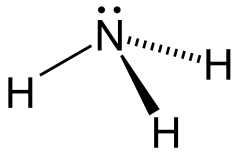
CHEM1032 Cumulative Review (So Far!)

We've covered so much ground since January! This week is a good time to practice some of the concepts and problems we've worked on this semester. (You should get out your plastic-covered equation sheet for these problems.)

Nitrogen is an essential element, necessary for every molecule of protein and DNA and many others. Your body can't directly use N_2, the most common form of nitrogen. Instead, you need "fixed nitrogen." Ammonia (NH_3) is a very important molecule because it provides "fixed nitrogen" to support life.



One way we produce NH_3 industrially for fertilizer is by using the Haber-Bosch process:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

About 2% of the world's annual energy consumption goes into this process.

Here are some data about NH_3:

ΔG_f° = -16.6 kJ/mol
ΔH_f° = -45.9 kJ/mol
S° = 192.77 J/mol·K
normal boiling point is -33.4 °C
C_p (NH_3 gas) = 37.0 J/mol·K
C_p (NH_3 liquid) = 80.8 J/mol·K
ΔH_{vap}° = 23.25 kJ/mol (at the normal boiling point)
pK_b is 4.74

Phase changes

What is the stable state of matter of NH_3 at 25 °C?

How much total heat would it take to convert 100.0 g of NH_3 from -50.0 °C to + 50.0 °C?

Solubility

Do you think NH_3 would be very soluble in water? What intermolecular forces would favor solubility? Support your answer with drawings.

Determine the Henry's Law constant for NH_3 in water at 25 °C if an NH_3 pressure of 0.0220 atm produces a solution with a concentration of 1.30 M. (For this question, you can ignore any reactions between NH_3 and water...but you can also think about whether they will make a big difference to the value you calculate.)

Equilibrium

Think for a second about whether you'd expect the value of $\Delta S_{rxn}°$ for the Haber-Bosch process to be positive or negative. Calculate the actual value of $\Delta S_{rxn}°$ at 25 °C.

At equilibrium at some temperature, the concentrations of NH_3, H_2, and N_2 are 1.8×10^{-2}, 3.0×10^{-2}, and 1.5×10^{-2} M respectively. Calculate the equilibrium constant (K_c) for the formation of NH_3 at that temperature.

If you were to add 0.8×10^{-2} M N_2 to the reaction above, would the resulting value of ΔG at that moment be positive, negative, or zero? Set up the ICE table and the equilibrium expression that you'd make to determine what the new equilibrium concentration of NH_3 would be. The math gets ugly, so you don't have to solve it all the way through.

Calculate K for the Haber-Bosch reaction at 25 °C.

If you were in charge of the chemical plant making NH_3, would it be a good suggestion to improve the production of NH_3 by decreasing the volume (and thus increasing the pressure) of the reaction? Why or why not?

If you were in charge of the chemical plant making NH_3, would it be a good suggestion to improve the production of NH_3 by heating up the reaction? Why or why not?

Acid-base chemistry

NH_3 is a base. Draw an example of NH_3 behaving as a Brønsted base.

Draw an example of NH_3 behaving as a Lewis base.

Write the chemical equation for the reaction quantitated by the K_b for NH_3 and give the value of the K_b.

Sketch the general shape (no numbers necessary!) of the acid-base titration of NH_3 with HBr. Would the pH at the equivalence point be greater than, less than, or equal to 7? What would be the pH range where a NH_3/NH_4^+ buffer system would do a good job of buffering pH?