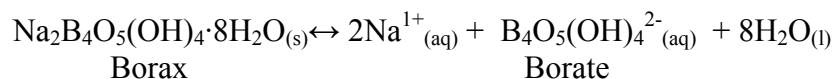


Thermodynamics of Borax Dissolution

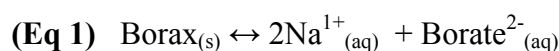
Introduction

Borax, $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4 \cdot 8\text{H}_2\text{O}$, dissolves slightly in water to give sodium ions, a borate ion, and water according to the equation:



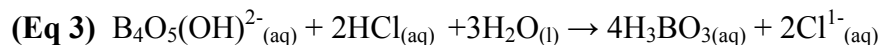
The K expression is: $K = [\text{Na}^{1+}]^2[\text{B}_4\text{O}_5(\text{OH})_4^{2-}]$

The above equations can be simplified as :



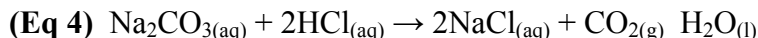
$$\text{(Eq 2)} \quad K = [\text{Na}^{1+}]^2[\text{Borate}^{2-}]$$

The concentration of the borate ion can be determined by titration with a standardized HCl solution according to the equation:



The sodium ion concentration will be twice that of the borate ion. (Eq 1)

The HCl solution is standardized by titration with sodium carbonate as follows:



By evaluating the K at two temperatures (room temperature and ice bath temperature) the enthalpy (ΔH^0) for the dissolution process can be evaluated from the equation:

$$\text{(Eq 5)} \quad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

The Gibb's free energy change (ΔG^0) for the dissolution process can be evaluated at each temperature using the equation:

$$\text{(Eq 6)} \quad \Delta G^0 = -RT\ln(K)$$

Once ΔG^0 and ΔH^0 are known, the entropy change (ΔS^0) can be evaluated from the Gibb's equation:

$$\text{(Eq 7)} \quad \Delta G^0 = \Delta H^0 - T\Delta S^0$$

The enthalpy change and the entropy change should not change with temperature while the Gibb's free energy change will vary with temperature.

Procedure

Preparation of Borax-Borate Equilibrium Mixtures

Room Temperature. Add 3 grams of solid borax, 50 mL of distilled water and a stir bar to a 100 mL beaker. Place on a magnetic stirrer and stir the mixture for at least 15 minutes. Periodically stop the stirring and **make sure there is undissolved borax present**. If not add some more borax. **There MUST be undissolved solid borax present in order to have equilibrium.**

Ice Bath temperature. Add 3 grams of solid borax, 50 mL of distilled water and a stir bar to a second 100 mL beaker. Place this beaker in an ice-water bath and place the bath on a magnetic stirrer and stir for 25-30 minutes. **As above, check to make sure there is undissolved borax present and add some more if necessary.**

Preparation and Standardization of 0.1M HCl

While the borax systems are equilibrating, prepare and standardize 0.10 M HCl. To a 500 mL Erlenmeyer flask, add about 3 mL of concentrated HCl (12 M) and 350 mL of distilled water. **Be sure to mix the solution well.** Clean a 50 mL buret, rinse it with 5-10 mL of the 0.10 M HCl., and fill it with the prepared 0.10 M HCl solution.

Weigh 0.15 grams of the primary standard Na_2CO_3 into two separate Erlenmeyer flasks. Add 50 mL of distilled water and stir to dissolve the solid. Add 4 drops of bromocresol green indicator to give an initial blue solution. Titrate this solution with the HCl to a **yellow color** using a magnetic stirrer. There should be no green tint to the endpoint. Add more of the indicator if the color fades. Do a third titration if the first two do not give reproducible results. Calculate the molarity of the HCl using equation 4.

Room Temperature Borax K_2

About 5 minutes before titrating this mixture, stop the stirring and let the undissolved borax settle. Measure the temperature of the mixture with a Celsius thermometer. Into two separate 125 mL Erlenmeyer flasks, pipet a 10.00 mL aliquot of the equilibrium solution. Add 20 mL of distilled water and 4 drops of bromocresol green indicator to give an initial blue color. **Do not pipet any of the solid borax.** Titrate each with the HCl solution to a **yellow endpoint** (no green tint). Do a third titration if the first two do not agree within 1 mL.

