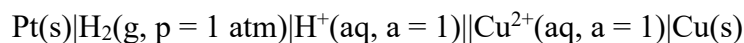


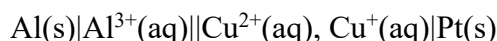
Electrochemistry and the Nernst Equation Problem

1. The measured electromotive force (EMF) for the cell



is +0.337 V. Write down the cell reaction and calculate the value of ΔG° for this reaction.

2. For the following hypothetical cell,



at 298 K:

- (i) State the cell reaction.
- (ii) Give the Nernst equation for the cell.
- (iii) Calculate the cell EMF when
 - (a) $a_{\text{Al}^{3+}} = a_{\text{Cu}^{2+}} = a_{\text{Cu}^+} = 1.0$
 - (b) $a_{\text{Al}^{3+}} = a_{\text{Cu}^{2+}} = a_{\text{Cu}^+} = 0.1$

The standard electrode potentials are:

$$E^\circ_{\text{Cu}^+|\text{Cu}^{2+}} = +0.15 \text{ V}$$

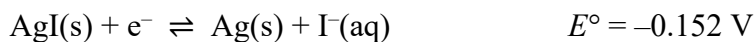
$$E^\circ_{\text{Al}|\text{Al}^{3+}} = -1.61 \text{ V}$$

3. At 298 K, the EMF of the cell shown below is +0.84 V.



- (i) Define what is meant by the standard EMF of the cell.
- (ii) Write down the cell reaction and the Nernst equation for the cell.
- (iii) Calculate the equilibrium constant for the cell reaction at 298 K.

4. From the following standard electrode potential data, calculate the solubility product (K_{sp}) of AgI at 298 K.



5. For the electrochemical cell

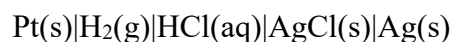


The EMF at temperatures near 298 K obeys the following equation:

$$E^\circ/\text{V} = -0.00558 + 2.6967 \times 10^{-3}T - 8.2299 \times 10^{-6}T^2 + 5.869 \times 10^{-9}T^3$$

Where T is the absolute temperature measured in K. Calculate ΔG° , ΔH° and ΔS° for the reaction at 298 K

6. Consider the cell



for which $E^\circ = +0.2225$ V at 298 K. If the concentration of HCl is such that the measured cell potential is +0.385 V when the pressure of H_2 gas is one atmosphere, what is the pH of the solution?

7. For the reduction of ClO_4^- to ClO_3^- the standard electrode potential under alkaline conditions is +0.37 V, while under acidic conditions it is +1.20 V.

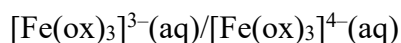
Write a balanced half-cell reaction for each reduction and deduce the value for the ionic product of water, K_w .

8. In a fuel cell, hydrazine, N_2H_4 , is oxidized to nitrogen, and oxygen is reduced to water. The standard electrode potentials for the reduction of N_2 to N_2H_4 and of O_2 to H_2O at 298 K are -1.155 V and $+0.401$ V, respectively, both under alkaline conditions.

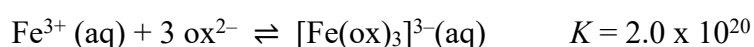
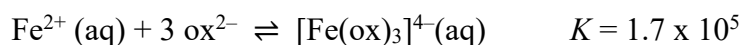
(i) Write a balanced equation for both of the half cell reactions under alkaline conditions. For the cell reaction where the hydrazine electrode is on the left, calculate the standard EMF of the cell at 298 K.

(ii) In a practical cell the concentrations of N_2H_4 and OH^- are 0.5 M and 1.0 M, respectively, and the pressure of O_2 and N_2 are 0.2 bar and 0.8 bar, respectively. Use the Nernst equation to estimate the cell EMF at 298 K, assuming all activity coefficients are unity.

9. Calculate the standard electrode potential for the aqueous couple



from the following data (298 K), where ox^{2-} refers to the oxalate anion, $\text{C}_2\text{O}_4^{2-}$:



(Harvey, D. 2000. *Modern Analytical Chemistry*, USA : McGraw-Hill.)

