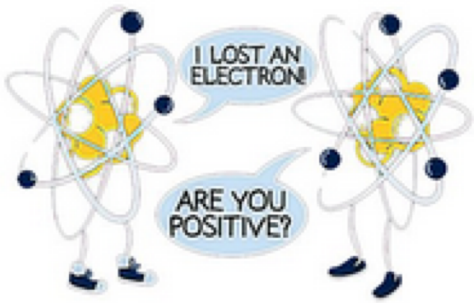
Signature: _____ ID Number: _____

Note that entire exam packet, including periodic table and any other supplementary material must be turned in or points will be deducted.

| | ΔH° (kJ/mol) | S° (J/molK) |
|---|---|---|
| $Li_2S$ | -447 | 63 |
| $Na_2S$ | -370.3 | 77.4 |
| $K_2S$ | -428.4 | 111.3 |
| $Cu_2S$ | -62 | 14 |
| $Ag_2S$ | -31.8 | 146 |
| $Li^+$ | -278.5 | 14 |
| $Na^+$ | -239.7 | 60.2 |
| $K^+$ | -251.2 | 103 |
| $Cu^+$ | 51.9 | -26 |
| $Ag^+$ | 105.9 | 73.93 |
| $S^{2-}$ | 41.8 | 22 |

# CHM 112
# Exam 4
# 30 April 2019




$nF = At$

$C = I \cdot t$

$\ln[A] = -kt + \ln[A]_0$

$[A] = -kt + [A]_0$

$1/[A] = kt + 1/[A]_0$

$t_{1/2} = 1/(k[A]_0)$

$t_{1/2} = [A]_0/2k$

$t_{1/2} = 0.693/k$

$\%\ \text{Ionization} = ([H_3O^+]_{eq}/[HA]_{initial})*100$

$$\ln\left(\frac{[A]}{[A]_0}\right) = -kt$$

$\mathbf{M_1V_1 = M_2V_2}$

$E = E^\circ_{cell} - (RT/nF)\ln Q$

$\Delta G_{rxn} = \Sigma\Delta G_{prod} - \Sigma\Delta G_{react}$

$\Delta S_{rxn} = \Sigma\Delta S_{prod} - \Sigma\Delta S_{react}$

$\Delta H_{rxn} = \Sigma\Delta H_{prod} - \Sigma\Delta H_{react}$

$$\mathbf{pH = pK_a + \log \frac{[A^-]}{[HA]}}$$

$$\frac{-b \pm (b^2-4ac)^{(1/2)}}{2a}$$

$w_{max} = -nFE$

$E^\circ_{cell} = (RT/nF)\ln K$

$\Delta G = -nFE$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$\Delta G^\circ = -RT\ln K$

$\Delta G = \Delta G^\circ + RT\ln Q$

$S = \Delta H/T$

$\Delta G = \Delta H - T\Delta S$

$pH = -\log[H_3O^+]$

$pOH = -\log[OH^-]$

$[H_3O^+] = 10^{-pH}$

$[OH^-] = 10^{-pOH}$

$pK_{a\ or\ b} = -\log[K_{a\ or\ b}]$

$[K_{a\ or\ b}] = 10^{-pKa\ or\ b}$

$\text{Avg Rate} = ([\text{Final}] - [\text{Initial}])/\text{time}$

$K_p = K_c \cdot (RT)^{\Delta n}$

$k = Ae^{-Ea/RT}$

$\mathbf{PV = nRT}$

$\ln k = (-E_a/RT) + \ln A$

$$\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Avogadro's Number:
$6.022 \times 10^{23}$ particles/mole
R values: 8.314 J/mol K
$8.314 \times 10^{-3}$ kJ/molK
0.0821 L atm/mol K
K = °C + 273.15
$K_w = 1.0 \times 10^{-14}$
F = 96485 C/mol ($J\ V^{-1}\ mol^{-1}$)

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)\quad E_{red} = -0.83V$
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-\quad E_{ox} = -1.23V$

