; these can convert the equation (2) into:

$$p_{H_2O}V\Delta TC_{H_2O} = H_{solution}\frac{m_{NH_4Cl}}{M_{NH_4Cl}} \quad (3)$$

In equation (3), the only two variables are the change of temperature and the mass of ammonium chloride, others are all constance. It tells the relationship that the change temperature of water is directly proportional to the mass of ammonium chloride dissolved in water. If the system is isolated from the environment, and the amount of ammonium chloride is dissolved completely (its solubility is 37.2g/100g water), the equation is valid. By doing multiple trials, the line of best fit for the data set reduces system errors and gives a better estimation of the mass of ammonium chloride that is needed for decrease 5 degree Celsius for the 100ml drinkable water and its 100ml solution surrounding.

Material:

- Calorimeter made with a foam
- Electronic thermometer
- Tap water 600mL
- Ammonium chloride 28g
- Electronic balance
- 50 ml Graduated cylinder
- Aluminum can
- Calorimeter (foam cup)
- Lab2quest

Procedure

1. Fill one can with 100 mL of water.
2. Place the can in the calorimeter.
3. Put a thermometer in the can.
4. Measure 6.56 g of NH_4Cl.
5. Fill the calorimeter with 100 mL of water
6. Record the initial temperature of the water in the can.
7. Place your sample of NH_4Cl in the water of the calorimeter
8. Shake the calorimeter to speed up the dissolving process.

9. Wait until the temperature stabilize, record it.
10. Repeat step 1 to 9 twice with fresh water and replace the mass of NH_4Cl in number 4 with 13.4 g the first time and 8.17g the next time

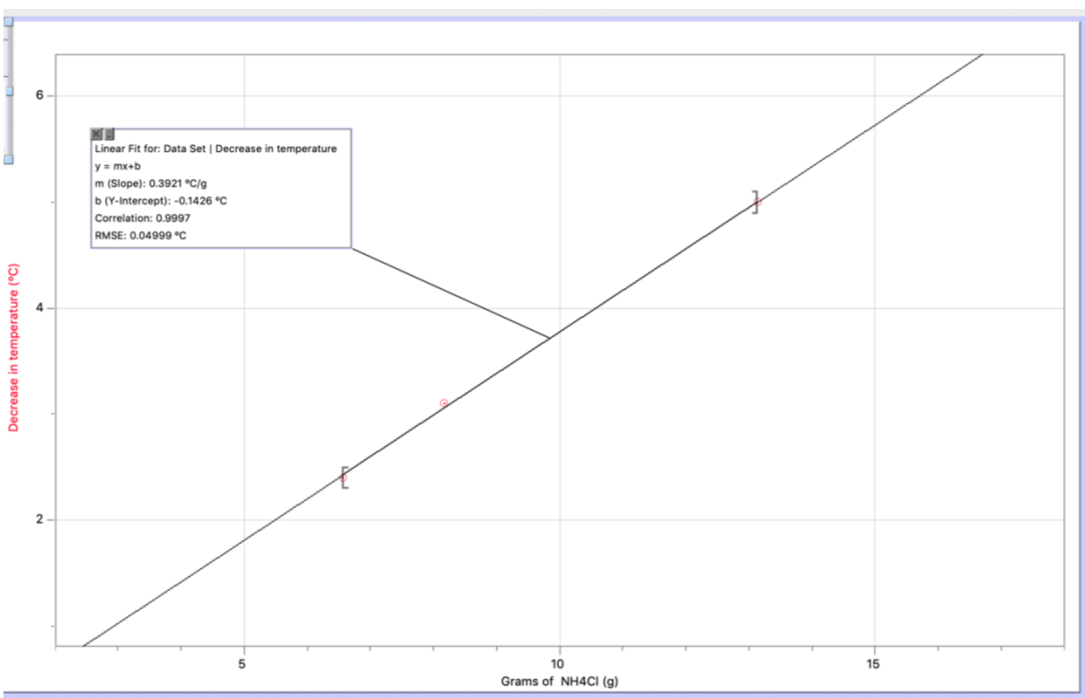
Observation

Table1. Values obtained in the experiment

Grams of **NH_4Cl**	Temperature-I (ºC)	Temperature-F (ºC)	Change
6.56	**22.7**	**20.3**	**2.4**
13.14	**22.2**	**17.2**	**5**
8.17	**22.2**	**19.1**	**3.1**

	Data Set	
	x (g)	y (° C)
1	6.56	2.4
2	8.18	3.1
3	13.14	5

Figure 1. Grams of NH_4Cl used vs decreasing in temperature obtained



Equation obtained:

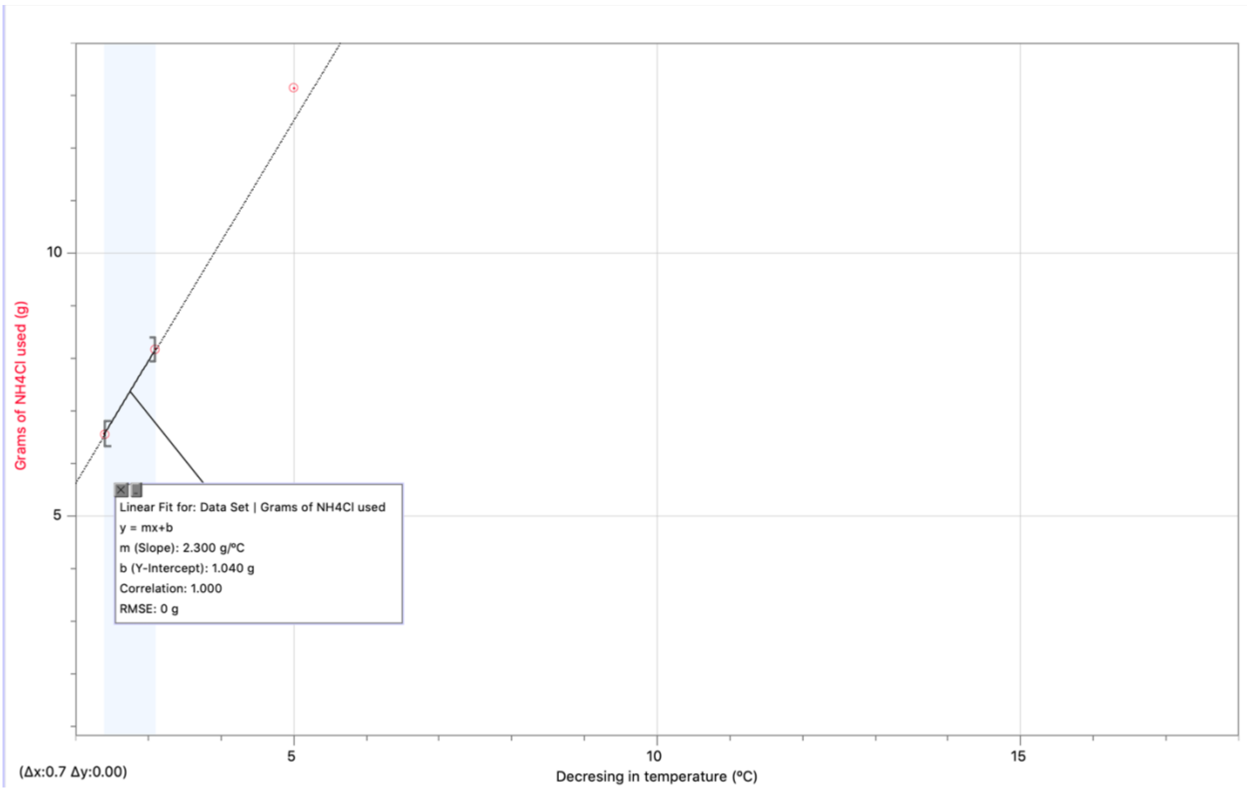
Y= mx+b

Where…

M(slope)= 0.3921 ºC

B= -0.1426 ºC

Figure 2. Decreasing in temperature obtained vs Grams of NH_4Cl used



- Ammonium chloride is a white crystal.
- In the first and the second trial, ammonium chloride is dissolved completely into a colorless solution. However, the second trial is left with some white power at the bottom.
- While the reaction is in progress, the foam cup remains moderate.
- All three trials are within 5 minutes.

Number of trial	Mass(g)	Total volume of water (ml)	Initial temperature (°C)	Final temperature(°C)	Decreased temperature(°C)
1	6.56	200	22.7	20.3	2.4
2	13.14	200	22.2	17.2	5.0
3	8.17	200	22.2	19.1	3.1

Calculations

Applying equation 13 to the salt NH_4Cl we obtain

$$\Delta H_{NH_4Cl} = \Delta Le_{NH_4Cl} + \Delta Hyd_{NH_4} + \Delta Hyd_{Cl}$$

Using the values given:

Quantity	Enthalpy Change (kJ/mol)
$\boldsymbol{\Delta Le_{NH_4Cl}}$	705
$\boldsymbol{\Delta Hyd_{NH_4}}$	-307
$\boldsymbol{\Delta Hyd_{Cl}}$	-381

$$\Delta H_{NH_4Cl} = 705\frac{kJ}{mol} + \left(-307\frac{kJ}{mol}\right) + \left(-381\frac{kJ}{mol}\right)$$

$$\Delta H_{NH_4Cl} = 705\frac{kJ}{mol} - 688\frac{kJ}{mol}$$

$$[A]\Delta H_{NH_4Cl} = 17\ kJ/mol$$

Interpreting the results for ΔNH_4Cl throw that when 1 mol of NH_4Cl reacts with water it takes 17 kJ from the surroundings.

