CHEMISTRY 123 – FALL 2010
Midterm #2

Test Booklet **A** - For Question 1

Your name: ____

Your Student ID number: ____

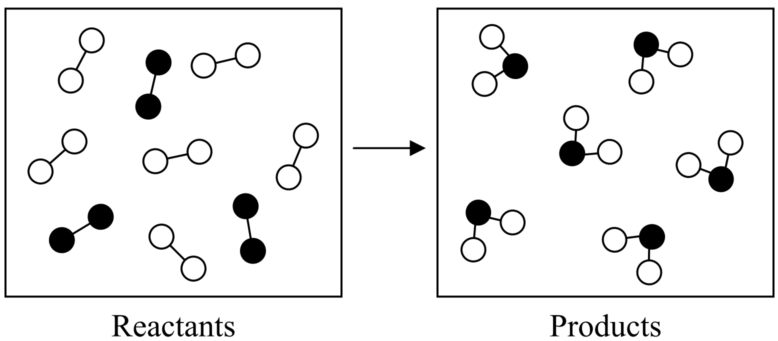
Your TA: ____

This packet MUST be turned in following the exam

There are multiple versions of the exam. You are taking Version A.
Unless otherwise stated all reactions are assumed to occur at 25 ^oC, and 1 atm.

1. **[0 Points]** What test booklet do you have? This is on the first page.
   A) A
   B) B

For problems 1 and 2 consider the reaction depicted below (all molecules shown are in the gas phase, assume all bond enthalpies to be the same):



2. **[7 points]** Predict the sign of ΔH_{rxn} and ΔS_{rxn} for the reaction shown above.
   a. ΔS_{rxn} is positive, ΔH_{rxn} is positive
   b. ΔS_{rxn} is positive, ΔH_{rxn} is negative
   c. ΔS_{rxn} is negative, ΔH_{rxn} is positive
   d. ΔS_{rxn} is negative, ΔH_{rxn} is negative
   e. ΔS_{rxn} is negative, ΔH_{rxn} is zero

3. **[7 points]** What general statement can you make about the relationship between spontaneity and temperature for the reaction shown above?
   a. The reaction is spontaneous at all temperatures
   b. The reaction is not spontaneous at any temperature
   c. The reaction becomes more spontaneous as the temperature decreases
   d. The reaction becomes more spontaneous as the temperature increases
   e. There is not enough information given to answer this question

4. **[7 points]** For which of the following reactions would you expect ΔS_{rxn} to be negative?
   a. $SO_2(g) + 2H_2(g) \rightarrow S(s) + 2H_2O(g)$
   b. $NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$
   c. $CoCl_2(s) \rightarrow Co^{2+}(aq) + 2Cl^-(aq)$
   d. $2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$
   e. $H_2O(l) \rightarrow H_2O(g)$

5. **[7 points]** Which of the following reactions should occur faster?
   a. $2H_2$ (g) + O_2 (g) → $2H_2O$ (l) $\Delta G^o = -474.26$ kJ/mol
   b. CH_4 (g) + $2O_2$ (g) → CO_2 (g) + 2 H_2O (l) $\Delta G^o = -817.86$ kJ/mol
   c. 2Mg (s) + O_2 (g) → 2MgO (s) $\Delta G^o = -1139.2$ kJ/mol
   d. 2NaBr → 2Na (s) + Br_2 (l) $\Delta G^o = +698.6$ kJ/mol
   e. There is not enough information given to answer this question

For questions 6-7 refer to the following table;

Chemical	**ΔH_f^o (kJ mol^{-1})**	**ΔG_f^o (kJ mol^{-1})**	**S^o (J mol^{-1} K^{-1})**
$TiCl_4$(l)	-804.2	-728.2	221.9
$TiCl_4$(g)	-763.2	-726.9	354.9
H_2S(g)	-20.17	-33.01	205.6
Li_2S(s)	-441.8	-435.9	70.1
LiCl (s)	-408.3	-384.0	59.30
TiS_2 (s)	-415.0	-402.6	52.9
Cl_2 (g)	0	0	222.96
HCl (g)	-92.3	-95.27	186.69

6. **[7 points]** One of the current projects in Prof. Goldberger's lab involves the synthesis of TiS_2 as a thermoelectric material, a material that converts heat directly into electricity.

