K_{sp}, ΔG^o, ΔS^o and the Common Ion Effect

In this experiment you will measure the K_{sp}, ΔG^o, ΔH^o,and ΔS^o for dissolving potassium hydrogen tartate ($KHC_4H_4O_6$, or KHT for short) in water at several different temperatures. You will also observe the common ion effect.

EQUIPMENT

You will need two 250 mL Erlenmeyer flasks, a 25 mL burette, a LabQuest 2, a temperature robe for the LabQuest, a pH probe for the LaQuest, a drop counter for the LabQuest, a Surface Pro 3 (SP3), a hot plate that stirs, a magnetic stir bar, a magnetic stirrer (a hot plate that stirs will work, but don't turn on the heat), and a 10.00 mL graduated cylinder. There should also be a couple of graduated pipettes by the saturated KHT solution.

CHEMICALS

You will need about 1 gram of potassium hydrogen tartrate, about 1 gram of potassium iodide, about 50 mL of a standardized 0.1 – 0.2 M NaOH solution, and a saturated solution of KHT (about 25g/500 mL) in a warm water bath at about 60.0 °C (prepared by Matt several hours ahead of time).

WASTE DISPOSAL

All solutions used in this experiment can go down the drain. Any solid waste can go in the trash.

SAFETY

Wear your goggles the entire time.

PROCEDURE

Part A: K_{sp} as a Function of Temperature

Potassium hydrogen tartrate is a somewhat soluble salt. It dissolves in water according to the following equation:

$$KHC_4H_4O_6(s) \rightleftharpoons K^+(aq) + HC_4H_4O_6^-(aq) \quad K_{sp} = [K^+][HC_4H_4O_6^-]$$

Weigh out about 1 gram of KHT into a tared 250 mL Erlenmeyer flask. Record the mass to 3 places past the decimal in your data table.

Weigh out about 1 gram of KI into a weigh boat and record the mass of KI to three places past the decimal in your data table.

Using a burette, add about 25 mL of D.I. water to the 250 mL Erlenmeyer flask. Record the actual volume delivered to 2 places past the decimal.

Place the magnetic stir bar in the 250 mL Erlenmeyer flask.

Place the 250 mL Erlenmeyer flask on a hot plate and heat it until the potassium hydrogen tartrate dissolves (you should not have to go much past 80 °C – use medium heat).

While waiting for the solution to heat up, attach the temperature probe to the LabQuest and the LabQuest to the SP3.

Start LoggerPro on the SP3.

Don't turn off the hot plate, but remove the 250 mL Erlenmeyer flask and place it on a stirrer that is not heated and continue stirring the solution while it cools. Monitor the temperature with the LabQuest.

At the first sign of precipitate (white cloudy matter) record the temperature in your data table. This is run 1.

Using the burette, add about 10 mL of D.I. water to the 250 mL Erlenmeyer flask. Record the actual volume of D.I. water delivered to two places past the decimal.

Repeat the heating and cooling procedure above, recording the temperature that the precipitate first appears in your data table. This is run 2.

Add about 10 more mL of D.I. water, again recording the actual volume delivered to two places past the decimal and repeat. This is run 3.

Add about 10 more mL of D.I. water, again recording the actual volume delivered to two places past the decimal and repeat. This is run 4.

Now add the potassium iodide to the 250 mL Erlenmeyer flask and repeat (do not add any D.I. water this time). This is run 5.

Part B: K_{sp} by Titration

Rinse the syringe part of the drop counter with the standardized NaOH solution and fill the syringe with the standardized NaOH solution.

Set the drop rate to about 1 drop every second.

Record the [NaOH] of the standardized NaOH solution in your data table.

Transfer about 10 mL of the saturated KHT solution from the warm water bath to your 250 mL Erlenmeyer flask using a graduated pipette and a 10.00 mL graduated cylinder. Record the actual volume transferred to 2 places past the decimal in your data table.

Immediately record the temperature of the saturated KHT solution in the warm water bath (the one prepared by Matt) in your data table.

Add about 50 mL of D.I. water to the 250 mL Erlenmeyer flask.

Attach the drop counter and pH probe to the LabQuest.

Make sure LoggerPro on the computer is plotting pH vs. Volume.

Titrate the KHT solution with the NaOH past the equivalence point.

Record the volume of NaOH solution added at the equivalence point in your data table.

<u>CALCULATIONS</u>

You will need to calculate:

1.) The K_{sp} at each of the temperatures for runs 1-4 (part A). You know the moles of KHT and the volume of solution (assume that the KHT does not affect the volume of solution). Calculate the [KHT]. This is equal to $[K^+]$ and $[HC_4H_4O_6^-]$. $K_{sp} = [K^+][HC_4H_4O_6^-]$.
2.) The K_{sp} for run 5. The only thing different here is that the mole K^+ = moles KHT + moles KI.
3.) The saturation temperature for runs 1-5 in Kelvin.

4.) The K_{sp} for KHT by titration (part B). Here moles NaOH added = moles KHT in solution = moles K^+ = moles $HC_4H_4O_6^-$. The volume of solution = 10.00 mL = 0.01000 L.

5.) Using a spreadsheet, plot the ln[K_{sp}] vs. 1/T(K) for runs 1-4. Have your spreadsheet draw the best-fit straight line and get the equation of the line. The slope of this line is – $\Delta H^o/R$ where R = 8.3145 J/K·mol. The y-intercept is $\Delta S^o/R$. Find ΔH^o and ΔS^o. Calculate ΔG^o using these values for the temperature of the saturated solution in part B.

6.) Using the equation for the best fit straight line from your graph, find K_{sp} for the temperature of the saturated solution in part B.

CONCLUSION

Report the saturation temperature and K_{sp} for runs 1-5.

Report and comment on the values of ΔH^o and ΔS^o from your graph.

Comment on the different in the saturation temperature between runs 4 and 5 of part A.

Comment on the difference of the value for K_{sp} at the temperature of the water bath in part B that you got from the graph and the value you got from the titration.

Report and comment on your value of ΔG^o for the temperature of the water bath in part B.