Solubility

Experiment
6

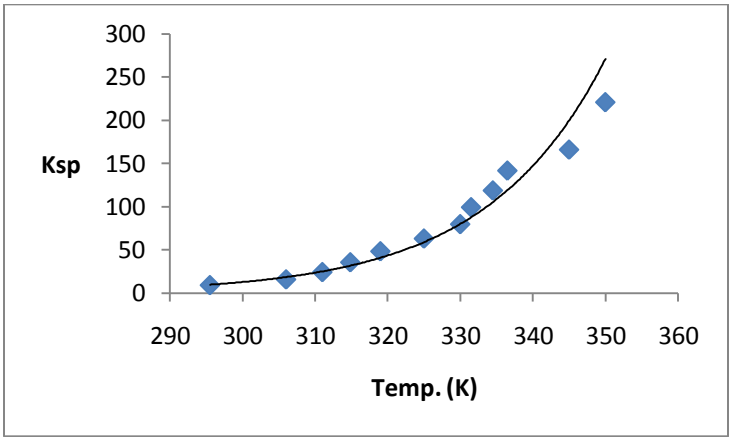
Introduction

The solubility of KNO_3 will be measured at various temperatures. From the molal solubility, s = moles of solute per kilogram of solvent, a value of the solubility product constant, K_{sp}, can be calculated at various temperatures for the following reaction:

$$KNO_{3(s)} \rightleftarrows K^+_{(aq)} + NO_3^-{}_{(aq)}$$

$$K_{sp} = [K^+][NO_3^-] = s^2$$

The solubility of a solid is exponential with respect with temperature. A plot of the solubility product constant, K_{sp}, vs temperature (K) will give an exponential curve.



The relationship between ΔH^o and the K_{sp} comes from the free energy equations

(1) $\Delta G^o = -RT \ln K$, where R = the gas constant, 8.3143 Joule/mol K
and T = absolute temperature in degrees Kelvin.

(2) $\Delta G^o = \Delta H^o - T\Delta S^o$, where ΔH^o is the standard enthalpy change
and ΔS^o is the standard entropy change.

From (1) and (2) comes the equation

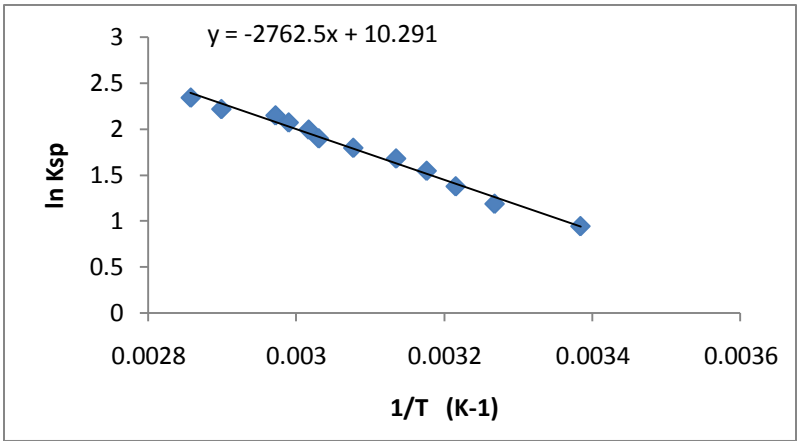
(3) $-RT \ln K = \Delta H^o - T\Delta S^o$,

Both the molal heat of solution ΔH^o and the entropy ΔS^o values can be obtained for the reaction by solving the equation relating the slope of the graph with ΔH^o and the y-

intercept with ΔS^o. The plot of ln K vs 1/T in K^{-1} will give the following equation of a straight line:

$$lnK = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R}$$

y = mx + b



Each group will be assigned a different composition of solution to measure. The data from each group will be combined and plotted.

SAFETY PRECAUTIONS

- KNO_3 is flammable and strong oxidizing agent. Therefore, dispose of all wastes by flushing them down the sink with plenty of running water.
- Avoid any contact between the KNO_3 and paper.

Procedure

Part 1 - (Day 1 – Data Collection)

1. In a 20ml glass beaker, weigh a sample of KNO_3 to the nearest 0.01g. The instructor will assign a sample weight to each pair. Sample sizes will range from 3 to 15 grams in 2 gram increments.
2. Depending on Sample size, transfer the crystals to a larger beaker, if necessary, so that the crystals take up one-third to one-half the volume of the beaker.
3. Pipet 10 mL of distilled water into the beaker. Suspend a thermometer so that the bulb is immersed in the liquid. Stir the mixture with a glass rod.
4. Gently warm the mixture until the crystals dissolve. From the larger sample sizes, an evaporating dish can be used as a water bath to transfer heat more evenly. Try to note the temperature at which the last crystals go into solution. Then allow the solution to cool until crystals reappear and again note the temperature. Reheat just enough to cause the crystals to re-dissolve trying to narrow the discrepancy between the temperature readings. The smallest samples may dissolve completely at room temperature. In that case, use an ice bath to cool the solution until

crystals appear, then allow the solution to warm up until the crystals re-dissolve. As with the larger samples, try to narrow the discrepancy between the temperatures at which the crystals disappear and reappear.

5. Record the saturation temperature you have just determined and enter your values in the class data table on the chalkboard. Reproduce the data table in your notebook with all the values filled in.

KNO_3 solubility Calculations

Part 2 – (Day 2 – Calculations) Need computer with Excel.

A. K_{sp} values.

1. Write the equation for the equilibrium between solid KNO_3 and its ions in solution and the expression for the K_{sp} of KNO_3.
2. From the weight-volume data, calculate the molal concentration of KNO_3 for each composition. This is the molal solubility at the saturation temperature measured.
3. Calculate the solubility product of KNO_3 for each trial. Use the concentrations found in step 1, molality in place of molarity.
4. Tabulate the resulting values of solubility, K_{sp}, and temperature in your lab notebook.
5. Using Excel, graph temperature (Kelvin) on the horizontal axis (x-axis) versus K_{sp} on the vertical axis (y-axis).

B. Molal heat of solution of KNO_3.

1. Using excel calculate values of 1/T, the reciprocal of the absolute temperature, and ln K_{sp} for each of the points graphed in part A.
2. Make a new graph with ln K_{sp} on the vertical axis and 1/T (K^{-1}) on the horizontal axis. Use the linear curve fit option in excel to obtain the best fit linear fit.
3. From the slope of your graph calculate ΔH^o, the heat of solution for KNO_3. Also determine ΔS^o from the y-intercept.

Tabulate data for the written report and include the curve fit equation with the plot of lnK_{sp} vs 1/T.