Aluminum	E° (V)	$E^{\circ'}$ (V)
$\text{Al}^{3+} + 3e^- \rightleftharpoons \text{Al}(s)$	-1.676	
$\text{Al}(\text{OH})_4^- + 3e^- \rightleftharpoons \text{Al}(s) + 4\text{OH}^-$	-2.310	
$\text{AlF}_6^{3-} + 3e^- \rightleftharpoons \text{Al}(s) + 6\text{F}^-$	-2.07	
Antimony	E° (V)	$E^{\circ'}$ (V)
$\text{Sb}(s) + 3\text{H}^+ + 3e^- \rightleftharpoons \text{SbH}_3(g)$	-0.510	
$\text{Sb}_2\text{O}_5(s) + 6\text{H}^+ + 4e^- \rightleftharpoons 2\text{SbO}^+ + 3\text{H}_2\text{O}$	0.605	
$\text{SbO}^+ + 2\text{H}^+ + 3e^- \rightleftharpoons \text{Sb}(s) + \text{H}_2\text{O}$	0.212	
Arsenic	E° (V)	$E^{\circ'}$ (V)
$\text{As}(s) + 3\text{H}^+ + 3e^- \rightleftharpoons \text{AsH}_3(g)$	-0.225	
$\text{H}_3\text{AsO}_4 + 2\text{H}^+ + 2e^- \rightleftharpoons \text{HAsO}_2 + 2\text{H}_2\text{O}$	0.560	
$\text{HAsO}_2 + 3\text{H}^+ + 3e^- \rightleftharpoons \text{As}(s) + 2\text{H}_2\text{O}$	0.240	
Barium	E° (V)	$E^{\circ'}$ (V)
$\text{Ba}^{2+} + 2e^- \rightleftharpoons \text{Ba}(s)$	-2.92	
$\text{BaO}(s) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{Ba}(s) + \text{H}_2\text{O}$	2.365	
Beryllium	E° (V)	$E^{\circ'}$ (V)
$\text{Be}^{2+} + 2e^- \rightleftharpoons \text{Be}(s)$	-1.99	
Bismuth	E° (V)	$E^{\circ'}$ (V)
$\text{Bi}^{3+} + 3e^- \rightleftharpoons \text{Bi}(s)$	0.317	
$\text{BiCl}_4^- + 3e^- \rightleftharpoons \text{Bi}(s) + 4\text{Cl}^-$	0.199	
Boron	E° (V)	$E^{\circ'}$ (V)
$\text{B}(\text{OH})_3 + 3\text{H}^+ + 3e^- \rightleftharpoons \text{B}(s) + 3\text{H}_2\text{O}$	-0.890	
$\text{B}(\text{OH})_4^- + 3e^- \rightleftharpoons \text{B}(s) + 4\text{OH}^-$	-1.811	
Bromine	E° (V)	$E^{\circ'}$ (V)
$\text{Br}_2 + 2e^- \rightleftharpoons 2\text{Br}^-$	1.087	
$\text{HOBr} + \text{H}^+ + 2e^- \rightleftharpoons \text{Br}^- + \text{H}_2\text{O}$	1.341	
$\text{HOBr} + \text{H}^+ + e^- \rightleftharpoons \frac{1}{2}\text{Br}_2(l) + \text{H}_2\text{O}$	1.604	
$\text{BrO}^- + \text{H}_2\text{O} + 2e^- \rightleftharpoons \text{Br}^- + 2\text{OH}^-$		0.76 1 M NaOH
