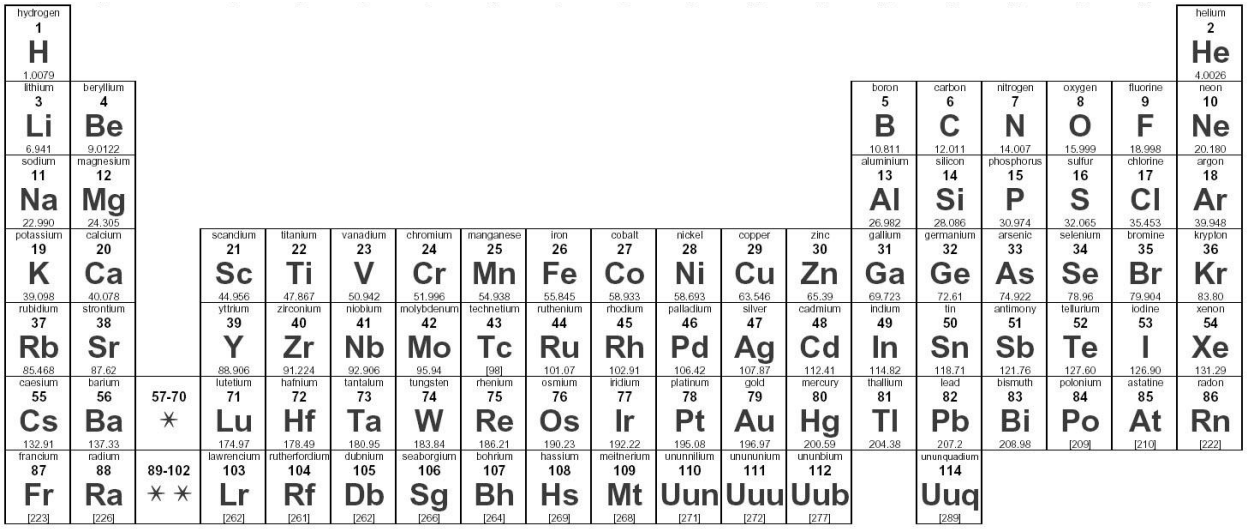
CH 233H

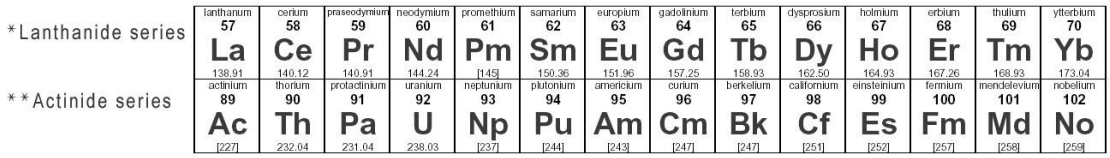
First Midterm Exam Friday, April 22, 2016

Name_____

Please show your work for partial credit. If you need more spacefor an answer, use the back of the page and indicate where we should look.

You may not use notes or other materials with chemical information without the instructor's approval; necessary information is provided on pages at the back of the exam. Please do not use ipods or other music players.





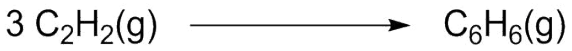
1. (15 points) Provide a concise definition in terms of energy for each of the three laws of thermodynamics.

First Law:

Second Law:

Third Law:

2. (20 points) A reaction you saw briefly was the formation of benzene (C_6H_6) from acetylene (C_2H_2):



A. What is $\Delta H_r°$?

B. What is $\Delta S_r°$?

2. (continued) C. At what temperature does a total pressure of 1.000 atm show an equilibrium partial pressure of 0.3167 atm benzene?

D. Because of the thermodynamics of this reaction, acetylene is never handled as a compressed gas but rather as a moderately (1.5 atm) pressurized solution (from which it easily vaporizes). Explain why you think this is more because of enthalpy or because of entropy.

