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 ($KHC_4H_5O_6$, or KHT for short) in water at several different temperatures. You will also observe the common ion effect.

EQUIPMENT

You will need a 125 mL Erlenmeyer flask, two 25 mL burettes, a digital thermometer, 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), a 10.00 mL volumetric pipette, and a 250 mL Erlenmeyer flask.

CHEMICALS

You will need about 1 gram of potassium hydrogen tartrate, about 1 gram of potassium iodide, a few drops of phenolphthalein solution, and about 50 mL of a standardized 0.1 – 0.2 M NaOH solution.

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:

$$KHC_4H_5O_6(s) \rightleftharpoons K^+(aq) + HC_4H_5O_6^-(aq) \quad K_{sp} = [K^+][HC_4H_5O_6^-]$$

Weigh out about 1 gram of KHT into a tared 125 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 tared 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 flask. Record the actual volume delivered to 2 places past the decimal.

Place the magnetic stir bar in the Erlenmeyer flask.

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

Don't turn off the hot plate, but remove the 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 digital thermometer.

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 Erlenmeyer flask. Record the actual volume of D.I. 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., 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., 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 Erlenmeyer flask and repeat (do not add any D.I. this time). This is run 5.

Part B: K_{sp} by Titration

Rinse your second 25 mL burette with a little of the standardized NaOH solution and fill the burette with the NaOH solution, making sure to get the air out of the tip.

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

Rinse your 10 mL volumetric pipette with a little of the saturated KHT solution that is in the warm water bath.

Pipette 10.00 mL of the saturated KHT solution from the warm water bath to your 250 mL Erlenmeyer flask.

Immediately record the temperature of the saturated KHT solution in the warm water bath in your data table.

Add about 50 mL of D.I. water and 3-4 drops of phenolphthalein to the 250 mL Erlenmeyer flask.

Titrate the KHT solution with the NaOH to the equivalence point (the first hint of pink that doesn't go away).

Record the volume of NaOH solution added to 2 places past the decimal 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 $[HC_4H_5O_6^-]$. $K_{sp} = [K^+][HC_4H_5O_6^-]$.
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 $HC_4H_5O_6^-$. The volume of solution = 10.00 mL = 0.01000 L.
5.) Using Excel, plot the $\ln[K_{sp}]$ vs. 1/T(K) for runs 1-4. Have Excel 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 = 8.314 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.