CH 223 Spring 2026:
Problem Set #2
Instructions

Step One:

• **Learn the material** for Problem Set #2 by **reading Chapter 13** of the textbook and/or by watching the videos found on the website (https://mhchem.org/223video)

• **Try the problems** for Problem Set #2 found on the next pages on your own first. Write your answers in the space provided or write your answers on separate paper (your choice.) Include your name on your problem set!

Step Two:

Watch the recitation video for Problem Set #2:

http://mhchem.org/3/2

Self correct *all* of the problems while viewing the video. Mark correct problems with a star (or other similar mark), and correct all incorrect problems (show the correct answer and the steps required to achieve it.)

Step Three:

Turn the Problem Set in at the beginning of recitation to the instructor on **Monday, April 13 (section L1)** *or* **Wednesday, April 15 (section L2.)** The graded problem set will be returned to you the following week during recitation.

Do *not* include this page to avoid a point penalty; your front page should be page II-2-3.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

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CH 223 Problem Set #2

Name:

Complete the problem set on your own first using these sheets for your work or separate paper (your choice.) **Self correct your work *(all problems!)*** using the recitation video for this problem set, found here: **http://mhchem.org/3/2**

***** *Covering:* **Chapter Thirteen** *and* **Chapter Guide Two**

***** *Important Tables and/or Constants:* **periodic table** found here: http://mhchem.org/pertab, **R = 0.082057 L atm mol^{-1} K^{-1}, 760 mm Hg = 1 atm, R = 8.3145 J mol^{-1} K^{-1}**

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1. Write equilibrium constant expressions for the following reactions. For gases use either pressures or concentrations.
   a. $3\ O_2(g) \rightleftharpoons 2\ O_3(g)$

   b. $Fe(s) + 5\ CO(g) \rightleftharpoons Fe(CO)_5(g)$

   c. $(NH_4)_2CO_3(s) \rightleftharpoons 2\ NH_3(g) + CO_2(g) + H_2O(g)$

   d. $Ag_2SO_4(s) \rightleftharpoons 2\ Ag^+(aq) + SO_4^{2-}(aq)$

2. The equilibrium constant, *K*, for the reaction:

$$2\ NOCl(g) \rightleftharpoons 2\ NO(g) + Cl_2(g)$$

   is **3.9 x 10^{-3}** at 300 °C. A mixture contains the gases at the following concentrations: [NOCl] = 5.0 x 10^{-3} M, [NO] = 2.5 x 10^{-3} M, and [Cl_2] = 2.0 x 10^{-3} M. Is the reaction at equilibrium at 300 °C? If not, in which direction does the reaction proceed to come to equilibrium?

3. An equilibrium mixture of SO_2, O_2 and SO_3 at 1000 K contains the gases at the following concentrations: $[SO_2] = 3.77 \times 10^{-3}$ M, $[O_2] = 4.30 \times 10^{-3}$ M, and $[SO_3] = 4.13 \times 10^{-3}$ M. Calculate the equilibrium constant, K_c, for the reaction:

$$2\ SO_2(g)\ +\ O_2(g)\ \rightleftharpoons\ 2\ SO_3(g)$$

4. You place 3.00 mol of pure SO_3 in an 8.00 L flask at 1150 K. At equilibrium, 0.58 mol of O_2 has formed. Calculate K_c for the reaction at 1150 K using the reaction:

$$2\ SO_3(g)\ \rightleftharpoons\ 2\ SO_2(g)\ +\ O_2(g)$$

5. Cyclohexane, C_6H_{12}, a hydrocarbon, can isomerize or change into methylcyclopentane, $C_5H_9CH_3$, a compound of the same formula but with a different molecular structure. The equilibrium constant has been estimated to be 0.12 at 25 °C. If you originally placed 0.045 mol of cyclohexane in a 2.8 L flask, what would be the concentrations of cyclohexane and methylcyclopentane when equilibrium is established? Use the equation:

$$C_6H_{12}(g)\ \rightleftharpoons\ C_5H_9CH_3(g)$$

6. K_p for the following reaction is 0.16 at 25 °C:

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

The enthalpy change for the reaction at standard conditions is +16.3 kJ. Predict the effect of the following changes on the position of the equilibrium; that is, state which way the equilibrium will shift (**left**, **right**, or **no change**) when each of the following changes is made.

a. adding more $Br_2(g)$
b. removing some NOBr(g)
c. decreasing the temperature
d. increasing the container volume
e. adding a catalyst

7. The equilibrium constant for the reaction

$$N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g)$$

is 1.7×10^{-3} at 2300 K.

a. What is K for the reaction when written as follows:

$$^1/_2\ N_2(g) + {}^1/_2\ O_2(g) \rightleftharpoons NO(g)$$

b. What is K for the following reaction?

$$2\ NO(g) \rightleftharpoons N_2(g) + O_2(g)$$

8. Ammonium iodide dissociates reversibly to ammonia and hydrogen iodide if the salt is heated to a sufficiently high temperature. Some ammonium iodide is placed in a flask, which is then heated to 400 °C. If the total pressure in the flask when equilibrium has been achieved is 705 mm Hg, what is the value of K_p (when partial pressures are in atmospheres)?

$$NH_4I(s) \rightleftharpoons NH_3(g) + HI(g)$$

9. In the gas phase, acetic acid exists as an equilibrium of monomer and dimer molecules. The dimer consists of two molecules of acetic acid linked through hydrogen bonds. The equilibrium constant, K, for the monomer-dimer equilibrium shown below has been determined to be 3.2×10^4. Assume that acetic acid is present initially at a concentration of 5.4×10^{-4} M at 25 °C and that no dimer is present initially.

$$2\ CH_3CO_2H(g) \rightleftharpoons (CH_3CO_2H)_2(g)$$

   a. What percentage of the acetic acid is converted to the dimer?
   b. As the temperature increases, in which direction does the equilibrium shift? (Recall that hydrogen bond formation is an exothermic process.)

10. The formation of $O_3(g)$ from $O_2(g)$ has a standard free energy change, $\Delta G°$, of +163.2 kJ/mol at 25 °C. Calculate K_p at this temperature. Comment on the connection between the sign of $\Delta G°$ and the magnitude of K_p.