# BOULDER SCIENTIFIC COMPANY

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Atomic Number
Element Symbol
Atomic Weight

| 1 IA | | | | | | | | | | | | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 VIIIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H Hydrogen 1.00794 | 2 IIA | | | | | | | | | | | | | | | | 2 He Helium 4.00260 |
| 3 Li Lithium 6.941 | 4 Be Beryllium 9.01218 | | | | | | | | | | | 5 B Boron 10.811 | 6 C Carbon 12.011 | 7 N Nitrogen 14.0067 | 8 O Oxygen 15.9994 | 9 F Fluorine 18.9984 | 10 Ne Neon 20.180 |
| 11 Na Sodium 22.9898 | 12 Mg Magnesium 24.305 | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 | 9 VIIIB | 10 | 11 IB | 12 IIB | 13 Al Aluminum 26.9815 | 14 Si Silicon 28.0855 | 15 P Phosphorus 30.9738 | 16 S Sulfur 32.066 | 17 Cl Chlorine 35.453 | 18 Ar Argon 39.948 |
| 19 K Potassium 39.0983 | 20 Ca Calcium 40.078 | 21 Sc Scandium 44.9559 | 22 Ti Titanium 47.867 | 23 V Vanadium 50.9415 | 24 Cr Chromium 51.996 | 25 Mn Manganese 54.938 | 26 Fe Iron 55.845 | 27 Co Cobalt 58.933 | 28 Ni Nickel 58.693 | 29 Cu Copper 63.546 | 30 Zn Zinc 65.39 | 31 Ga Gallium 69.723 | 32 Ge Germanium 72.61 | 33 As Arsenic 74.922 | 34 Se Selenium 78.96 | 35 Br Bromine 79.904 | 36 Kr Krypton 83.80 |
| 37 Rb Rubidium 85.4678 | 38 Sr Strontium 87.62 | 39 Y Yttrium 88.9059 | 40 Zr Zirconium 91.224 | 41 Nb Niobium 92.9064 | 42 Mo Molybdenum 95.94 | 43 Tc Technetium (98) | 44 Ru Ruthenium 101.07 | 45 Rh Rhodium 102.906 | 46 Pd Palladium 106.42 | 47 Ag Silver 107.868 | 48 Cd Cadmium 112.411 | 49 In Indium 114.82 | 50 Sn Tin 118.71 | 51 Sb Antimony 121.76 | 52 Te Tellurium 127.60 | 53 I Iodine 126.904 | 54 Xe Xenon 131.29 |
| 55 Cs Cesium 132.905 | 56 Ba Barium 137.33 | 57* La Lanthanum 138.906 | 72 Hf Hafnium 178.49 | 73 Ta Tantalum 180.948 | 74 W Tungsten 183.84 | 75 Re Rhenium 186.207 | 76 Os Osmium 190.23 | 77 Ir Iridium 192.217 | 78 Pt Platinum 195.078 | 79 Au Gold 196.967 | 80 Hg Mercury 200.59 | 81 Tl Thallium 204.383 | 82 Pb Lead 207.2 | 83 Bi Bismuth 208.980 | 84 Po Polonium (209) | 85 At Astatine (210) | 86 Rn Radon (222) |
| 87 Fr Francium (223) | 88 Ra Radium (226) | 89** Ac Actinium (227) | 104 Rf Rutherfordium (261) | 105 Db Dubnium (262) | 106 Sg Seaborgium (263) | 107 Bh Bohrium (264) | 108 Hs Hassium (265) | 109 Mt Meitnerium (268) | | | | | | | | | |

Reference: R.D. Vocke, Jr., *Atomic Weights of the Elements*, **1997**, National Institute of Standards and Technology. Parentheses ( ) indicate the mass number of the most stable isotope.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Lanthanide Series | 58* Ce Cerium 140.116 | 59 Pr Praseodymium 140.908 | 60 Nd Neodymium 144.24 | 61 Pm Promethium (145) | 62 Sm Samarium 150.36 | 63 Eu Europium 151.96 | 64 Gd Gadolinium 157.25 | 65 Tb Terbium 158.93 | 66 Dy Dysprosium 162.50 | 67 Ho Holmium 164.93 | 68 Er Erbium 167.26 | 69 Tm Thulium 168.93 | 70 Yb Ytterbium 173.04 | 71 Lu Lutetium 174.97 |
| ** Actinide Series | 90** Th Thorium 232.038 | 91 Pa Protactinium 231.036 | 92 U Uranium 238.029 | 93 Np Neptunium (237) | 94 Pu Plutonium (244) | 95 Am Americium (243) | 96 Cm Curium (247) | 97 Bk Berkelium (247) | 98 Cf Californium (251) | 99 Es Einsteinium (252) | 100 Fm Fermium (257) | 101 Md Mendelevium (258) | 102 No Nobelium (259) | 103 Lr Lawrencium (262) |

