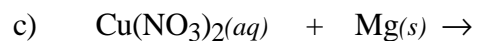
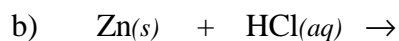
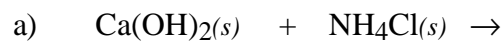


INSTRUCTIONS:

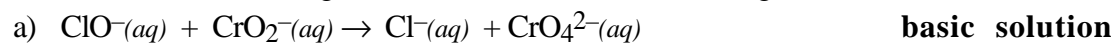
1. This examination consists of a total of 9 different pages. The last 4 pages include important mathematical equations and constants, a periodic table, and a table of solubility equilibrium constants, standard thermodynamic values and standard reduction potentials. All work should be done in this booklet. You may *carefully* remove the last 4 pages of the examination.
2. PRINT your name, your TA's name and your laboratory section now in the space at the top of this sheet. **DO NOT SEPARATE THE PAGES.**
3. Answer all questions that you can and whenever called for show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.
4. *No credit* will be awarded if your work is not shown in problems 2 – 5, 7 and 8. Please circle your final answer!
5. Point values are shown next to the problem number.
6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.
7. Look through the exam before beginning; plan your work; then begin.
8. **Relax** and do well.

	Page 2	Page 3	Page 4	Page 5	TOTAL
SCORES	<u> </u> (21)	<u> </u> (24)	<u> </u> (26)	<u> </u> (29)	<u> </u> (100)

(9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify the phase of each product as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.



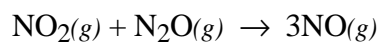
(12) 2. Balance the following oxidation-reduction reaction using the half-reaction method.



identify the oxidizing agent _____

identify the reducing agent _____

(24)3a. Calculate $\Delta G^\circ_{\text{rxn}}$, $\Delta H^\circ_{\text{rxn}}$ and $\Delta S^\circ_{\text{rxn}}$ for the reaction



- b) What would be the values of these three functions at 400 °C. (Note: State any assumptions.)
- c) What is the magnitude of the equilibrium constant, K_p , for the reaction at 25 °C?
- d) Is the reaction spontaneous at 25 °C? How would an increase in the temperature effect the spontaneity of the reaction? At what temperatures is the reaction spontaneous?

(16)4a. Calculate the solubility of PbI_2 in pure water at 25°C .

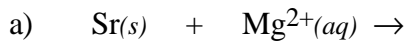
b) Calculate the solubility of PbI_2 in 0.0500 M CaI_2 .

(10) 5. 100.0 mL of 0.100 M AgNO_3 are mixed with 100.0 mL of 0.100 M ZnCl_2 .

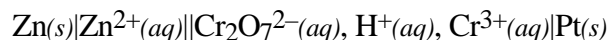
a) Write the chemical equation which describes the reaction which will occur when the two solutions are mixed.

b) Calculate the equilibrium concentrations of $\text{Ag}^+(\text{aq})$, $\text{NO}_3^-(\text{aq})$, Zn^{2+} , and Cl^- .

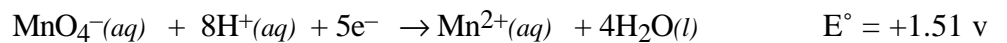
(9) 6. Write the chemical formula(s) of the product(s) and balance the following reactions.



(4) 7. Write the half-reactions and determine E° for the electrochemical cell as described below, include the overall chemical equation.



(16) 8. Given the two half-reactions



Write the chemical equation for the spontaneous reaction which can occur. Calculate the E° , K and ΔG° for the spontaneous reaction.