   What is the ΔG^o of the following reaction?

   $TiCl_4$(l) + $2Li_2S$ (s) → TiS_2 (s) + 4 LiCl (s)

   a. 378 kJ/mol
   b. 423 kJ/mol
   c. -339 kJ/mol
   d. -360 kJ/mol
   e. -72 kJ/mol

7. **[7 points]** If Prof. Goldberger attempted to synthesize TiS_2, using H_2S as the sulfur source, at what temperature would he need to carry out the following reaction, if we assume entropy and enthalpy do not change as a function of temperature?

   $TiCl_4$(g) + $2H_2S$(g) → TiS_2 (s) + 4HCl (g)

   a. 50 °C
   b. 150 °C
   c. 250 °C
   d. 350 °C
   e. None of the above

8. **[7 points]** The commercial production of laughing gas (N_2O) involves the careful decomposition of ammonium nitrate according to the following reaction.

$$NH_4NO_3\ (s) \rightleftharpoons 2\ H_2O\ (g) + N_2O\ (g)$$

Given the following table of thermodynamic data at 298 K:

Substance	**ΔH_f^o (kJ mol^{-1})**	**S^o (J mol^{-1} K^{-1})**
NH_4NO_3 (s)	–365.6	151
H_2O(g)	–241.82	188.83
N_2O (g)	81.6	220.0

Assuming entropy and enthalpy do not change as a function of temperature, the value of the equilibrium constant K_{eq} for the reaction at 170 °C is __________.

a. $K_{eq} = 2.3 \times 10^{2}$
b. $K_{eq} = 4.4 \times 10^{27}$
c. $K_{eq} = 1.1$
d. $K_{eq} = 2.3 \times 10^{-28}$
e. $K_{eq} = 5.2 \times 10^{29}$

9. **[7 points]** Calculate ΔG for the following reaction, given the pressures listed

Substance	**ΔG_f^o (kJ mol^{-1})**
NOCl (g)	66.3
NO (g)	86.71
Cl_2(g)	0

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

$P_{NOCl} = 0.30$ atm, $P_{NO} = 2.4$ atm, $P_{Cl2} = 0.50$ atm

a. 17 kJ/mol
b. 32 kJ/mol
c. 37 kJ/mol
d. 41 kJ/mol
e. 49 kJ/mol

10. **[7 points]** Calculate the K_{sp} of $FeCl_3$ at room temperature, given the following thermodynamic data;

Substance	**ΔG_f^o (kJ mol^{-1})**
$FeCl_3$ (s)	-334
Fe^{3+} (aq)	-10.54
Cl^- (aq)	-131.2

a. 2.1×10^{-34}
b. 1.9×10^{12}
c. 0.925
d. 1.03
e. 2.0×10^{-11}

11. **[7 points]** Consider the Haber Process.

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

Substance	**ΔG_f^o (kJ mol^{-1})**
NH_3 (g)	-16.7

If you were holding a container at room temperature with $P_{H2} = 0.05$ atm, $P_{N2} = 0.03$ atm, and $P_{NH3} = 1$ atm, in which direction would the equilibrium shift?

a. The equilibrium would shift toward reactants.
b. The equilibrium would shift towards products.
c. The system is already under equlibrium
d. It is impossible to determine with the information given.