**BOULDER SCIENTIFIC COMPANY** P.O. Box 548 / 598 Third Street, Mead, Colorado 80542 ☏ **970-535-4494 / Fax 970-535-4584**

**Soluble**

- Ammonium ($NH_4^+$)
- Hydrogen ($H^+$)
- Alkali metals (group 1A)
- Nitrate ($NO_3^-$)
- Perchlorate ($ClO_4^-$)
- Acetate ($CH_3COO^-$)

**Always soluble**

**Usually Soluble**

| | Exceptions (insoluble if with): |
|---|---|
| Halides ($F^-$,$Cl^-$,$Br^-$,& $I^-$) | $Pb^{2+}$, $Hg_2^{2+}$, $Ag^+$ |
| Sulfate ($SO_4^{2-}$) | $Pb^{2+}$, $Hg_2^{2+}$, $Ag^+$, $Ba^{2+}$, $Ca^{2+}$, $Sr^{2+}$ |

**Sparingly Soluble (Insoluble)**

- Sulfide ($S^{2-}$)
- Hydroxide ($OH^-$)
- Oxide ($O^{2-}$)
- Carbonate ($CO_3^{2-}$)
- Phosphate ($PO_4^{3-}$)

**Exceptions:**
**soluble if with any of the cations listed in the always soluble box**

| Half-Reaction | $E°$(V) |
|---|---|
| $F_2(g) + 2e^- \longrightarrow 2F^-(aq)$ | +2.87 |
| $O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O$ | +2.07 |
| $Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$ | +1.82 |
| $H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O$ | +1.77 |
| $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O$ | +1.70 |
| $Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$ | +1.61 |
| $MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$ | +1.51 |
| $Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$ | +1.50 |
| $Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$ | +1.36 |
| $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$ | +1.33 |
| $MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O$ | +1.23 |
| $O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O$ | +1.23 |
| $Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$ | +1.07 |
| $NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O$ | +0.96 |
| $2Hg^{2+}(aq) + 2e^- \longrightarrow Hg_2^{2+}(aq)$ | +0.92 |
| $Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$ | +0.85 |
| $Ag^+(aq) + e^- \longrightarrow Ag(s)$ | +0.80 |
| $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$ | +0.77 |
| $O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$ | +0.68 |
| $MnO_4^-(aq) + 2H_2O + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$ | +0.59 |
| $I_2(s) + 2e^- \longrightarrow 2I^-(aq)$ | +0.53 |
| $O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-(aq)$ | +0.40 |
| $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ | +0.34 |
| $AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$ | +0.22 |
| $SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO_2(g) + 2H_2O$ | +0.20 |
| $Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$ | +0.15 |
| $Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$ | +0.13 |
| $2H^+(aq) + 2e^- \longrightarrow H_2(g)$ | 0.00 |
| $Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$ | −0.13 |
| $Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$ | −0.14 |
| $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$ | −0.25 |
| $Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$ | −0.28 |
| $PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$ | −0.31 |
| $Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$ | −0.40 |
| $Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$ | −0.44 |
| $Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$ | −0.74 |
| $Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$ | −0.76 |
| $2H_2O + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$ | −0.83 |
| $Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$ | −1.18 |
| $Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$ | −1.66 |
| $Be^{2+}(aq) + 2e^- \longrightarrow Be(s)$ | −1.85 |
| $Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$ | −2.37 |
| $Na^+(aq) + e^- \longrightarrow Na(s)$ | −2.71 |
| $Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$ | −2.87 |
| $Sr^{2+}(aq) + 2e^- \longrightarrow Sr(s)$ | −2.89 |
| $Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$ | −2.90 |
| $K^+(aq) + e^- \longrightarrow K(s)$ | −2.93 |
| $Li^+(aq) + e^- \longrightarrow Li(s)$ | −3.05 |

**MULTIPLE CHOICE (2 pts each): Write the letter corresponding to the correct answer on the line next to each question. The LETTER ASSOCIATED WITH THE CORRECT ANSWER MUST BE WRITTEN ON THE LINE NEXT TO THE QUESTION in order to receive full credit.**