Useful Information

Equations

$$\Delta H^{\circ}_{\text{rxn}} = \sum(\Delta H_f^{\circ}(\text{products})) - \sum(\Delta H_f^{\circ}(\text{reactants}))$$

$$\Delta S^{\circ}_{\text{rxn}} = \sum(S^{\circ}(\text{products})) - \sum(S^{\circ}(\text{reactants}))$$

$$\Delta G^{\circ}_{\text{rxn}} = \sum(\Delta G_f^{\circ}(\text{products})) - \sum(\Delta G_f^{\circ}(\text{reactants}))$$

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

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

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

$$\text{pH} = -\log[\text{H}^+]$$

$$\Delta G^{\circ} = -nFE^{\circ}$$

$$E_{\text{cell}} = E^{\circ} - \frac{0.0257}{n} \ln Q$$

$$E^{\circ} = \frac{0.0257}{n} \ln K$$

$$E_{\text{cell}} = E^{\circ} - \frac{0.059}{n} \log Q$$

$$E^{\circ} = \frac{0.059}{n} \log K$$

Constants

$$1 \text{ amp} \cdot \text{sec} = 1 \text{ coulomb}$$

$$F = 96,500 \frac{\text{J}}{\text{volt} \cdot \text{mol}} = 96,500 \text{ coulombs}$$

$$R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}} = 8.314 \frac{\text{J}}{\text{mole} \cdot \text{K}}$$

Periodic Table of the Elements

	IA											VIIIA						
1	1 H 1.008																	
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.30	IIIB	IVB	VB	VIB	VIIB	VIII		IB	IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95	
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)									

Lanthanides

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
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Actinides

90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)
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E. 3 SOLUBILITY-PRODUCT CONSTANTS FOR COMPOUNDS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	BaCO ₃	5.1 x 10 ⁻⁹
Barium chromate	BaCrO ₄	1.2 x 10 ⁻¹⁰
Barium Fluoride	BaF ₂	1.0 x 10 ⁻⁶
Barium hydroxide	Ba(OH) ₂	5 x 10 ⁻³
Barium oxalate	BaC ₂ O ₄	1.6 x 10 ⁻⁷
Barium phosphate	Ba ₃ (PO ₄) ₂	3.4 x 10 ⁻²³
Barium sulfate	BaSO ₄	1.1 x 10 ⁻¹⁰
Cadmium carbonate	CdCO ₃	5.2 x 10 ⁻¹²
Cadmium hydroxide	Cd(OH) ₂	2.5 x 10 ⁻¹⁴
Cadmium sulfide	CdS	8.0 x 10 ⁻²⁷
Calcium carbonate	CaCO ₃	2.8 x 10 ⁻⁹
Calcium chromate	CaCrO ₄	7.1 x 10 ⁻⁴
Calcium fluoride	CaF ₂	3.9 x 10 ⁻¹¹
Calcium hydroxide	Ca(OH) ₂	5.5 x 10 ⁻⁶
Calcium phosphate	Ca ₃ (PO ₄) ₂	2.0 x 10 ⁻²⁹
Calcium sulfate	CaSO ₄	9.1 x 10 ⁻⁶
Cerium(III) fluoride	CeF ₃	8 x 10 ⁻¹⁶
Chromium(III) fluoride	CrF ₃	6.6 x 10 ⁻¹¹
Chromium(III) hydroxide	Cr(OH) ₃	6.3 x 10 ⁻³¹
Cobalt(II) carbonate	CoCO ₃	1.4 x 10 ⁻¹³
Cobalt(II) hydroxide	Co(OH) ₂	1.6 x 10 ⁻¹⁵
Cobalt(III) hydroxide	Co(OH) ₃	1.6 x 10 ⁻⁴⁴
Copper(I) bromide	CuBr	5.3 x 10 ⁻⁹
Copper(I) chloride	CuCl	1.2 x 10 ⁻⁶
Copper(I) sulfide	Cu ₂ S	2.5 x 10 ⁻⁴⁸
Copper(II) carbonate	CuCO ₃	1.4 x 10 ⁻¹⁰
Copper(II) chromate	CuCrO ₄	3.6 x 10 ⁻⁶
Copper(II) hydroxide	Cu(OH) ₂	2.2 x 10 ⁻²⁰
Copper(II) phosphate	Cu ₃ (PO ₄) ₂	1.3 x 10 ⁻³⁷
Copper(II) sulfide	CuS	6.3 x 10 ⁻³⁶
Gold(III) chloride	AuCl ₃	3.2 x 10 ⁻²⁵
Iron(II) carbonate	FeCO ₃	3.2 x 10 ⁻¹¹
Iron(II) hydroxide	Fe(OH) ₂	8.0 x 10 ⁻¹⁶
Iron(II) sulfide	FeS	6.3 x 10 ⁻¹⁸
Iron(III) hydroxide	Fe(OH) ₃	4 x 10 ⁻³⁸
Lanthanum fluoride	LaF ₃	7 x 10 ⁻¹⁷
Lanthanum iodate	La(IO ₃) ₃	6.1 x 10 ⁻¹²
Lead carbonate	PbCO ₃	7.4 x 10 ⁻¹⁴
Lead chloride	PbCl ₂	1.6 x 10 ⁻⁵
Lead chromate	PbCrO ₄	2.8 x 10 ⁻¹³
Lead fluoride	PbF ₂	2.7 x 10 ⁻⁸
Lead hydroxide	Pb(OH) ₂	1.2 x 10 ⁻¹⁵
Lead iodide	PbI ₂	7.1 x 10 ⁻⁹
Lead sulfide	PbS	8.0 x 10 ⁻²⁸
Magnesium hydroxide	Mg(OH) ₂	1.8 x 10 ⁻¹¹
Magnesium oxalate	MgC ₂ O ₄	8.6 x 10 ⁻⁵
Manganese carbonate	MnCO ₃	1.8 x 10 ⁻¹¹
Mercury(I) sulfide	Hg ₂ S	1.0 x 10 ⁻⁴⁷
Mercury(II) sulfide	HgS	4.0 x 10 ⁻⁵³
Silver chloride	AgCl	1.8 x 10 ⁻¹⁰
Silver sulfide	Ag ₂ S	6.3 x 10 ⁻⁵⁰
Strontium fluoride	SrF ₂	2.5 x 10 ⁻⁹