$\text{BrO}_3^- + 6\text{H}^+ + 5e^- \rightleftharpoons \frac{1}{2}\text{Br}_2(l) + 3\text{H}_2\text{O}$	1.5	
$\text{BrO}_3^- + 6\text{H}^+ + 6e^- \rightleftharpoons \text{Br}^- + 3\text{H}_2\text{O}$	1.478	
Cadmium	E° (V)	$E^{\circ'}$ (V)
$\text{Cd}^{2+} + 2e^- \rightleftharpoons \text{Cd}(s)$	-0.4030	
$\text{Cd}(\text{CN})_4^{2-} + 2e^- \rightleftharpoons \text{Cd}(s) + 4\text{CN}^-$	-0.943	
$\text{Cd}(\text{NH}_3)_4^{2+} + 2e^- \rightleftharpoons \text{Cd}(s) + 4\text{NH}_3$	-0.622	
Calcium	E° (V)	$E^{\circ'}$ (V)
$\text{Ca}^{2+} + 2e^- \rightleftharpoons \text{Ca}(s)$	-2.84	
Carbon	E° (V)	$E^{\circ'}$ (V)
$\text{CO}_2(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}$	-0.106	
$\text{CO}_2(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{HCO}_2\text{H}$	-0.20	
$2\text{CO}_2(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2\text{C}_2\text{O}_4$	-0.481	
$\text{HCHO} + 2\text{H}^+ + 2e^- \rightleftharpoons \text{CH}_3\text{OH}$	0.2323	
Cerium	E° (V)	$E^{\circ'}$ (V)
$\text{Ce}^{3+} + 3e^- \rightleftharpoons \text{Ce}(s)$	-2.336	
$\text{Ce}^{4+} + e^- \rightleftharpoons \text{Ce}^{3+}$	1.72	1.70 1 M HClO ₄ 1.44 1 M H ₂ SO ₄ 1.61 1 M HNO ₃ 1.28 1 M HCl
Chlorine	E° (V)	$E^{\circ'}$ (V)
$\text{Cl}_2(g) + 2e^- \rightleftharpoons 2\text{Cl}^-$	1.396	
$\text{ClO}^- + \text{H}_2\text{O} + e^- \rightleftharpoons \frac{1}{2}\text{Cl}_2(g) + 2\text{OH}^-$		0.421 1 M NaOH
$\text{ClO}^- + \text{H}_2\text{O} + 2e^- \rightleftharpoons \text{Cl}^- + 2\text{OH}^-$		0.890 1 M NaOH
$\text{HClO}_2 + 2\text{H}^+ + 2e^- \rightleftharpoons \text{HOCl} + \text{H}_2\text{O}$	1.64	
$\text{ClO}_3^- + 2\text{H}^+ + e^- \rightleftharpoons \text{ClO}_2(g) + \text{H}_2\text{O}$	1.175	
$\text{ClO}_3^- + 3\text{H}^+ + 2e^- \rightleftharpoons \text{HClO}_2 + \text{H}_2\text{O}$	1.181	
$\text{ClO}_4^- + 2\text{H}^+ + 2e^- \rightleftharpoons \text{ClO}_3^- + \text{H}_2\text{O}$	1.201	

