CH 223 Spring 2026:
Problem Set #4
Instructions

Step One:

- **Learn the material** for Problem Set #4 by **reading Chapter 15** of the textbook and/or by watching the videos found on the website (https://mhchem.org/223video)
- **Try the problems** for Problem Set #4 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 #4:

http://mhchem.org/3/4

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, May 4 (section L1)** *or* **Wednesday, May 6 (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-4-3.

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 #4

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/3/4**
* *Covering:* **Chapter Fifteen** *and* **Chapter Guide Four**
* *Important Tables and/or Constants:* **periodic table** found here: http://mhchem.org/pertab, **Solubility Table** (*found here*: **https://mhchem.org/sol**), **"Solubility Product Constant (K_{sp}) Values at 25 °C"** *and* "**Complex Ion Formation Constant (K_f) Values at 25 °C"** *at the end of problem set #4*

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1. Using a solubility table, predict whether the following are **insoluble** or **soluble** in water.
   a. $Pb(NO_3)_2$

   b. $Fe(OH)_3$

   c. $ZnCl_2$

   d. CuS

   e. If a solution has both aqueous Cu^{2+} and Ag^+ ions, propose a simple method to separate these ions by adding one reagent to precipitate one of them as an insoluble salt and leave the other in solution

2. a. For **$PbSO_4$** *and* **BaF_2**, (i) write a balanced equation showing the equilibrium occurring when each insoluble salt is added separately to water, and (ii) write the K_{sp} expression.

   b. Write a balanced equation showing the equilibrium occurring for the formation of the complex ion **$Zn(NH_3)_4^{2+}$**(aq) and write the corresponding K_f expression.

3. At 20 °C, a saturated aqueous solution of silver acetate, $AgCH_3CO_2$, contains 0.74 g of the silver compound dissolved in 100.0 mL of solution. Calculate K_{sp} for silver acetate.

$$AgCH_3CO_2(s) \rightleftharpoons Ag^+(aq) + CH_3CO_2^{-1}(aq)$$

4. What is the molar concentration of Au^{+}(aq) in a saturated solution of AuCl (K_{sp} = 2.0 x 10^{-13}) in pure water at 25 °C? The equation:

$$AuCl(s) \rightleftharpoons Au^{+}(aq) + Cl^{-}(aq)$$

5. Estimate the solubility of lead(II) bromide (a) in moles per liter and (b) in grams per liter of pure water. (K_{sp} for lead(II) bromide = 6.6 x 10^{-6})

6. If 75 mg of lead(II) sulfate is placed in 250 mL of pure water, does all of it dissolve? If not, how much dissolves? (K_{sp} for lead(II) sulfate = 2.5 x 10^{-8})

7. Which compound in each of the following pairs is the more soluble?
    a. AgBr (K_{sp} = 5.0 x 10^{-13}) or AgSCN (K_{sp} = 1.0 x 10^{-12})

    b. $SrCO_3$ (K_{sp} = 9.3 x 10^{-10}) or $SrSO_4$ (K_{sp} = 3.4 x 10^{-7})

    c. AgI (K_{sp} = 8.3 x 10^{-17}) or PbI_2 (K_{sp} = 9.8 x 10^{-9})

8. You have 95 mL of a solution that has a lead(II) concentration of 0.0012 M. Will $PbCl_2$ precipitate when 1.20 g of solid NaCl is added? (K_{sp} for $PbCl_2 = 1.7 \times 10^{-5}$)

9. Solid silver(I) iodide, AgI, can be dissolved by adding aqueous sodium cyanide to it (see equation below.) Show that this equation is the sum of two other equations, one for dissolving AgI ($K_{sp} = 8.3 \times 10^{-17}$) to give its ions and the other for the formation of the $[Ag(CN)_2]^{-1}$ ion ($K_f = 1.3 \times 10^{21}$) from Ag^+ and CN^{-1}. Calculate K_{net} for the overall reaction. The equation:

$$AgI(s) + 2\,CN^{-1}(aq) \rightleftharpoons [Ag(CN)_2]^{-1}(aq) + I^{-}(aq)$$

10. Decide whether each of the following substances should be classified as a Lewis acid or a Lewis base.
    a. BCl_3 (Hint: draw the electron dot structure)
    b. H_2NNH_2, hydrazine (Hint: draw the electron dot structure)
    c. The reactants in the reaction:

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

Solubility Product Constant (K_{sp}) Values at 25 °C

Cation	Compound	K_{sp}
Ba^{2+}	*$BaCrO_4$	1.2×10^{-10}
	$BaCO_3$	2.6×10^{-9}
	BaF_2	1.8×10^{-7}
	*$BaSO_4$	1.1×10^{-10}
Ca^{2+}	$CaCO_3$ (calcite)	3.4×10^{-9}
	*CaF_2	5.3×10^{-11}
	*$Ca(OH)_2$	5.5×10^{-5}
	$CaSO_4$	4.9×10^{-5}
Cu^{+}, Cu^{2+}	$CuBr$	6.3×10^{-9}
	CuI	1.3×10^{-12}
	$Cu(OH)_2$	2.2×10^{-20}
	$CuSCN$	1.8×10^{-13}
Au^{+}	$AuCl$	2.0×10^{-13}
Fe^{2+}	$FeCO_3$	3.1×10^{-11}
	$Fe(OH)_2$	4.9×10^{-17}
Pb^{2+}	$PbBr_2$	6.6×10^{-6}
	$PbCO_3$	7.4×10^{-14}
	$PbCl_2$	1.7×10^{-5}
	$PbCrO_4$	2.8×10^{-13}
	PbF_2	3.3×10^{-8}
	PbI_2	9.8×10^{-9}
	$Pb(OH)_2$	1.4×10^{-15}
	$PbSO_4$	2.5×10^{-8}
Mg^{2+}	$MgCO_3$	6.8×10^{-6}
	MgF_2	5.2×10^{-11}
	$Mg(OH)_2$	5.6×10^{-12}
Mn^{2+}	$MnCO_3$	2.3×10^{-11}
	*$Mn(OH)_2$	1.9×10^{-13}
Hg_2^{2+}	*Hg_2Br_2	6.4×10^{-23}
	Hg_2Cl_2	1.4×10^{-18}
	*Hg_2I_2	2.9×10^{-29}
	Hg_2SO_4	6.5×10^{-7}
Ni^{2+}	$NiCO_3$	1.4×10^{-7}
	$Ni(OH)_2$	5.5×10^{-16}
Ag^{+}	*$AgBr$	5.4×10^{-13}
	*$AgBrO_3$	5.4×10^{-5}
	$AgCH_3CO_2$	1.9×10^{-3}
	$AgCN$	6.0×10^{-17}
	Ag_2CO_3	8.5×10^{-12}
	*$Ag_2C_2O_4$	5.4×10^{-12}
	*$AgCl$	1.8×10^{-10}
	Ag_2CrO_4	1.1×10^{-12}
	*AgI	8.5×10^{-17}
	$AgSCN$	1.0×10^{-12}
	*Ag_2SO_4	1.2×10^{-5}
Sr^{2+}	$SrCO_3$	5.6×10^{-10}
	SrF_2	4.3×10^{-9}
	$SrSO_4$	3.4×10^{-7}
Tl^{+}	$TlBr$	3.7×10^{-6}
	$TlCl$	1.9×10^{-4}
	TlI	5.5×10^{-8}
Zn^{2+}	$Zn(OH)_2$	3×10^{-17}
	$Zn(CN)_2$	8.0×10^{-12}

The values reported in this table were taken from J. A. Dean: *Lange's Handbook of Chemistry,* 15th ed. New York: McGraw-Hill Publishers, 1999. Values have been rounded off to two significant figures.

*Calculated solubility from these K_{sp} values will match experimental solubility for this compound within a factor of 2. Experimental values for solubilities are given in R. W. Clark and J. M. Bonicamp: *Journal of Chemical Education,* Vol. 75, p. 1182, 1998.

Complex Ion Formation Constant (K_f) Values at 25 °C

Formation Equilibrium	K
$Ag^+ + 2\ Br^- \rightleftarrows [AgBr_2]^-$	2.1×10^7
$Ag^+ + 2\ Cl^- \rightleftarrows [AgCl_2]^-$	1.1×10^5
$Ag^+ + 2\ CN^- \rightleftarrows [Ag(CN)_2]^-$	1.3×10^{21}
$Ag^+ + 2\ S_2O_3^{2-} \rightleftarrows [Ag(S_2O_3)_2]^{3-}$	2.9×10^{13}
$Ag^+ + 2\ NH_3 \rightleftarrows [Ag(NH_3)_2]^+$	1.1×10^7
$Al^{3+} + 6\ F^- \rightleftarrows [AlF_6]^{3-}$	6.9×10^{19}
$Al^{3+} + 4\ OH^- \rightleftarrows [Al(OH)_4]^-$	1.1×10^{33}
$Au^+ + 2\ CN^- \rightleftarrows [Au(CN)_2]^-$	2.0×10^{38}
$Cd^{2+} + 4\ CN^- \rightleftarrows [Cd(CN)_4]^{2-}$	6.0×10^{18}
$Cd^{2+} + 4\ NH_3 \rightleftarrows [Cd(NH_3)_4]^{2+}$	1.3×10^7
$Co^{2+} + 6\ NH_3 \rightleftarrows [Co(NH_3)_6]^{2+}$	1.3×10^5
$Cu^+ + 2\ CN^- \rightleftarrows [Cu(CN)_2]^-$	1.0×10^{24}
$Cu^+ + 2\ Cl^- \rightleftarrows [CuCl_2]^-$	3.2×10^5
$Cu^{2+} + 4\ NH_3 \rightleftarrows [Cu(NH_3)_4]^{2+}$	2.1×10^{13}
$Fe^{2+} + 6\ CN^- \rightleftarrows [Fe(CN)_6]^{4-}$	1.0×10^{35}
$Hg^{2+} + 4\ Cl^- \rightleftarrows [HgCl_4]^{2-}$	1.2×10^{15}
$Ni^{2+} + 4\ CN^- \rightleftarrows [Ni(CN)_4]^{2-}$	2.0×10^{31}
$Ni^{2+} + 6\ NH_3 \rightleftarrows [Ni(NH_3)_6]^{2+}$	5.5×10^8
$Zn^{2+} + 4\ OH^- \rightleftarrows [Zn(OH)_4]^{2-}$	4.6×10^{17}
$Zn^{2+} + 4\ NH_3 \rightleftarrows [Zn(NH_3)_4]^{2+}$	2.9×10^9

*Data reported in this table are taken from J. A. Dean: *Lange's Handbook of Chemistry,* 15th ed. New York: McGraw-Hill Publishers, 1999.

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