Thermodynamic Values (25 °C)

Substance and State	ΔH_f° ($\frac{\text{kJ}}{\text{mol}}$)	ΔG_f° ($\frac{\text{kJ}}{\text{mol}}$)	S° ($\frac{\text{J}}{\text{K}\cdot\text{mol}}$)	Substance and State	ΔH_f° ($\frac{\text{kJ}}{\text{mol}}$)	ΔG_f° ($\frac{\text{kJ}}{\text{mol}}$)	S° ($\frac{\text{J}}{\text{K}\cdot\text{mol}}$)
Carbon				Nitrogen			
C(s) (graphite)	0	0	6	N ₂ (g)	0	0	192
C(s) (diamond)	2	3	2	NCl ₃ (g)	230	271	-137
CO(g)	-110.5	-137	198	NF ₃ (g)	-125	-83.6	-139
CO ₂ (g)	-393.5	-394	214	NH ₃ (g)	?	-17	193
CH ₄ (g)	?	-51	186	NH ₃ (aq)	?	-27	111
CH ₃ OH(g)	-201	-163	240	NH ₂ CONH ₂ (aq)	?	?	174
CH ₃ OH(l)	-239	-166	127	NO(g)	90	87	211
H ₂ CO(g)	-116	-110	219	NO ₂ (g)	32	52	240
HCOOH(g)	-363	-351	249	N ₂ O(g)	82	104	220
HCN(g)	135.1	125	202	N ₂ O ₄ (g)	10	98	304
C ₂ H ₂ (g)	227	209	201	N ₂ O ₅ (g)	-42	134	178
C ₂ H ₄ (g)	52	68	219	N ₂ H ₃ CH ₃ (l)	54	180	166
CH ₃ CHO(g)	-166	-129	250	HNO ₃ (aq)	-207	-111	146
C ₂ H ₅ OH(l)	-278	-175	161	HNO ₃ (l)	-174	-81	156
C ₂ H ₆ (g)	-84.7	-32.9	229.5	NH ₄ Cl(s)	-314	-201	95
C ₃ H ₆ (g)	20.9	62.7	266.9	NH ₄ ClO ₄ (s)	-295	-89	186
C ₃ H ₈ (g)	-104	-24	270	Silver			
Bromine				Ag(s)	0	0	42.6
Br ₂ (l)	0	0	152.	Ag ⁺ (aq)	105.6	77.1	72.7
BrCl(g)	14.64	-0.96	240	Ag(S ₂ O ₃) ³⁻ (aq)	-1285.7	--	--
Chlorine				AgBr(s)	-100.4	-96.9	107.1
Cl ₂ (g)	0	0	223	AgCl(s)	-127.1	-109.8	96.2
Cl ₂ (aq)	-23	7	121	Sulfur			
Cl ⁻ (aq)	-167	-131	57	S(rhombic)	0	0	31.8
HCl(g)	-92	-95	187	SO ₂ (g)	-296.8	-300.2	248.8
Fluorine				SO ₃ (g)	-395.7	-371.1	256.3
F ₂ (g)	0	0	203	H ₂ S(g)	-20.17	-33.0	205.6
F(aq)	-333	-279	-14	Titanium			
HF(g)	-271	-273	174	TiCl ₄ (g)	-763	-727	355
Hydrogen				TiO ₂ (s)	-945	-890	50
H ₂ (g)	0	0	131	Aluminum			
H(g)217	203	115		AlCl ₃ (s)	-526	-505	184
H ⁺ (aq)	0	0	0	Barium			
OH ⁻ (aq)	-230	-157	-11	BaCl ₂ (aq)	-872	-823	123
H ₂ O(l)	-286	-237	70	Ba(OH) ₂ ·8H ₂ O(s)	-3342	-2793	427
H ₂ O(g)	-242	-229	189	Iodine			
Magnesium				I ₂ (s)	0	0	116.7
Mg(s)	0	0	33	HI(g)	25.94	1.30	206.3
Mg(aq)	-492	-456	-118				
MgO(s)	-601	-569	26.9				
Oxygen							
O ₂ (g)	0	0	205				
O(g)249	232	161					
O ₃ (g)	143	163	239				

