NORGES TEKNISK-
NATURVITENSKAPELIGE UNIVERSITET
INSTITUTT FOR KJEMI

EKSAMEN I GENERELL KJEMI, KJ1000
Mandag 19. desember 2011, 09:00 – 14:00

Eksamenssettet består av: Oppgavetekst (2 sider i tillegg til denne) og vedlegg (5 sider)

I vedlegget er periodisk system, oversikt over diverse ligninger, termodynamiske data og standard reduksjonspotensialer. Dessuten er flg. konstanter oppgitt:
R = 8,314 J/(mol·K), R = 0,08206 L·atm/(mol·K), F = 96485 C/mol

Hjelpemidler: Kalkulator (godkjente typer er: Citizen SR-270X eller Hewlett Packard HP30S)

Faglærer og kontakt under eksamen: Kolbjørn Hagen, tlf: 91348136

Sensur: Senest 13. januar 2012

1. a (2p) Balanser følgende reaksjonsligninger:
$Mn^{2+}(aq) + PbO_2(s) \rightarrow MnO_4^-(aq) + Pb^{2+}(aq)$ (sur vannoppløsning)
$CN^-(aq) + MnO_4^-(aq) \rightarrow CNO^-(aq) + MnO_2(s)$ (basisk vannoppløsning)

b (3p) Bruk VSEPR-teorien til å forutsi strukturen av SF_4, XeF_4 og CF_4.
Vil disse molekylene ha et permanent dipolmoment? Begrunn svaret

c (2p) Angi antall protoner, nøytroner og elektroner i $^{35}Cl^-$ og ^{15}N
Angi elektronkonfigurasjonen til fosfor (P) og avgjør om dette er et paramagnetisk eller diamagnetisk grunnstoff

d (3p) Hvilke nukleider (kjernepartikler) dannes ved følgende radioaktive prosesser? Skriv reaksjonsligninger for det som skjer:
1. Uran-238 sender ut en α-partikkel
2. Nitrogen-15 og hydrogen-1 reagerer og en α-partikkel dannes sammen med en ny isotop
3. Elektroninnfanging ("electron capture") skjer hos ^{201}Hg

e (2p) Hvordan endres størrelsen på atomene innenfor:
1. en periode?
2. en hovedgruppe?
Bruk dette til å sette opp følgende atomer i rekkefølge etter økende størrelse: Cl, Mg, Li, K

f (2p) Skisser fasediagrammet til vann og angi de områdene hvor is, vann og vanndamp er stabile. Angi på diagrammet posisjonen til trippelpunktet og til kritisk punkt. Beskriv på diagrammet hvor is og vanndamp er i likevekt.

g (3p) En prøve av askorbinsyre (Vitamin C) inneholder 4,092 g karbon, 0,458 g hydrogen og 5,450 g oksygen. Hvilken empirisk formel gir dette? 2,50 g askorbinsyre løses opp i 100,0 g vann og frysepunktet for oppløsningen måles deretter til -0,264 °C. Hvilken molar masse kan du ut fra dette beregne for askorbinsyre? Hva er molekylformelen for askorbinsyre?
Oppgitt: $K_f(H_2O) = 1,86$ °C/molal

2. a (2p) Beregn pH i en 0,010 M vannoppløsning av H_2SO_4.
Anta at svovelsyre er en sterk syre i første trinn.
Oppgitt: $K_a (HSO_4^-) = 1,2 \cdot 10^{-2}$.

b (2p) Hva blir pH dersom 1,00 L 0,10 M $NaHSO_4$-oppløsning tilsettes 14,2 g Na_2SO_4? Hva kaller vi normalt en slik oppløsning?

c (1p) Hvor mange gram kalsium sulfat, $CaSO_4$, vil løses i 1,00 L rent vann?
Oppgitt: $K_{sp}(CaSO_4) = 7,10 \cdot 10^{-5}$

3. En galvanisk celle beskrives med følgende celledíagram:

$$Pt(s) \mid Cl_2(g),\ 1{,}00\ atm \mid Cl^-(aq),\ 0{,}050M \parallel Cu^{2+}(aq),\ 1{,}00\ M \mid Cu(s)$$

a (2p) Hvilken reaksjon er spontan i cellen og hvilke spenning måles ved 25 °C? Hvilken elektrode er katode?

b (2p) Beregn verdien av likevektskonstanten (K) for cellereaksjonen og beregn deretter Gibbs fri energi (ΔG^o) for denne reaksjonen. Begge beregninger skal gjøres ved hjelp av utleverte elektrokjemiske data.

c (2p) Beregn ΔH^o og ΔS^o for cellereaksjonen ved hjelp av utleverte termodynamiske data.