continued

Table 1 Standard Reduction Potentials – *continued*(Harvey, D. 2000. *Modern Analytical Chemistry*, USA : McGraw-Hill.)**Standard Reduction Potentials^a—continued**

Chromium	E° (V)	$E^{\circ'}$ (V)	Iron	E° (V)	$E^{\circ'}$ (V)
$\text{Cr}^{3+} + e^- \rightleftharpoons \text{Cr}^{2+}$	-0.424		$\text{Fe}^{2+} + 2e^- \rightleftharpoons \text{Fe}(s)$	-0.44	
$\text{Cr}^{2+} + 2e^- \rightleftharpoons \text{Cr}(s)$	-0.90		$\text{Fe}^{3+} + 3e^- \rightleftharpoons \text{Fe}(s)$	-0.037	
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6e^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	1.36		$\text{Fe}^{3+} + e^- \rightleftharpoons \text{Fe}^{2+}$	0.771	0.70 1 M HCl
$\text{CrO}_4^{2-} + 4\text{H}_2\text{O} + 3e^- \rightleftharpoons \text{Cr}(\text{OH})_4^- + 4\text{OH}^-$		-0.13 1 M NaOH			0.767 1 M HClO_4
	E° (V)	$E^{\circ'}$ (V)			0.746 1 M HNO_3
Cobalt					0.68 1 M H_2SO_4
$\text{Co}^{2+} + 2e^- \rightleftharpoons \text{Co}(s)$	-0.277		$\text{Fe}(\text{CN})_6^{3-} + e^- \rightleftharpoons \text{Fe}(\text{CN})_6^{4-}$	0.356	0.44 0.3 M H_3PO_4
$\text{Co}^{3+} + e^- \rightleftharpoons \text{Co}^{2+}$	1.92		$\text{Fe}(\text{phen})_3^{3+} + e^- \rightleftharpoons \text{Fe}(\text{phen})_3^{2+}$	1.147	0.71 1 M HCl
$\text{Co}(\text{NH}_3)_6^{3+} + e^- \rightleftharpoons \text{Co}(\text{NH}_3)_6^{2+}$	0.1		$\text{Fe}(\text{CN})_6^{3-} + e^- \rightleftharpoons \text{Fe}(\text{CN})_6^{4-}$	0.356	
$\text{Co}(\text{OH})_3(s) + e^- \rightleftharpoons \text{Co}(\text{OH})_2(s) + \text{OH}^-$	0.17			E° (V)	$E^{\circ'}$ (V)
$\text{Co}(\text{OH})_2(s) + 2e^- \rightleftharpoons \text{Co}(s) + 2\text{OH}^-$	-0.746		Lanthanum		
	E° (V)	$E^{\circ'}$ (V)	$\text{La}^{3+} + 3e^- \rightleftharpoons \text{La}(s)$	-2.38	
Copper				E° (V)	$E^{\circ'}$ (V)
$\text{Cu}^+ + e^- \rightleftharpoons \text{Cu}(s)$	0.520		Lead		
$\text{Cu}^{2+} + e^- \rightleftharpoons \text{Cu}^+$	0.159		$\text{Pb}^{2+} + 2e^- \rightleftharpoons \text{Pb}(s)$	-0.126	
$\text{Cu}^{2+} + 2e^- \rightleftharpoons \text{Cu}(s)$	0.3419		$\text{PbO}_2(s) + 4\text{H}^+ + 2e^- \rightleftharpoons \text{Pb}^{2+} + 2\text{H}_2\text{O}$	1.46	
$\text{Cu}^{2+} + \text{I}^- + e^- \rightleftharpoons \text{CuI}(s)$	0.86		$\text{PbO}_2(s) + \text{SO}_4^{2-} + 4\text{H}^+ + 2e^- \rightleftharpoons \text{PbSO}_4(s) + 2\text{H}_2\text{O}$	1.690	
$\text{Cu}^{2+} + \text{Cl}^- + e^- \rightleftharpoons \text{CuCl}(s)$	0.559		$\text{PbSO}_4(s) + 2e^- \rightleftharpoons \text{Pb}(s) + \text{SO}_4^{2-}$	-0.356	
	E° (V)	$E^{\circ'}$ (V)		E° (V)	$E^{\circ'}$ (V)
Fluorine			Lithium		