12. **[7 points]** The old adage states "Diamonds are Forever." To determine if this is true, First, calculate the equilibrium constant for the interconversion of Carbon diamond into Carbon graphite; and Second, determine if this conversion is spontaneous at room temperature? The interconversion reaction is;

$$C_{diamond}(s) \rightarrow C_{graphite}(s)$$

Compound	**ΔH_f^o (kJ mol^{-1})**	**S^o (J mol^{-1} K^{-1})**
C (s) diamond	1.88	2.43
C (s) graphite	0	5.69

a. 0.317, Nonspontaneous
b. 0.317, Spontaneous
c. 2.85, Spontaneous
d. 3.16, Spontaneous
e. -974, Nonspontaneous

13. **[7 points]** What is the sign of the ΔH^o, ΔS^o, and ΔG^o for the melting of ice at 0 °C?

Answer	ΔH^o	ΔS^o	ΔG^o
a.	+	+	0
b.	+	–	+
c.	–	+	0
d.	–	–	–
e.	0	+	–

14. **[7 points]** Which statement is true for the following electrochemical reaction?

$$Ag^+(aq) + Cu(s) \rightarrow Ag(s) + Cu^{2+}(aq)$$

(a) Cu^{2+} is oxidized
(b) The $Ag^+(aq)|Ag(s)$ half reaction occurs at the anode
(c) Ag^+ acts as the reducing agent
(d) Ag^+ is reduced
(e) Both (c) and (d) are true

15. **[7 points]** Balance the following redox reaction in basic solution.

$$Cr^{3+}(aq) + MnO_2(s) \rightarrow Mn^{2+}(aq) + CrO_4^{2-}(aq)$$

(a) $2\ H_2O(l) + 2\ Cr^{3+}(aq) + 3\ MnO_2(s) \rightarrow 3\ Mn^{2+}(aq) + 2\ CrO_4^{2-}(aq) + 4\ H^+(aq)$
(b) $2\ Cr^{3+}(aq) + 4\ OH^-(aq) + 3\ MnO_2(s) \rightarrow 2\ CrO_4^-(aq) + 2\ H_2O(l) + 3\ Mn^{2+}(aq)$
(c) $2\ OH^-(aq) + Cr^{3+}(aq) + MnO_2(s) \rightarrow Mn^{2+}(aq) + CrO_4^{2-}(aq) + 2\ H^+(aq)$
(d) $Cr^{3+}(aq) + 2\ O_2(g) + MnO_2(s) \rightarrow CrO_4^-(aq) + Mn^{2+}(aq)$
(e) $2\ OH^-(aq) + Cr^{3+}(aq) + MnO_2(s) \rightarrow Mn^{2+}(aq) + CrO_4^{2-}(aq) + 4\ H_2O(l)$

16. **[7 points]** Which of the following species is the best oxidizing agent?
(a) Al(s)
(b) $Al^{3+}(aq)$
(c) $Fe^{3+}(aq)$
(d) $Fe^{2+}(aq)$
(e) $H_2(g)$

17. **[7 points]** An electrochemical process occurs in a voltaic cell. What is the cell EMF for this reaction?

$$2\ Au^{3+}(aq) + 3\ Ni(s) \rightarrow 2\ Au(s) + 3\ Ni^{2+}(aq)$$

(a) +1.76 V
(b) +1.24 V
(c) +2.22 V
(d) –1.24 V
(e) +3.78 V

18. **[7 points]** Which of the following statements is correct if each substance is in its standard state? Assume potentials are given in water at 25 °C.

$$Ni^{2+}(aq) + 2\,e^- \rightarrow Ni(s) \qquad E^\circ_{red} = -0.28\ V$$
$$Sn^{4+}(aq) + 2\,e^- \rightarrow Sn^{2+}(aq) \qquad E^\circ_{red} = +0.15\ V$$
$$Br_2(l) + 2\,e^- \rightarrow 2\,Br^- \qquad E^\circ_{red} = +1.06\ V$$