Table of Standard Reduction Potentials (25 °C)

A. Acidic Solution

	$E^{\circ}(\text{V})$	$\text{Pt}^{2+} + 2\text{e}^{-} \rightarrow \text{Pt}(\text{s})$	~1.2
		$\text{ClO}_3^{-} + 3\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{HClO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$	1.21
$\text{Li}^{+} + \text{e}^{-} \rightarrow \text{Li}(\text{s})$	-3.045	$\text{O}_2(\text{g}) + 4\text{H}^{+} + 4\text{e}^{-} \rightarrow 2\text{H}_2\text{O}(\text{l})$	1.229
$\text{K}^{+} + \text{e}^{-} \rightarrow \text{K}(\text{s})$	-2.925	$\text{O}_2(\text{g}) + 4\text{H}^{+}(\text{pH} = 7) + 4\text{e}^{-} \rightarrow 2\text{H}_2\text{O}(\text{l})$	0.83
$\text{Ba}^{2+} + 2\text{e}^{-} \rightarrow \text{Ba}(\text{s})$	-2.906	$\text{MnO}_2(\text{s}) + 4\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{Mn}^{2+} + 2\text{H}_2\text{O}(\text{l})$	1.23
$\text{Sr}^{2+} + 2\text{e}^{-} \rightarrow \text{Sr}(\text{s})$	-2.888	$2\text{HNO}_2(\text{aq}) + 4\text{H}^{+} + 4\text{e}^{-} \rightarrow \text{N}_2\text{O}(\text{g}) + 3\text{H}_2\text{O}(\text{l})$	1.29
$\text{Ca}^{2+} + 2\text{e}^{-} \rightarrow \text{Ca}(\text{s})$	-2.866	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^{+} + 6\text{e}^{-} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}(\text{l})$	1.33
$\text{Na}^{+} + \text{e}^{-} \rightarrow \text{Na}(\text{s})$	-2.714	$\text{Cl}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{Cl}^{-}$	1.360
$\text{Mg}^{2+} + 2\text{e}^{-} \rightarrow \text{Mg}(\text{s})$	-2.363	$\text{PbO}_2(\text{s}) + 4\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{Pb}^{2+} + 2\text{H}_2\text{O}(\text{l})$	1.455
$\text{H}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{H}^{-}$	-2.25	$\text{Au}^{3+} + 3\text{e}^{-} \rightarrow \text{Au}(\text{s})$	1.498
$\text{Al}^{3+} + 3\text{e}^{-} \rightarrow \text{Al}(\text{s})$	-1.662	$\text{MnO}_4^{-} + 8\text{H}^{+} + 5\text{e}^{-} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}(\text{l})$	1.51
$\text{Mn}^{2+} + 2\text{e}^{-} \rightarrow \text{Mn}(\text{s})$	-1.185	$2\text{HClO}(\text{aq}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{Cl}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	1.63
$\text{Zn}^{2+} + 2\text{e}^{-} \rightarrow \text{Zn}(\text{s})$	-0.763	$\text{HClO}_2(\text{aq}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{HClO}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	1.645
$\text{Cr}^{3+} + 3\text{e}^{-} \rightarrow \text{Cr}(\text{s})$	-0.744	$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow 2\text{H}_2\text{O}(\text{l})$	1.776
$\text{Fe}^{2+} + 2\text{e}^{-} \rightarrow \text{Fe}(\text{s})$	-0.440	$\text{S}_2\text{O}_8^{2-} + 2\text{e}^{-} \rightarrow 2\text{SO}_4^{2-}$	2.00
$\text{Cr}^{3+} + \text{e}^{-} \rightarrow \text{Cr}^{2+}$	-0.408	$\text{O}_3(\text{g}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	2.07
$\text{Cd}^{2+} + 2\text{e}^{-} \rightarrow \text{Cd}(\text{s})$	-0.403	$\text{F}_2(\text{g}) + 2\text{e}^{-} \rightarrow 2\text{F}^{-}$	2.87