3. (24 points) Many watch batteries or other “button” type batteries use the following reaction for the electrochemical cell:

$$Zn\ (s) + Ag_2O\ (s) \longrightarrow ZnO\ (s) + 2\ Ag\ (s)$$

A. Write the two half-cell reactions responsible for generating electrons in this battery.

B. Specify which metal will represent the anode, and which the cathode. Explain your reasoning.

C. What is the maximum voltage this cell can produce?

4. (21 points) We saw a demonstration where we bubbled CO_2 through a saturated solution of $Ca(OH)_2$.

A. Write a balanced chemical equation for the reaction that occurred, and point out how the product that forms leads to a visible change in appearance.

B. If enough CO_2 is bubbled through the solution, it becomes clear again. Use the following equilibria to explain what happens.

$$CaCO_3\,(s) \rightleftharpoons Ca^{+2}\,(aq) + CO_3^{-2}\,(aq) \quad K_{sp} = 2.8 \times 10^{-9}$$

$$CO_2\,(g) + 2H_2O\,(l) \rightleftharpoons H_3O^{+}(aq) + HCO_3^{-}(aq) \quad K_{eq} = 4.4 \times 10^{-7}$$

$$HCO_3^{-}\,(aq) + H_2O\,(l) \rightleftharpoons H_3O^{+}\,(aq) + CO_3^{-2}\,(aq) \quad K_{eq} = 4.7 \times 10^{-11}$$

C. Many of the world's historic artwork, monuments and architecture are made of marble, which is mostly crystalline $CaCO_3$. Based on the chemistry you describe in (B), explain whether you think it appropriate to keep a historically significant sculpture in an outdoor setting.

5. (20 points) Write the expected products for each of the following (possible) reactions. If you do not expect any reaction, write "NR."

A. $Cu_2O\ (s) + C\ (s) \xrightarrow{\text{Heat}}$

B. $Li_2O(s) + C\ (s) \xrightarrow{\text{Heat}}$

C. $AgCl\ (s) + 2NH_3\ (aq) \longrightarrow$

D. $FeCl_3\ (aq) + 6\ KCN\ (aq) \longrightarrow$

E. $CoCl_2\ (aq) + 4\ NH_3\ (aq) \longrightarrow$

Selected data that may be of use:

Physical constants:

$g = 9.8\ m/s^2$	Gravitational Constant
$\varepsilon_0 = 8.85419 \times 10^{-12}\ C^2/(Nm^2)$	Electric susceptibility of a vacuum
$c = 2.99792458 \times 10^{10}\ cm/s$	Speed of light
$R = 0.08206\ L\text{-}atm/(mol\text{-}K) = 8.314\ J/(mol\text{-}K)$	Gas constant
$N = 6.022 \times 10^{23}$	Avogadro's Number
$k = 1.381 \times 10^{-23}\ m^2kg/(K\text{-}s^2)$	Boltzmann constant
$h = 6.626 \times 10^{-34}\ m^2kg/s$	Planck's constant
$F = 96485\ C/mol$	Faraday's constant
$\pi = 3.14159$	
$e = 2.71828$	

Properties of State

Species	$\Delta H°_f$	S°
N_2 (g)	0 kJ/mol	191.6 J/(mol-K)
O_2 (g)	0 kJ/mol	205.1 J/(mol-K)
NO (g)	90.25 kJ/mol	210.8 J/(mol-K)
C (s) (graphite)	0 kJ/mol	5.74 J/(mol-K)
C_2H_2 (g)	226.7 kJ/mol	200.9 J/(mol-K)
C_6H_6 (g)	82.6 kJ/mol	269.3 J/(mol-K)
CO_2 (g)	-393.5 kJ/mol	213.7 J/(mol-K)
Ag (s)	0 kJ/mol	42.55 J/(mol-K)
Ag^+ (aq)	105.6 kJ/mol	72.68 J/(mol-K)
K^+(aq)	-254.4 kJ/mol	102.5 J/(mol-K)
Zn (s)	0 kJ/mol	41.63 J/(mol-K)
Zn^{+2} (aq)	-153.9 kJ/mol	112.1 J/(mol-K)
Li (s)	0 kJ/mol	29.12 J/(mol-K)
Li_2O (s)	-595.8 kJ/mol	37.89 J/(mol-K)
Cu (s)	0 kJ/mol	33.15 J/(mol-K)
Cu_2O (s)	-170 kJ/mol	93 J/(mol-K)