$\text{F}_2(g) + 2\text{H}^+ + 2e^- \rightleftharpoons 2\text{HF}$	3.053		$\text{Li}^+ + e^- \rightleftharpoons \text{Li}(s)$	-3.040	
$\text{F}_2(g) + 2e^- \rightleftharpoons 2\text{F}^-$	2.87			E° (V)	$E^{\circ'}$ (V)
	E° (V)	$E^{\circ'}$ (V)	Magnesium		
Gallium			$\text{Mg}^{2+} + 2e^- \rightleftharpoons \text{Mg}(s)$	-2.356	
$\text{Ga}^{3+} + 3e^- \rightleftharpoons \text{Ga}(s)$	-0.529		$\text{Mg}(\text{OH})_2(s) + 2e^- \rightleftharpoons \text{Mg}(s) + 2\text{OH}^-$	-2.687	
	E° (V)	$E^{\circ'}$ (V)		E° (V)	$E^{\circ'}$ (V)
Gold			Manganese		
$\text{Au}^+ + e^- \rightleftharpoons \text{Au}(s)$	1.83		$\text{Mn}^{2+} + 2e^- \rightleftharpoons \text{Mn}(s)$	-1.17	
$\text{Au}^{3+} + 2e^- \rightleftharpoons \text{Au}^+$	1.36		$\text{M}^{3+} + e^- \rightleftharpoons \text{Mn}^{2+}$	1.5	
$\text{Au}^{3+} + 3e^- \rightleftharpoons \text{Au}(s)$	1.52		$\text{MnO}_2(s) + 4\text{H}^+ + 2e^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	1.23	
$\text{AuCl}_4^- + 3e^- \rightleftharpoons \text{Au}(s) + 4\text{Cl}^-$	1.002		$\text{MnO}_4^- + 4\text{H}^+ + 3e^- \rightleftharpoons \text{MnO}_2(s) + 2\text{H}_2\text{O}$	1.70	
	E° (V)	$E^{\circ'}$ (V)	$\text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51	
Hydrogen			$\text{MnO}_4^- + 2\text{H}_2\text{O} + 3e^- \rightleftharpoons \text{MnO}_2(s) + 4\text{OH}^-$	0.60	
$2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2(g)$	0.00000			E° (V)	$E^{\circ'}$ (V)
$\text{H}_2\text{O} + e^- \rightleftharpoons \frac{1}{2}\text{H}_2(g) + \text{OH}^-$	-0.828		Mercury		
	E° (V)	$E^{\circ'}$ (V)	$\text{Hg}^{2+} + 2e^- \rightleftharpoons \text{Hg}(\ell)$	0.8535	
Iodine			$2\text{Hg}^{2+} + 2e^- \rightleftharpoons \text{Hg}_2^{2+}$	0.911	
$\text{I}_2(s) + 2e^- \rightleftharpoons 2\text{I}^-$	0.5355		$\text{Hg}_2^{2+} + 2e^- \rightleftharpoons 2\text{Hg}(\ell)$	0.7960	
$\text{I}_3^- + 2e^- \rightleftharpoons 3\text{I}^-$	0.536		$\text{Hg}_2\text{Cl}_2(s) + 2e^- \rightleftharpoons 2\text{Hg}(\ell) + 2\text{Cl}^-$	0.2682	
$\text{HIO} + \text{H}^+ + 2e^- \rightleftharpoons \text{I}^- + \text{H}_2\text{O}$	0.985		$\text{HgO}(s) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{Hg}(\ell) + \text{H}_2\text{O}$	0.926	
$\text{IO}_3^- + 6\text{H}^+ + 5e^- \rightleftharpoons \frac{1}{2}\text{I}_2(s) + 3\text{H}_2\text{O}$	1.195		$\text{Hg}_2\text{Br}_2(s) + 2e^- \rightleftharpoons 2\text{Hg}(\ell) + 2\text{Br}^-$	0.1392	
$\text{IO}_3^- + 3\text{H}_2\text{O} + 6e^- \rightleftharpoons \text{I}^- + 6\text{OH}^-$	0.257		$\text{Hg}_2\text{I}_2(s) + 2e^- \rightleftharpoons 2\text{Hg}(\ell) + 2\text{I}^-$	-0.0405	

