Experiment 6

Date: 18-10-2005

Application of Hess's law to Determine the Enthalpy Change of Hydration of Magnesium Sulphate(VI)

Objective

To determine enthalpy change of hydration of magnesium sulphate (VI) .

Introduction

The enthalpy of a substance refers to its total energy content. During reactions, the enthalpy of the substances involved changes. This is known as the enthalpy change of a substance. Enthalpy change of substances from their initial states to their final states is independent of the pathways. This means that no matter how many reactions the reactants undergo to form the same products, the change in enthalpy is always the same. This principle governing the change of enthalpy of substances is known as the Hess's Law.

For example, a certain amount of magnesium sulphate (VI) powder is dissolved in distilled water, and the enthalpy change, $\mathbf{H_1}$ is recorded. Magnesium sulphate (VI)-7-water is also dissolved in water and its enthalpy change, $\mathbf{H_2}$ is also recorded.

By Hess's Law, the enthalpy change for magnesium sulphate to turn to magnesium sulphate -7-water is equal to $\mathbf{H_1 - H_2}$**,** as shown in the above born-haber cycle diagram.

The enthalpy change for the crystallization of magnesium sulphate is not measured directly because the reaction does not favour the direct measurement of the enthalpy change. During crystallization, a lot of heat would be lost to the surroundings and the results would be inaccurate.

Procedure

1. A polystyrene foam cup was weighed. The cup was then put into a beaker.
2. 50 cm^3 of distilled water was poured into the polystyrene cup. The initial temperature was measured.
3. 3.01 g of anhydrous magnesium sulphate was weighed out. Then, it was added into the polystyrene cup.
4. The temperature change was recorded.
5. Steps 2 to 4 were repeated again but magnesium sulphate (VI)-7-water was used instead of anhydrous magnesium sulphate.

Data and Calculation

Enthalpy change of anhydrous magnesium sulphate

Weight of polystyrene cup=1.936g

Weight of bottle and anhydrous magnesium sulphate= 7.678g

Weight of empty bottle= 4.66g

Mass of anhydrous magnesium sulphate= 3.018g

Number of moles of anhydrous magnesium sulphate= 3.018/ (120.4) = 0.0251mol

Initial temperature of $MgSO_4$=26.5^{o}C

Final temperature of $MgSO_4$= 30.0^{o}C

Temperature change= 3.5^{o}C

Mass of solution= 50.0 + 3.018= 53.018g

Energy change= 3.5 X 53.018 X4.2 + 3.5 X 1.936 X 1.3 = 788.1734 J

Energy change per mole of magnesium sulphate= 788.1734 / 0.0251 = 31.44 kJ

Enthalpy change per mole of magnesium sulphate (H_1): -31.44kJ

Enthalpy change of magnesium sulphate -7-water

Weight of bottle and magnesium sulphate-7-water= 10.8375 g

Weight of empty bottle= 4.6777g

Mass of magnesium sulphate-7-water= 6.1598 g

Number of moles of magnesium sulphate-7-water= 6.1598/ (246.4) = 0.250mol

Initial temperature of $MgSO_4$-7H_2O=25.8^{o}C

Final temperature of $MgSO_4$-7H_2O= 23.0^{o}C

Temperature change= 2.8^{o}C

Mass of solution= 50.0 + 6.1598= 56.1598 g

Energy change= 2.8 X 56.1598 X4.2 + 2.8 X 1.936 X 1.3 =667.5 J

Energy change per mole of magnesium sulphate-7-water

= 788.1734 / 0.0250 = 26.7 kJ

Enthalpy change per mole of magnesium sulphate-7-water (H_2): 26.7kJ

Enthalpy change for hydration of magnesium sulphate

By the above born-haber cycle diagram, the enthalpy change for hydration of 1 mole of magnesium sulphate is H_1-H_2 = 58.14kJ

Conclusion

The enthalpy change for 1 mole of anhydrous magnesium sulphate to become hydrated is 58.14kJ.

Discussion

1. When the temperature of the solution has a different temperature than its surroundings, energy will be transferred from the higher area to the lower area. So, the temperature of the solution, after the reaction, will eventually restore the temperature of its surroundings. The longer the time used in the reaction, the more the heat lost to the surroundings. Therefore, the longer the time used in the reaction, the more inaccurate the results would be.
   For example, it took a long time for the anhydrous magnesium sulphate to dissolve fully in water. So, a large amount of heat is lost to the surroundings. Although only the greatest temperature change is needed, the temperature loss still has a bad effect on the accuracy of the experiment.
   In order to reduce the errors in this experiment, we need to shorten the time. How can we shorten the time? We can speed up the dissolution process of the anhydrous magnesium sulphate by adding a larger volume of water. With a larger volume of solute, the magnesium sulphate crystals will be more easily dissolved. Also, we can speed up the reaction by using heated distilled water. When the water temperature is higher, the rate of reaction would be higher. Unfortunately, the second method does have its drawback. With a higher water temperature, the temperature difference to the surroundings would also be higher. This would increase the rate of heat loss to the surroundings. So, it is not a good way to speed up the reaction in this case.

2. In this experiment, liquid-in-glass thermometers are used. We had to read the readings of the temperatures by the marks on the thermometer. This may create inaccuracy. Why? We may wrongly read the readings of the thermometers easily, because the marking of the thermometer does not move much. For example, if the error in measuring the temperature is 0.05^{o}C, then the percentage error in determining the temperature of hydration of anhydrous magnesium sulphate crystals is 0.1/ 3.5= 2.857%.
   Therefore, there is some degree of inaccuracy in using such thermometers to measure the temperature.
   So, how can we improve the accuracy of the temperature measurement? I suggest the use of digital thermometers to measure the temperature of the solution. This is because digital thermometers give us the readings directly. In other words, it does not require us the read the thermometer scale. Procedures

done without human intervention is always more accurate. So, using digital thermometers can reduce the error.

Answers to Study Question

4. What assumptions have you made in this experiment?

There are 2 assumptions that I made in my experiment. First, I assumed that the temperature of the surroundings remain constant throughout the whole experiment. Why is this important? A constant surrounding temperature means that under normal circumstances, the temperature of distilled water will not change. It also means that if the solution changes temperature, it is only due to the enthalpy change in the surroundings. Why is this necessary to make this assumption? This is because while I was doing my experiment, the sun was rising and the temperature was rising higher and higher.

Second, I assumed no heat loss to the surroundings. If there were heat loss, which was actually the case, I would have to consider the heat loss to the surroundings. There is a method to take into account the heat loss to the surroundings, but it is not a good method when the reaction takes a long time to complete. Also, as the final temperature does not have great difference from the surroundings, the heat loss can be neglected.

6. Why cannot the molar enthalpy change of hydration of magnesium sulphate (VI) be measured directly in the laboratory?

The reason why the molar enthalpy change of hydration is not measured directly can be traced back to how crystallization is carried out. The saturated solution of magnesium sulphate is to be left in a certain place for a long time until the water evaporates and crystals are formed. This method takes a long time. As mentioned above, the longer the time of reaction, the larger the heat loss. So, in this method of preparation involved a large amount of heat loss and the results would be extremely unreliable; the solution would maintain a constant temperature throughout the whole experiment.

So, the enthalpy change cannot be measured directly.