(a) $Sn^{4+}(aq)$ will oxidize $Ni(s)$ to $Ni^{2+}(aq)$
(b) $Br_2(l)$ will reduce $Sn^{4+}(aq)$ to $Sn^{2+}(aq)$
(c) $Sn^{4+}(aq)$ will oxidize $Br^-(aq)$ to $Br_2(l)$
(d) $Ni^{2+}(aq)$ will reduce $Sn^{4+}(aq)$ to $Sn^{2+}(aq)$
(e) $Sn^{4+}(aq)$ will reduce $Ni^{2+}(aq)$ to $Ni(s)$

19. **[7 points]** Consider this reaction:

$$Br_2(l) + 2\,Ce^{3+}(aq) \rightarrow 2\,Br^-(aq) + 2\,Ce^{4+}(aq)$$

Calculate the cell potential, *E*, when $[Ce^{3+}] = 0.75$ M, $[Ce^{4+}] = 0.015$ M, and $[Br^-] = 0.040$.

$$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq) \quad E^\circ_{red} = +1.61\ V$$
$$Br_2(l) + 2\,e^- \rightarrow Br^-(aq) \quad E^\circ_{red} = +1.06\ V$$

(a) −0.18 V
(b) −0.37 V
(c) −0.73 V
(d) +2.67 V
(e) −0.55 V

20. **[7 points]** Which of the following set of conditions given below would produce the most positive cell potential for the following reaction:

$$2\,NO_3^-(aq) + 8\,H^+(aq) + 6\,Hg(l) \rightarrow 3\,Hg_2^{2+}(aq) + 2\,NO(g) + 4\,H_2O(l)$$

(a) $[NO_3^-] = 1.0$ M; $[Hg_2^{2+}] = 1.0$ M; $P_{NO(g)} = 1.0$ atm; pH = 7.0
(b) $[NO_3^-] = 2.0$ M; $[Hg_2^{2+}] = 0.50$ M; $P_{NO(g)} = 0.75$ atm; pH = 10.0
(c) $[NO_3^-] = 0.5$; $[Hg_2^{2+}] = 2.0$ M; $P_{NO(g)} = 2.0$ atm; pH = 10.0
(d) $[NO_3^-] = 2.0$; $[Hg_2^{2+}] = 0.50$; $P_{NO(g)} = 0.75$ atm; pH = 5.0
(e) $[NO_3^-] = 0.5$; $[Hg_2^{2+}] = 2.0$ M; $P_{NO(g)} = 2.0$ atm; pH = 2.0

21. **[7 points]** Determine the value for ΔG° for the following reactions carried out in a voltaic cell:

$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$

(a) –1158 kJ/mol
(b) –193 kJ/mol
(c) –579 kJ/mol
(d) –386 kJ/mol
(e) +579 kJ/mol

22. **[7 points]** Determine the value of the equilibrium constant, K, at 25°C for the following reaction:

$$Sn^{4+}(aq) + 2\ Ag(s) \rightarrow Sn^{2+}(aq) + 2\ Ag^{+}(aq)$$

(a) 1×10^{42}
(b) 1×10^{-22}
(c) 1×10^{-11}
(d) 1×10^{22}
(e) 1×10^{11}

23. **[7 points]** What mass of aluminum could be plated on an electrode from the electrolysis of a $Al(NO_3)_3$ solution with a current of 2.50 A for 30.0 minutes?
(a) 0.140 grams
(b) 0.00699 grams
(c) 0.419 grams
(d) 1.40 grams
(e) 0.0210 grams

24. **[7 points]** Manganese is a transition metal with varying oxidation states. Using a manganese salt, 2.89×10^5 Coulombs plate out 41.2 g of manganese. What form of manganese ion is in the solution of this salt?
(a) Mn^{+}
(b) Mn^{2+}
(c) Mn^{3+}
(d) Mn^{4+}
(e) Mn^{7+}

25. **[7 points]** Which one or more of the following would serve to protect an iron pipe from corrosion by serving as the anode in a cathodic protection scheme?
(a) Zn(s)
(b) Cu(s)
(c) Ag(s)
(d) Al(s)
(e) Both (a) and (d)

