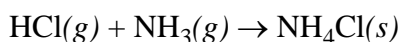


## Predicting the Sign of Thermodynamic Parameters

If you open a bottle of concentrated HCl next to an open bottle of concentrated NH<sub>3</sub>, a white smoke immediately forms in the space above the bottles. Smoke is nothing more than very small particulates, typically about 2.5 μm in diameter (compared to 100 μm for the diameter of human hair). The reaction taking place is a gas-phase acid-base reaction (both HCl and NH<sub>3</sub> are volatile), producing particulate NH<sub>4</sub>Cl



1. Predict the signs of  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  for this reaction and clearly explain your reasoning. If you have insufficient information to assign a sign to any or all of these thermodynamic parameters, then clearly explain why you cannot do so. Do not use the tables in your textbook to answer this question!
2. Using data from Appendix B.16, determine the actual values for  $\Delta G^\circ$ ,  $\Delta H^\circ$  and  $\Delta S^\circ$  at 25°C. If there is a discrepancy between the actual signs and your predictions, then explain why the calculated sign makes sense and identify the error in your reasoning when answering question 1.
3. How do you expect the favorability of this reaction to change with temperature? If the reaction is not favorable at all temperatures, determine the temperature at which the reaction changes from favorable to unfavorable.

4. If you place a sample of  $\text{NH}_4\text{Cl}(s)$  in a test tube and gently heat the test tube's bottom with a Bunsen burner, a white powder forms near the top of the test tube. In a few sentences, clearly explain, using a thermodynamic argument, what is happening in the test tube.