Table 1 Standard Reduction Potentials – *continued*(Harvey, D. 2000. *Modern Analytical Chemistry*, USA : McGraw-Hill.)

Molybdenum	E° (V)	$E^{\circ'}$ (V)	Selenium	E° (V)	$E^{\circ'}$ (V)
$\text{Mo}^{3+} + 3e^- \rightleftharpoons \text{Mo}(s)$	-0.2		$\text{Se}(s) + 2e^- \rightleftharpoons \text{Se}^{2-}$		-0.670 1 M NaOH
$\text{MoO}_2(s) + 4\text{H}^+ + 4e^- \rightleftharpoons \text{Mo}(s) + 2\text{H}_2\text{O}$	-0.152		$\text{Se}(s) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2\text{Se}(g)$	-0.115	
$\text{MoO}_4^{2-} + 4\text{H}_2\text{O} + 6e^- \rightleftharpoons \text{Mo}(s) + 8\text{OH}^-$	-0.913		$\text{H}_2\text{SeO}_3 + 4\text{H}^+ + 4e^- \rightleftharpoons \text{Se}(s) + 3\text{H}_2\text{O}$	0.74	
	E° (V)	$E^{\circ'}$ (V)	$\text{SeO}_4^{3-} + 4\text{H}^+ + e^- \rightleftharpoons \text{H}_2\text{SeO}_3 + \text{H}_2\text{O}$	1.151	
Nickel	E° (V)	$E^{\circ'}$ (V)	Silicon	E° (V)	$E^{\circ'}$ (V)
$\text{Ni}^{2+} + 2e^- \rightleftharpoons \text{Ni}(s)$	-0.257		$\text{SiF}_6^{2-} + 4e^- \rightleftharpoons \text{Si}(s) + 6\text{F}^-$	-1.37	
$\text{Ni}(\text{OH})_2(s) + 2e^- \rightleftharpoons \text{Ni}(s) + 2\text{OH}^-$	-0.72		$\text{SiO}_2(s) + 4\text{H}^+ + 4e^- \rightleftharpoons \text{Si}(s) + 2\text{H}_2\text{O}$	-0.909	
$\text{Ni}(\text{NH}_3)_6^{2+} + 2e^- \rightleftharpoons \text{Ni}(s) + 6\text{NH}_3$	-0.49		$\text{SiO}_2(s) + 8\text{H}^+ + 8e^- \rightleftharpoons \text{SiH}_4(g) + 2\text{H}_2\text{O}$	-0.516	
	E° (V)	$E^{\circ'}$ (V)	Silver	E° (V)	$E^{\circ'}$ (V)
Nitrogen	E° (V)	$E^{\circ'}$ (V)	$\text{Ag}^+ + e^- \rightleftharpoons \text{Ag}(s)$	0.7996	
$\text{N}_2(g) + 5\text{H}^+ + 4e^- \rightleftharpoons \text{N}_2\text{H}_5^+$	-0.23		$\text{AgBr}(s) + e^- \rightleftharpoons \text{Ag}(s) + \text{Br}^-$	0.071	
$\text{N}_2\text{O}(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{N}_2(g) + \text{H}_2\text{O}$	1.77		$\text{Ag}_2\text{C}_2\text{O}_4(s) + 2e^- \rightleftharpoons 2\text{Ag}(s) + \text{C}_2\text{O}_4^{2-}$	0.47	
$2\text{NO}(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{N}_2\text{O}(g) + \text{H}_2\text{O}$	1.59		$\text{AgCl}(s) + e^- \rightleftharpoons \text{Ag}(s) + \text{Cl}^-$	0.2223	
$\text{HNO}_2 + \text{H}^+ + e^- \rightleftharpoons \text{NO}(g) + \text{H}_2\text{O}$	0.996		$\text{AgI}(s) + e^- \rightleftharpoons \text{Ag}(s) + \text{I}^-$	-0.152	
$2\text{HNO}_2 + 4\text{H}^+ + 4e^- \rightleftharpoons \text{N}_2\text{O}(g) + 3\text{H}_2\text{O}$	1.297		$\text{Ag}_2\text{S}(s) + 2e^- \rightleftharpoons 2\text{Ag}(s) + \text{S}^{2-}$	-0.71	
$\text{NO}_3^- + 3\text{H}^+ + 2e^- \rightleftharpoons \text{HNO}_2 + \text{H}_2\text{O}$	0.94		$\text{Ag}(\text{NH}_3)_2^+ + e^- \rightleftharpoons \text{Ag}(s) + 2\text{NH}_3$	0.373	
	E° (V)	$E^{\circ'}$ (V)	Sodium	E° (V)	$E^{\circ'}$ (V)
Oxygen	E° (V)	$E^{\circ'}$ (V)	$\text{Na}^+ + e^- \rightleftharpoons \text{Na}(s)$	-2.713	