Electromotive series:

TABLE 20.1 Some Selected Standard Electrode (Reduction) Potentials at 25 °C

Reduction Half-Reaction	$E°$, V
Acidic solution	
$F_2(g) + 2\,e^- \longrightarrow 2\,F^-(aq)$	+2.866
$O_3(g) + 2\,H^+(aq) + 2\,e^- \longrightarrow O_2(g) + H_2O(l)$	+2.075
$S_2O_8^{2-}(aq) + 2\,e^- \longrightarrow 2\,SO_4^{2-}(aq)$	+2.01
$H_2O_2(aq) + 2\,H^+(aq) + 2\,e^- \longrightarrow 2\,H_2O(l)$	+1.763
$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \longrightarrow Mn^{2+}(aq) + 4\,H_2O(l)$	+1.51
$PbO_2(s) + 4\,H^+(aq) + 2\,e^- \longrightarrow Pb^{2+}(aq) + 2\,H_2O(l)$	+1.455
$Cl_2(g) + 2\,e^- \longrightarrow 2\,Cl^-(aq)$	+1.358
$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6\,e^- \longrightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(l)$	+1.33
$MnO_2(s) + 4\,H^+(aq) + 2\,e^- \longrightarrow Mn^{2+}(aq) + 2\,H_2O(l)$	+1.23
$O_2(g) + 4\,H^+(aq) + 4\,e^- \longrightarrow 2\,H_2O(l)$	+1.229
$2\,IO_3^-(aq) + 12\,H^+(aq) + 10\,e^- \longrightarrow I_2(s) + 6\,H_2O(l)$	+1.20
$Br_2(l) + 2\,e^- \longrightarrow 2\,Br^-(aq)$	+1.065
$NO_3^-(aq) + 4\,H^+(aq) + 3\,e^- \longrightarrow NO(g) + 2\,H_2O(l)$	+0.956
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.800
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.771
$O_2(g) + 2\,H^+(aq) + 2\,e^- \longrightarrow H_2O_2(aq)$	+0.695
$I_2(s) + 2\,e^- \longrightarrow 2\,I^-(aq)$	+0.535
$Cu^{2+}(aq) + 2\,e^- \longrightarrow Cu(s)$	+0.340
$SO_4^{2-}(aq) + 4\,H^+(aq) + 2\,e^- \longrightarrow 2\,H_2O(l) + SO_2(g)$	+0.17
$Sn^{4+}(aq) + 2\,e^- \longrightarrow Sn^{2+}(aq)$	+0.154
$S(s) + 2\,H^+(aq) + 2\,e^- \longrightarrow H_2S(g)$	+0.14
$2\,H^+(aq) + 2\,e^- \longrightarrow H_2(g)$	0
$Pb^{2+}(aq) + 2\,e^- \longrightarrow Pb(s)$	−0.125
$Sn^{2+}(aq) + 2\,e^- \longrightarrow Sn(s)$	−0.137
$Fe^{2+}(aq) + 2\,e^- \longrightarrow Fe(s)$	−0.440
$Zn^{2+}(aq) + 2\,e^- \longrightarrow Zn(s)$	−0.763
$Al^{3+}(aq) + 3\,e^- \longrightarrow Al(s)$	−1.676
$Mg^{2+}(aq) + 2\,e^- \longrightarrow Mg(s)$	−2.356
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.713
$Ca^{2+}(aq) + 2\,e^- \longrightarrow Ca(s)$	−2.84
$K^+(aq) + e^- \longrightarrow K(s)$	−2.924
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.040
Basic solution	
$O_3(g) + H_2O(l) + 2\,e^- \longrightarrow O_2(g) + 2\,OH^-(aq)$	+1.246
$OCl^-(aq) + H_2O(l) + 2\,e^- \longrightarrow Cl^-(aq) + 2\,OH^-(aq)$	+0.890
$O_2(g) + 2\,H_2O(l) + 4\,e^- \longrightarrow 4\,OH^-(aq)$	+0.401
$2\,H_2O(l) + 2\,e^- \longrightarrow H_2(g) + 2\,OH^-(aq)$	−0.828