1) Which of the following would be the strongest oxidizing agent? 1) _____

a) $Fe^{3+}$ b) $Cr^{3+}$ c) $Al^{3+}$ d) $Au^{3+}$

2) What is the oxidation number on chromium in the dichromate ion ($Cr_2O_7^{2-}$)? 2) _____

a) +7 b) +3 c) +6 d) +12

3) What is the entropy of a process that has a $\triangle H$ of 326J/mol at 18°C? 3) _____

a) 18.1 J/mol K b) 2.24 J/mol K

c) 5868 J/mol K d) 1.12 J/ mol K

4) Which of the following statements are true? 4) _____

I: electrons move toward the cathode

II: electrons move toward the anode

III: cations move toward the cathode

IV: anions move toward the cathdoe

a) I & IV b) II & III c) II & IV d) I & III

5) What is the equilibrium constant for a process with a stadard Gibbs Free Energy value of 0.0654kJ at 28°C? 5) _____

a) 0.974 b) 0.755 c) 1.32 d) 1.03

6) What is the maximum electrical work that can be done when 3 moles of $Cl_2$ are reduced to $Cl^-$ in a system will a cell potential of +2.20V? 6) _____

a) $-3.18 \times 10^5$ J b) $-1.06 \times 10^6$ J c) $-1.27 \times 10^6$ J d) $-6.37 \times 10^5$ J

7) Which of the following cations would be reduced in aqueous solution? 7) _____

a) $Ba^{2+}$ b) $Pb^{2+}$ c) $Li^+$ d) $Na^+$

8) Which of the following processes would lead to greater entropy? 8) _____

a) synthesizing aspirin

b) growing a tree

c) organizing your dorm room

d) turining your chemistry notes into confetti

**A solutions key is not currently available. If I am able to finish making up your exam 4 early enough, I will add the solutions tonight, but I cannot guarantee this will be possible.**

**SHORT ANSWER (14 pts each): Completely answer all of the following questions. Read all questions carefully!!! Show all work. Make sure to include units and report all mathematical answers to the correct number of significant figures. Write final answers in designated locations when indicated.**

1) Given the overall cell reaction: $Co^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Co(s)$

a.) Write the cell diagram. Answer a: _____

b.) What is the 1/2 reaction at the anode? Answer b: _____

c.) What is the 1/2 reaction at the cathode? Answer c: _____

d.) Calculate the standard cell potential for this cell. Answer d: _____

e.) Would Fe(s) spontaneously reduce $Co^{2+}$ to the free metal? Answer e:_____

f.) Is this a Galvanic cell? Answer f: _____

2) Balance the following equation: $Br_2 + SO_2 \rightarrow Br^- + SO_4^{2-}$

a.) In acidic solution:

Answer a:_____

b.) In basic solution:

Answer b:_____

c.) What element was oxidized in the reaction? Answer c:_____

d.) What element was reduced in the reaction? Answer d: _____

e.) How many electrons were transferred in the balanced equation? Answer e: _____

3) Given the following reaction: $Li_2S \rightarrow 2Li^+ + S^{2-}$ Use the table on the cover sheet to:

a.) Calculate $\triangle H$

Answer a:_____

b.) Calcuate $\triangle S$

Answer b:_____

c.) Calculate $\triangle G$ at 25°C

Answer c: _____

d.) At what temperature (°C) does this reaction transition between spontaneous & nonspontaneous?

Answer d:_____

4) A cell uses the following reaction: $Al^{3+}(aq) + Cr(s) \rightarrow Cr^{3+}(aq) + Al(s)$

a.) What is the $E_{cell}$ under standard conditions? Answer a: _____

b.) What is the $E_{cell}$ at 25°C if $[Al^{3+}] = 0.50M$ and $[Cr^{3+}] = 0.75M$?

Answer b:_____

c.) What is $\triangle G$ under standard conditions?

Answer c: _____

d.) What is $\triangle G$ under the conditions described in part b?

Answer d:_____

5) For the reaction $A(aq) + 2B(aq) \rightarrow C(aq)$ $\triangle G° = -3.974$ kJ/mol

a.) What is the value of K at 25°C? Answer a:_____

b.) What is the value of $\triangle G$ at 100°C? Q = 1.63 at this temperature.

Answer b:_____

c.) What is the value of $\triangle G$ at 25°C if [A] = 0.200M, [B] = 0.150M, [C] = 1.20M?

Answer c:_____

6) A 0.368 A current is passed through molten $NiCl_3$ for 45 minutes.

a.) What is the reduction 1/2 reaction? Answer a: _____

b.) How many electrons are transferred in this process? Answer b: _____

d.) How many moles of Ni(s) would be produced? Answer c: _____

e.) What mass of Ni(s) would be produced? Answer d: _____