$\text{O}_2(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2\text{O}_2$	0.695			E° (V)	$E^{\circ'}$ (V)
$\text{O}_2(g) + 4\text{H}^+ + 4e^- \rightleftharpoons 2\text{H}_2\text{O}$	1.229		Strontium	E° (V)	$E^{\circ'}$ (V)
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2e^- \rightleftharpoons 2\text{H}_2\text{O}$	1.763		$\text{Sr}^{2+} + 2e^- \rightleftharpoons \text{Sr}(s)$	-2.89	
$\text{O}_2(g) + 2\text{H}_2\text{O} + 4e^- \rightleftharpoons 4\text{OH}^-$	0.401			E° (V)	$E^{\circ'}$ (V)
$\text{O}_3(g) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{O}_2(g) + \text{H}_2\text{O}$	2.07		Sulfur	E° (V)	$E^{\circ'}$ (V)
	E° (V)	$E^{\circ'}$ (V)	$\text{S}(s) + 2e^- \rightleftharpoons \text{S}^{2-}$	-0.407	
Phosphorus	E° (V)	$E^{\circ'}$ (V)	$\text{S}(s) + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2\text{S}$	0.144	
$\text{P}(s, \text{white}) + 3\text{H}^+ + 3e^- \rightleftharpoons \text{PH}_3(g)$	-0.063		$\text{S}_2\text{O}_6^{2-} + 4\text{H}^+ + 2e^- \rightleftharpoons 2\text{H}_2\text{SO}_3$	0.569	
$\text{H}_3\text{PO}_3 + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_3\text{PO}_2 + \text{H}_2\text{O}$	-0.499		$\text{S}_2\text{O}_8^{2-} + 2e^- \rightleftharpoons 2\text{SO}_4^{2-}$	1.96	
$\text{H}_3\text{PO}_4 + 2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_3\text{PO}_3 + \text{H}_2\text{O}$	-0.276		$\text{S}_4\text{O}_6^{2-} + 2e^- \rightleftharpoons 2\text{S}_2\text{O}_3^{2-}$	0.080	
	E° (V)	$E^{\circ'}$ (V)	$2\text{SO}_3^{2-} + 2\text{H}_2\text{O} + 2e^- \rightleftharpoons \text{S}_2\text{O}_4^{2-} + 4\text{OH}^-$	-1.13	
Platinum	E° (V)	$E^{\circ'}$ (V)	$2\text{SO}_3^{2-} + 3\text{H}_2\text{O} + 4e^- \rightleftharpoons \text{S}_2\text{O}_3^{2-} + 6\text{OH}^-$		-0.576 1 M NaOH
$\text{Pt}^{2+} + 2e^- \rightleftharpoons \text{Pt}(s)$	1.188		$2\text{SO}_4^{2-} + 4\text{H}^+ + 2e^- \rightleftharpoons \text{S}_2\text{O}_6^{2-} + 2\text{H}_2\text{O}$	-0.25	
$\text{PtCl}_4^{2-} + 2e^- \rightleftharpoons \text{Pt}(s) + 4\text{Cl}^-$	0.758		$\text{SO}_4^{2-} + \text{H}_2\text{O} + 2e^- \rightleftharpoons \text{SO}_3^{2-} + 2\text{OH}^-$	-0.936	
	E° (V)	$E^{\circ'}$ (V)	$\text{SO}_4^{2-} + 4\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2\text{SO}_3 + \text{H}_2\text{O}$	+0.172	
Potassium	E° (V)	$E^{\circ'}$ (V)	Thallium	E° (V)	$E^{\circ'}$ (V)
$\text{K}^+ + e^- \rightleftharpoons \text{K}(s)$	-2.924		$\text{Tl}^{3+} + 2e^- \rightleftharpoons \text{Tl}^+$	1.25	1 M HClO_4
	E° (V)	$E^{\circ'}$ (V)		0.77	1 M HCL
Ruthenium	E° (V)	$E^{\circ'}$ (V)	$\text{Tl}^{3+} + 3e^- \rightleftharpoons \text{Tl}(s)$	0.742	
$\text{Ru}^{3+} + e^- \rightleftharpoons \text{Ru}^{2+}$	0.249				
$\text{RuO}_2(s) + 4\text{H}^+ + 4e^- \rightleftharpoons \text{Ru}(s) + 2\text{H}_2\text{O}$	0.68				
$\text{Ru}(\text{NH}_3)_6^{3+} + e^- \rightleftharpoons \text{Ru}(\text{NH}_3)_6^{2+}$	0.10				
$\text{Ru}(\text{CN})_6^{3-} + e^- \rightleftharpoons \text{Ru}(\text{CN})_6^{4-}$	0.86				