26. **[7 points]** Consider the cell reaction of a nickel-cadmium battery.

$$2\ NiO(OH)(s) + 2\ H_2O(l) + Cd(s) \rightarrow 2\ Ni(OH)_2(s) + Cd(OH)_2(s) \qquad E^{\circ}_{cell} = 1.2\ V$$

What is the ΔG°_{rxn} of the nickel-cadmium battery reaction?
(a) −231 kJ/mol
(b) −116 kJ/mol
(c) −347 kJ/mol
(d) −463 kJ/mol
(e) +116 kJ/mol

CHEMISTRY 123 – FALL 2010

Useful exam information and equations

This packet and your test booklet MUST be turned in following the exam

Your scan sheet must be completed using a PENCIL only

In a few moments, your Buck-ID will be exchanged for the test booklet

Before we take your Buck-ID, fill in your scan sheet with ONLY this information:

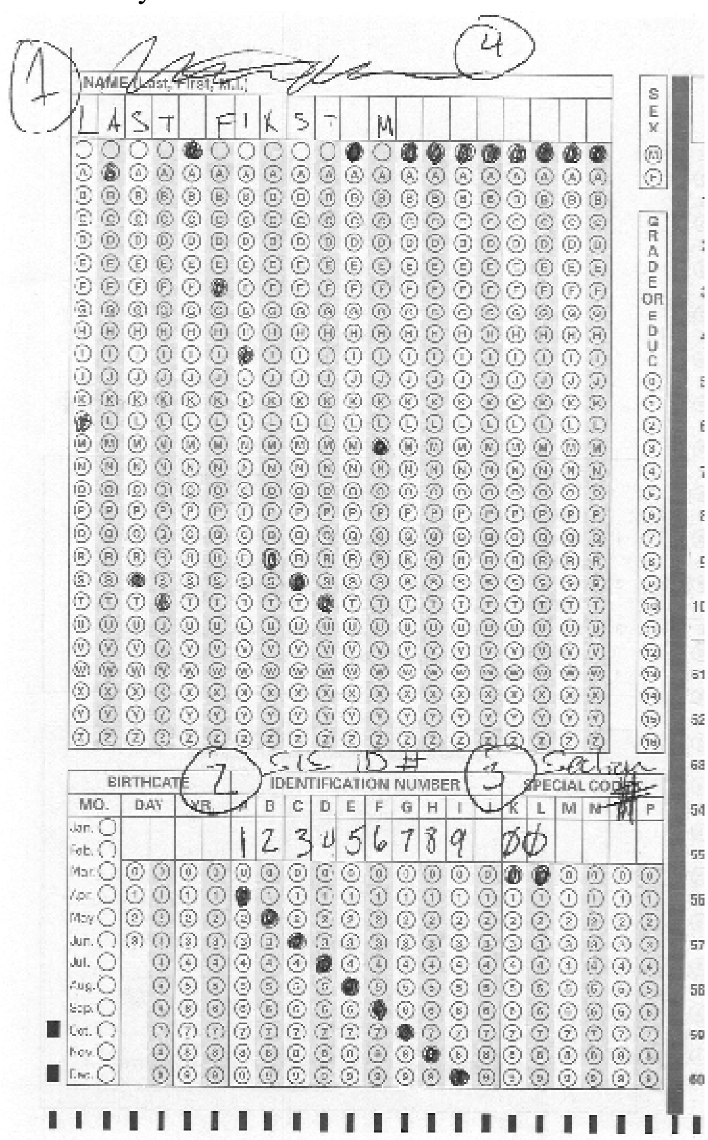
1. Write/bubble in your **last, first, middle initial**; each separated by a space
2. Starting in column A, fill in your 9 or 10 digit SIS ID # (aka Carmen ID #)
3. Fill in your section number in columns K-L based on your section by lab TA
4. Sign the top of the scan sheet above your name