To obtain how many moles of NH_4Cl are required to diminish 5ºC …

$$1.00\frac{g}{mL}(200\ mL)(\Delta T)\left(4.18\frac{J}{g^{\circ}C}\right) = \frac{1.7X10^4\frac{J}{mol}mNH_4CL}{53.5\frac{g}{mol}}$$

$$(\Delta T)\left(836\frac{J}{ºC}\right) = \frac{1.7X10^4 JmNH_4CL}{53.5g}$$

$$(\Delta T) = \frac{17X10^4 J}{447260\frac{Jg}{ºC}}(mNH_4CL)$$

$$(\Delta T) = \frac{17X10^4}{447260} g/ºC(mNH_4CL)$$

$$(\Delta T) = \frac{17X10^4}{447260} g/ºC(mNH_4CL)$$

$$(mNH_4CL) = \frac{447260}{17X10^4} ºC/g(\Delta T) \quad [4]$$

Knowing the difference is equal to 5 ºC we ….

$$(mNH_4CL) = \frac{447260}{17X10^4} ºC/g(5ºC)$$

$$(mNH_4CL) = 13\ g$$

1.Using the equation from Figure 2

$$y = 2.3x + 1.040$$

$$x = 5$$

$$y = 12.54\ g$$

2.To obtain % difference in the constant coefficient

$$\frac{\left|\frac{447260}{17X10^4} - 2.3\right|}{\frac{447260}{17X10^4}} = 12.57\ \%$$

3.To obtain the percentage of error …

$$\frac{|theorical\ value - experimental\ value|}{Theorical\ value} x\ 100$$

$$\frac{|13 - 12.54|}{13} x\ 100 = 3.5\%$$

Discussion 6/8
- good!
- could have gone into a little bit more discussion about your potential errors
- do your results follow along with what you expected?

Discussion

In the experiment, mass of the ammonium chloride is the independent variable, temperature is the dependent variable. Using this relation gets the line of best fit is: y=0.3921x-0.1426. It has a correlation of 0.9997 and shows a strong linear relation. However, having the negative Y-intersect means that at zero gram of ammonium chloride is added, the temperature increases 0.1426 degree Celsius. This is does not make sense. However, the number that is needed determine is the mass of ammonium chloride for decrease of 5 degree Celsius. Therefore, to find the relation of mass as the temperature decreased, y and x are flipped, showing in figure 2. Now, y is the mass of ammonium chloride in gram and x is the decreased of temperature in degree Celsius and they have a linear relationship of y=2.300x+1.040. It has a correlation of 1.000, showing that it is a strong linear relation between these two variables. In theory, the relation of mass of ammonium chloride and the decreased of temperature is:

$$p_{H_2O} V \Delta T C_{H_2O} = H_{solution} \frac{m_{NH_4Cl}}{M_{NH_4Cl}} \qquad (3)$$

Rearrange it, and use the mass of ammonium chloride as the dependent variable:

$$m_{NH_4Cl} = \frac{p_{H_2O} V C_{H_2O} M_{NH_4Cl}}{H_{solution}} \Delta T$$

(4) is approximated equal to: $m_{NH_4Cl} = 2.6309 g/°C \Delta T$

According to the equation above, y-intercept should be equal to zero. In other words, the temperature does not need to add any mass of ammonium chloride to maintain its original value. However, when the ammonium chloride is added into the water that surrounds the can, it absorbs heat from the environment, and the environment include the can, the 100ml water inside the can, 100ml water outside the can and the tip of the electronic thermometer. The metal can and the tip of the electronic thermometer release part of the heat to the dissolving process. This will result in a smaller change in temperature. The y-intersect will be affected by this. However, the released heat from the metals are also proportional to the change of temperature. In other words, the coefficient will be bigger in the experiment and the y-intersect should be zero.

As observed, the second trial that has 13.14g of ammonium chloride is not completely dissolved, so the actual dissolved amount is lesser then the measure mass. In the Figure 2, the linear of best fit at x=5 is lower than the y=13.14; it does not pass the point (5,13.14). In another word, the relation of m_{NH_4Cl}=2.300ΔT +1.040 is minimum the effect of incompletely dissolved.

However, the suggestive experimental value for the mass of ammonium chloride is 12.54g and this is smaller than the theoretical value, 13g, with a %difference of 3.5%. Also, the coefficient from experiment is 2.300, lower than the theoretic value, with %difference of 12.6%.

It is possible that due to the small number of trials is preformed, the relation equation is not representative. The error still affects the data in a big scale. It shows on that the experimental value of the mass of ammonium chloride and the coefficient constant are smaller than the ideal. From the reality perspective, the foam cup is not a completely isolated environment; heat is going to leak into the reaction system from outside, and it results in the smaller change in temperature and a bigger amount of ammonium chloride is needed. The existence of the metal can and the electronic thermometer also result in the bigger mass of ammonium chloride.

Conclusion

Conclusion 2/2

The mass of ammonium chloride required for deceasing 5 °C in 100 ml water surrounded by another 100ml water is 12.54g, having a %difference of 3.5%. The error of the experiment remains undetermined. Bigger number of trials should be performed.

References

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