Ice Bath Temperature Borax K_1

About 5 minutes before titrating this mixture stop the stirring to let the undissolved borax to settle. Record its temperature. **Keep the mixture in the ice bath until all titrations are complete.** Into two separate 125 mL Erlenmeyer flasks, pipet 10.00 mL of the equilibrium solution (**no solid**). Add 20 mL of distilled H_2O , 4 drops of bromocresol green and titrate to a **yellow endpoint** (no green tint). Do a third titration if necessary.

Name: _____

Data and Results

HCl Standardization

	Trial Number 1	Trial Number 2	Trial Number 3 (If Necessary)
Mass of Na_2CO_3 weighed, g			
Moles of Na_2CO_3			
Moles HCl Used (Equation 4)			
Final mL of HCl			
Initial mL of HCl			
mL HCl Used in titration			
Molarity of HCl			

Average Molarity of HCl _____

Name: _____

Room Temperature Borax K_2

	Trial Number 1	Trial Number 2	Trial Number 3 (If Necessary)
Final mL of HCL			
Initial mL of HCl			
mL of HCl Used in titration			
Molarity of HCl (page 3)			
Moles HCl Used			
Moles of Borate (Equation 3)			
mL of Borate Used (Aliquot taken)			
Molarity of Borate			
Molarity of Na^{1+} (Equation 1)			
K_2 of Borax (Equation 2)			

Average K_2 of Borax _____

Temperature of borate mixture in: (t_2) _____ °C and T_2 _____ K

Remember that the volume of the borate solution is 10.00 mL. Do not include the 20 mL of distilled water added in the titration.

Name: _____

Ice Bath Borax K_1

	Trial Number 1	Trial Number 2	Trial Number 3 (If Necessary)
Final mL of HCl			
Initial mL of HCl			
mL of HCl Used in titration			
Molarity of HCl (page 3)			
Moles HCl Used			
Moles Borate (Equation 3)			
mL Borate Used (Aliquot taken)			
Molarity of Borate			
Molarity of Na^{1+} (Equation 1)			
K_1 of Borax (Equation 2)			

Average K_1 of Borax _____

Temperature of borate mixture in: (t_1) _____ °C and T_1 _____ K

Remember the volume of the borate solution titrated is 10.00 mL. Do not include the 20 mL of distilled water added in the titration.

ΔH^0 of Borax Dissolution

Evaluate the enthalpy change (ΔH^0) for borax dissolution using **equation 5** where K_2 is the solubility product constant at room temperature in Kelvin, T_2 and K_1 is the solubility product constant at ice bath temperature in Kelvin, T_1 . Show your calculation and report the enthalpy change in **kJ/mol**. $R = 8.314 \times 10^{-3}$ kJ/mol-K.

ΔH^0 _____

Name: _____

ΔG^0 of Borax Dissolution

Calculate free energy change at the two temperatures using **equation 6**.

Show all your work and report the free energy change in **kJ/mol**.

$R = 8.314 \times 10^{-3} \text{ kJ/mol-K}$

Room temperature.

ΔG^0 _____

Ice Bath temperature.

ΔG^0 _____

ΔS^0 of Borax Dissolution

Calculate the entropy change at the two temperatures using **equation 7**. Show all your work and report the entropy change in **J/mol-K**.

Room temperature T_2

ΔS^0 _____

Ice Bath temperature T_1

ΔS^0 _____

Average entropy change . _____

Name: _____

Thermodynamics of Borax Dissolution

Prestudy

1. A 0.1586 gram sample of Na_2CO_3 is completely neutralized by 28.45 mL of an HCl solution. Calculate the molarity of the HCl solution using equations from page 1.

2. A 10.00 mL aliquot of a borax-borate equilibrium solution reacts completely with 32.33 mL of a 0.100 M HCl solution. Using the equations on page 1, evaluate the K_{sp} of borax.