Please, do not provide any additional information on your Scantron sheet

Section number
Enter in your lab TA

David Disilvestro	=	49
James Ross	=	50
Pratiq Patel	=	51
Eric Crouser	=	52
Min Gao	=	53
Tushar Kabre	=	54
Chi-Yueh Kao	=	55
Thi Trinh	=	56

SIS/CARMEN ID # (Note: may not be on older Buck-IDs)



Spectrochemical series

$I^- < Br^- < Cl^- < F^- < H_2O < NH_3 <$ en $< NO_2^-$ (N-bonded) $< CN^- <$ CO

Solubility Tables:

Water soluble compounds contain:	Exceptions:
Acetate	None
Nitrate	None
Iodide, Bromide, and Chloride	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
Sulfate	Compounds of Sr^{2+}, Ba^{2+},Hg_2^{2+}, and Pb^{2+}

Water insoluble compounds contain:	Exceptions:
Sulfide, Hydroxide	Compounds of the alkali metal cations, Ca^{2+}, Sr^{2+}, Ba^{2+}, and NH_4^+
Carbonate, Phosphate	Compounds of the alkali metal cations, and NH_4^+

Useful equations:

$K_w=[H^+][OH^-]$ ($K_w = 1.00\text{x}10^{-14}$ at 25˚C), $K_aK_b=K_w$

pX = -log [X], $[X] = 10^{-pX}$, log(xy) = log x + log y

$S = k_B \ln W$, $\Delta G = \Delta H - T\Delta S$, $\Delta G = \Delta G^\circ + RT \ln Q$, $\Delta G = -RT \ln K$

$E^\circ_{cell} = E^\circ_{red}$ (cathode) $- E^\circ_{red}$ (anode), $\Delta G = -nFE_{cell}$,

$$E_{cell} = E^\circ_{cell} - \frac{0.0592\ V}{n} \log Q$$

$N_A = 6.022 \text{ x } 10^{23}$, R = 8.314 J/mol·K = 0.08206 L·atm/mol·K

$c = 2.998 \text{ x } 10^8$ m/s, $h = 6.626 \text{ x } 10^{-34}$ J-s, 1 e^- = $1.60 \text{ x } 10^{-19}$ C

1 V = 1 J / 1 C, 1 W = 1 J / 1 s, 1 kW·h=$3.6\text{x}10^6$ J

F = 96,485 J/(V·mol) = 96,486 C/mol e^-

$t_{1/2} = 0.693/k$ (first order), $\ln[A]_t - \ln[A]_0 = -kt$ (first order)