$\text{PbSO}_4(\text{s}) + 2\text{e}^{-} \rightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}$	-0.359	$\text{F}_2(\text{g}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow 2\text{HF}(\text{aq})$	3.06
$\text{PbCl}_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Pb}(\text{s}) + 2\text{Cl}^{-}$	-0.268		
$\text{Ni}^{2+} + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s})$	-0.250		
$\text{Sn}^{2+} + 2\text{e}^{-} \rightarrow \text{Sn}(\text{s})$	-0.136		
$\text{Pb}^{2+} + 2\text{e}^{-} \rightarrow \text{Pb}(\text{s})$	-0.126		
$2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	0.000		
$\text{S}(\text{s}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2\text{S}(\text{aq})$	0.142		
$\text{Sn}^{4+} + 2\text{e}^{-} \rightarrow \text{Sn}^{2+}$	0.15		
$\text{Sb}_2\text{O}_3(\text{s}) + 6\text{H}^{+} + 6\text{e}^{-} \rightarrow 2\text{Sb}(\text{s}) + 3\text{H}_2\text{O}(\text{l})$	0.152		
$\text{Cu}^{2+} + \text{e}^{-} \rightarrow \text{Cu}^{+}$	0.153		
$\text{SO}_4^{2-} + 4\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	0.172		
$\text{AgCl}(\text{s}) + \text{e}^{-} \rightarrow \text{Ag}(\text{s}) + \text{Cl}^{-}$	0.222		
$\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	0.337		
$\text{SO}_4^{2-} + 8\text{H}^{+} + 6\text{e}^{-} \rightarrow \text{S}(\text{s}) + 4\text{H}_2\text{O}(\text{l})$	0.357		
$\text{H}_2\text{SO}_3(\text{aq}) + 4\text{H}^{+} + 4\text{e}^{-} \rightarrow \text{S}(\text{s}) + 3\text{H}_2\text{O}(\text{l})$	0.450		
$\text{I}_2(\text{s}) + 2\text{e}^{-} \rightarrow 2\text{I}^{-}$	0.536		
$\text{MnO}_4^{-} + \text{e}^{-} \rightarrow \text{MnO}_4^{2-}$	0.564		
$[\text{PtCl}_6]^{2-} + 2\text{e}^{-} \rightarrow [\text{PtCl}_4]^{2-} + 2\text{Cl}^{-}$	0.68		
$\text{O}_2(\text{g}) + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2\text{O}_2(\text{aq})$	0.682		
$\text{Fe}^{3+} + \text{e}^{-} \rightarrow \text{Fe}^{2+}$	0.771		
$\text{Hg}^{2+} + 2\text{e}^{-} \rightarrow \text{Hg}(\text{l})$	0.788		
$\text{Ag}^{+} + \text{e}^{-} \rightarrow \text{Ag}(\text{s})$	0.799		
$2\text{NO}_3^{-} + 4\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{N}_2\text{O}_4(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	0.803		
$2\text{Hg}^{2+} + 2\text{e}^{-} \rightarrow \text{Hg}_2^{2+}$	0.920		
$\text{NO}_3^{-} + 4\text{H}^{+} + 3\text{e}^{-} \rightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	0.96		
$\text{Pd}^{2+} + 2\text{e}^{-} \rightarrow \text{Pd}(\text{s})$	0.987		
$\text{Br}_2(\text{l}) + 2\text{e}^{-} \rightarrow 2\text{Br}^{-}$	1.065		
$\text{Br}_2(\text{aq}) + 2\text{e}^{-} \rightarrow 2\text{Br}^{-}$	1.087		
$\text{ClO}_4^{-} + 2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{ClO}_3^{-} + \text{H}_2\text{O}(\text{l})$	1.19		
$2\text{IO}_3^{-} + 12\text{H}^{+} + 10\text{e}^{-} \rightarrow \text{I}_2(\text{s}) + 6\text{H}_2\text{O}(\text{l})$	1.195		