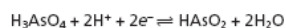
continued

Table 1 Standard Reduction Potentials – *continued*(Harvey, D. 2000. *Modern Analytical Chemistry*, USA : McGraw-Hill.)**Standard Reduction Potentials^a—continued**

Tin	E° (V)	$E^{\circ'}$ (V)	Uranium	E° (V)	$E^{\circ'}$ (V)
$\text{Sn}^{2+} + 2e^- \rightleftharpoons \text{Sn}(s)$	-0.19	1 M HCl	$\text{U}^{3+} + 3e^- \rightleftharpoons \text{U}(s)$	-1.66	
$\text{Sn}^{4+} + 2e^- \rightleftharpoons \text{Sn}^{2+}$	0.154	0.139 1 M HCl	$\text{U}^{4+} + e^- \rightleftharpoons \text{U}^{3+}$	-0.52	
			$\text{UO}_2^+ + 4\text{H}^+ + e^- \rightleftharpoons \text{U}^{4+} + 2\text{H}_2\text{O}$	0.27	
			$\text{UO}_2^{2+} + e^- \rightleftharpoons \text{UO}_2^+$	0.16	
			$\text{UO}_2^{2+} + 4\text{H}^+ + 2e^- \rightleftharpoons \text{U}^{4+} + 2\text{H}_2\text{O}$	0.327	
Titanium	E° (V)	$E^{\circ'}$ (V)	Vanadium	E° (V)	$E^{\circ'}$ (V)
$\text{Ti}^{2+} + 2e^- \rightleftharpoons \text{Ti}(s)$	-1.63		$\text{V}^{2+} + 2e^- \rightleftharpoons \text{V}(s)$	-1.13	
$\text{Ti}^{3+} + e^- \rightleftharpoons \text{Ti}^{2+}$	-0.37		$\text{V}^{3+} + e^- \rightleftharpoons \text{V}^{2+}$	-0.255	
			$\text{VO}^{2+} + 2\text{H}^+ + e^- \rightleftharpoons \text{V}^{3+} + \text{H}_2\text{O}$	0.337	
			$\text{VO}_2^+ + 2\text{H}^+ + e^- \rightleftharpoons \text{VO}^{2+} + \text{H}_2\text{O}$	1.000	
Tungsten	E° (V)	$E^{\circ'}$ (V)	Zinc	E° (V)	$E^{\circ'}$ (V)
$\text{WO}_2(s) + 4\text{H}^+ + 4e^- \rightleftharpoons \text{W}(s) + 2\text{H}_2\text{O}$	-0.119		$\text{Zn}^{2+} + 2e^- \rightleftharpoons \text{Zn}(s)$	-0.7618	
$\text{WO}_3(s) + 6\text{H}^+ + 6e^- \rightleftharpoons \text{W}(s) + 3\text{H}_2\text{O}$	-0.090		$\text{Zn}(\text{OH})_4^{2-} + 2e^- \rightleftharpoons \text{Zn}(s) + 4\text{OH}^-$	-1.285	
			$\text{Zn}(\text{NH}_3)_4^{2+} + 2e^- \rightleftharpoons \text{Zn}(s) + 4\text{NH}_3$	-1.04	
			$\text{Zn}(\text{CN})_4^{2-} + 2e^- \rightleftharpoons \text{Zn}(s) + 4\text{CN}^-$	-1.34	

Source: Values are compiled from the following sources: Bard, A. J.; Parsons, R.; Jordon, J., eds. *Standard Potentials in Aqueous Solutions*. Dekker: New York, 1985; Milazzo, G.; Caroli, S.; Sharma, V. K. *Tables of Standard Electrode Potentials*. Wiley: London, 1978; Swift, E. H.; Butler, E. A. *Quantitative Measurements and Chemical Equilibria*. Freeman: New York, 1972.

^aSolids, gases, and liquids are identified; all other species are aqueous. Reduction reactions in acidic solution are written using H^+ instead of H_3O^+ . Reactions may be rewritten by replacing H^+ with H_3O^+ and adding one molecule of H_2O to the opposite side of the reaction for each H^+ ; thus



becomes



Conditions for formal potentials ($E^{\circ'}$) are listed next to the potential.