Table of solubility product constants at 25˚C

Substance	K_{sp}	Substance	K_{sp}
$AgBr$	$5.4x10^{-13}$	$Cr(OH)_3$	$3.0x10^{-29}$
$AgCl$	$1.8x10^{-10}$	$Cr_3(PO_4)_2$	$2.4x10^{-23}$
AgI	$8.5x10^{-17}$	$CuCO_3$	$2.5x10^{-10}$
Ag_2CO_3	$8.5x10^{-12}$	$Cu(OH)_2$	$2.2x10^{-20}$
Ag_2CrO_4	$1.1x10^{-12}$	$Cu_3(PO_4)_2$	$1.4x10^{-37}$
Ag_3PO_4	$8.9x10^{-17}$	CuS*	$1.3x10^{-36}$
Ag_2S*	$6.7x10^{-50}$	$FeCO_3$	$3.1x10^{-11}$
Ag_2SO_4	$1.2x10^{-5}$	$Fe(OH)_2$	$4.9x10^{-17}$
$Al(OH)_3$	$1.8x10^{-33}$	$Fe(OH)_3$	$2.6x10^{-39}$
$AlPO_4$	$9.8x10^{-21}$	FeS*	$1.6x10^{-19}$
$BaCO_3$	$2.6x10^{-9}$	$NiCO_3$	$1.4x10^{-7}$
$BaCrO_4$	$1.2x10^{-10}$	$Ni(OH)_2$	$2.8x10^{-16}$
BaF_2	$1.8x10^{-7}$	NiS*	$1.1x10^{-21}$
$Ba_3(PO_4)_2$	$1.3x10^{-29}$	$PbBr_2$	$6.3x10^{-6}$
$BaSO_4$	$1.1x10^{-10}$	$PbCl_2$	$1.7x10^{-5}$
$Bi(OH)_3$	$3.2x10^{-40}$	PbI_2	$9.8x10^{-9}$
$BiPO_4$	$1.3x10^{-23}$	$PbCO_3$	$1.5x10^{-13}$
Bi_2S_3*	$1.8x10^{-99}$	$PbCrO_4$	$1.8x10^{-14}$
$CaCO_3$	$5.0x10^{-9}$	$Pb(OH)_2$	$1.4x10^{-20}$
CaF_2	$1.5x10^{-10}$	PbS*	$9.0x10^{-29}$
$Ca(OH)_2$	$5.0x10^{-6}$	$PbSO_4$	$1.8x10^{-8}$
$Ca_3(PO_4)_2$	$2.1x10^{-33}$	Sb_2S_3*	$1.6x10^{-93}$
$CaSO_4$	$7.1x10^{-5}$	SnS*	$1.0x10^{-26}$
$CoCO_3$	$8.0x10^{-13}$	$ZnCO_3$	$1.2x10^{-10}$
$Co(OH)_2$	$1.1x10^{-15}$	$Zn(OH)_2$	$4.5x10^{-17}$
$Co_3(PO_4)_2$	$2.1x10^{-35}$	$Zn_3(PO_4)_2$	$9.1x10^{-33}$
CoS*	$4.0x10^{-21}$	ZnS*	$2.9x10^{-25}$

*For the reaction: M_nS_m (s) + m H_2O (l) $\rightleftharpoons$ n M^{m+} + m SH^- (aq) + m OH^- (aq)

Equilibrium constants for of complex-ion formation reactions. Cations that form complex ions with OH^- and NH_3 are given for: Ag, Al, Bi, Co, Cr, Cu, Fe, Ni, Zn.

Formation reaction	K_f
$Ag^+ + 2\ Cl^- \rightleftharpoons AgCl_2^-$	1.8×10^5
$Ag^+ + 2\ NH_3 \rightleftharpoons Ag(NH_3)_2^+$	1.6×10^7
$Pb^{2+} + 3\ Cl^- \rightleftharpoons PbCl_3^-$	2.4×10^1
$Co^{2+} + 6\ NH_3 \rightleftharpoons Co(NH_3)_6^{2+}$	5.0×10^4
$Co^{3+} + 6\ NH_3 \rightleftharpoons Co(NH_3)_6^{3+}$	4.6×10^{33}
$Cu^{2+} + 4\ NH_3 \rightleftharpoons Cu(NH_3)_4^{2+}$	1.1×10^{13}
$Ni^{2+} + 6\ NH_3 \rightleftharpoons Ni(NH_3)_6^{2+}$	2.0×10^8
$Zn^{2+} + 4\ NH_3 \rightleftharpoons Zn(NH_3)_4^{2+}$	7.8×10^8
$Cu^{2+} + 4\ OH^- \rightleftharpoons Cu(OH)_4^{2-}$	1.3×10^{16}
$Zn^{2+} + 4\ OH^- \rightleftharpoons Zn(OH)_4^{2-}$	2.0×10^{20}
$Pb^{2+} + 3\ OH^- \rightleftharpoons Pb(OH)_3^-$	3.8×10^{14}
$Al^{3+} + 4\ OH^- \rightleftharpoons Al(OH)_4^-$	7.7×10^{33}
$Cr^{3+} + 4\ OH^- \rightleftharpoons Cr(OH)_4^-$	8×10^{29}

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

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