B. Alkaline Solution

 $E^{\circ}(\text{V})$

$\text{Mg}(\text{OH})_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Mg}(\text{s}) + 2\text{OH}^{-}$	-2.690
$\text{Al}(\text{OH})_3(\text{s}) + 3\text{e}^{-} \rightarrow \text{Al}(\text{s}) + 3\text{OH}^{-}$	-2.30
$\text{Zn}(\text{OH})_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Zn}(\text{s}) + 2\text{OH}^{-}$	-1.245
$\text{Fe}(\text{OH})_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Fe}(\text{s}) + 2\text{OH}^{-}$	-0.877
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}$	-0.828
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{pH} = 7)$	-0.43
$\text{Cd}(\text{OH})_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Cd}(\text{s}) + 2\text{OH}^{-}$	-0.809
$\text{Ni}(\text{OH})_2(\text{s}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s}) + 2\text{OH}^{-}$	-0.72
$\text{Fe}(\text{OH})_3(\text{s}) + \text{e}^{-} \rightarrow \text{Fe}(\text{OH})_2(\text{s}) + \text{OH}^{-}$	-0.56
$2\text{S}(\text{s}) + 2\text{e}^{-} \rightarrow \text{S}_2^{2-}$	-0.447
$\text{Cu}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow 2\text{Cu}(\text{s}) + 2\text{OH}^{-}$	-0.358
$\text{CrO}_4^{2-} + 4\text{H}_2\text{O}(\text{l}) + 3\text{e}^{-} \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 5\text{OH}^{-}$	-0.13
$\text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{Mn}(\text{OH})_2(\text{s}) + 2\text{OH}^{-}$	-0.05
$\text{NO}_3^{-} + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{NO}_2^{-} + 2\text{OH}^{-}$	0.01
$\text{HgO}(\text{s}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{Hg}(\text{l}) + 2\text{OH}^{-}$	0.098
$\text{PbO}_2(\text{s}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{PbO}(\text{s}) + 2\text{OH}^{-}$	0.247
$\text{ClO}_3^{-} + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{ClO}_2^{-} + 2\text{OH}^{-}$	0.33
$\text{ClO}_4^{-} + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{ClO}_3^{-} + 2\text{OH}^{-}$	0.36
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^{-} \rightarrow 4\text{OH}^{-}$	0.401
$\text{NiO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{OH})_2(\text{s}) + 2\text{OH}^{-}$	0.490
$\text{MnO}_4^{-} + 2\text{H}_2\text{O}(\text{l}) + 3\text{e}^{-} \rightarrow \text{MnO}_2(\text{s}) + 4\text{OH}^{-}$	0.588
$\text{BrO}_3^{-} + 3\text{H}_2\text{O}(\text{l}) + 6\text{e}^{-} \rightarrow \text{Br}^{-} + 6\text{OH}^{-}$	0.61
$\text{ClO}^{-} + \text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{Cl}^{-} + 2\text{OH}^{-}$	0.89