d (2p) Hvilken verdi for likevektskonstanten (K) for denne reaksjonen ved 298 K kan bestemmes ut fra termodynamiske data? Hvis reaksjonen skjedde ved 90°C, ville du da vente at likevektskonstanten var større eller mindre enn ved 25 °C? Svaret skal begrunnes. Kontroller deretter svaret ditt ved å beregne verdien av K ved 90 °C

4. Hydrogenperoksid spaltes til vann og oksygen etter slik reaksjon:

$$H_2O_2(l) \rightarrow H_2O(l) + \tfrac{1}{2}\, O_2(g)$$

Følgende data ble målt for denne spaltingen ved 25 °C

Tid (s)	0	100,0	200,0	500,0	1000,0	1500,0
$[H_2O_2]$ (M)	0,500	0,460	0,424	0,330	0,218	0,144

a (2p) Hva er reaksjonsorden for spaltingen av H_2O_2, og hvilken verdi har fartskonstanten, k?

b (2p) Hva er halveringstiden for spaltingen av H_2O_2 og hvor lang tid tar det før konsentrasjonen av hydrogenperoksid har sunket til 5 % av startverdien?

c (2p) For å få spaltingen til å gå fortere, økes temperaturen til 40 °C. Da måles en verdi på $k = 4{,}75 \cdot 10^{-3}\ s^{-1}$. Hva er aktiveringsenergien, E_a, til spaltingen? Finnes det andre metoder enn endring av temperaturen som kan endre reaksjonsfarten? Forklar i så fall hvordan dette kan gjøres.

Metals | Metalloids | Nonmetals

	Main groups 1A[a] 1	2A 2	Transition metals 3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	Main groups 3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											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 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	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 72.64	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 95.96	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	89 Ac [227.03]	104 Rf [261.11]	105 Db [262.11]	106 Sg [266.12]	107 Bh [264.12]	108 Hs [269.13]	109 Mt [268.14]	110 Ds [271]	111 Rg [272]	112* [277]		114 [289]		116 [292]		

Lanthanide series	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
Actinide series	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]	103 Lr [262.11]

[a] The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1, 2, etc.) are those recommended by the International Union of Pure and Applied Chemistry.

The names and symbols for elements 112 and above have not yet been decided.

Atomic masses in brackets are the masses of the longest-lived or most important isotope of radioactive elements.

*Element 112 has a proposed name of Copernicium which is, at the time of this publication, under review by IUPAC.

Selected Key Equations

Density (1.6)

$$d = \frac{m}{V}$$

Solution Dilution (4.4)

$$M_1V_1 = M_2V_2$$

Ideal Gas Law (5.4)

$$PV = nRT$$

Dalton's Law (5.6)

$$P_{total} = P_a + P_b + P_c + \ldots$$

Mole Fraction (5.6)

$$X_a = \frac{n_a}{n_{total}}$$

Average Kinetic Energy (5.8)

$$KE_{avg} = \frac{3}{2}RT$$

Root Mean Square Velocity (5.8)

$$u_{rms} = \sqrt{\frac{3\,RT}{\mathcal{M}}}$$

Effusion (5.9)

$$\frac{\text{rate A}}{\text{rate B}} = \sqrt{\frac{\mathcal{M}_B}{\mathcal{M}_A}}$$

Van der Waals Equation (5.10)

$$\left[P + a\left(\frac{n}{V}\right)^2\right] \times [V - nb] = nRT$$

Kinetic Energy (6.2)

$$KE = \frac{1}{2}mv^2$$

Internal Energy (6.3)

$$\Delta E = q + w$$

Heat Capacity (6.4)

$$q = m \times C_s \times \Delta T$$

Pressure-Volume Work (6.4)

$$w = -P\,\Delta V$$

Change in Enthalpy (6.6)

$$\Delta H = \Delta E + P\,\Delta V$$

Standard Enthalpy of Reaction (6.9)

$$\Delta H^\circ_{rxn} = \sum n_p\,\Delta H^\circ_f \text{ (products)} - \sum n_r\,\Delta H^\circ_f \text{ (reactants)}$$

Frequency and Wavelength (7.2)

$$\nu = \frac{c}{\lambda}$$

Energy of a Photon (7.2)

$$E = h\nu$$

$$E = \frac{hc}{\lambda}$$

De Broglie Relation (7.4)

$$\lambda = \frac{h}{mv}$$

Heisenberg's Uncertainty Principle (7.4)

$$\Delta x \times m\,\Delta v \geq \frac{h}{4\pi}$$

Energy of Hydrogen Atom Levels (7.5)

$$E_n = -2.18 \times 10^{-18}\,\text{J}\left(\frac{1}{n^2}\right) \quad (n = 1, 2, 3 \ldots)$$

Coulomb's Law (8.3)

$$E = \frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{r}$$

Dipole Moment (9.6)

$$\mu = qr$$

Clausius–Clapeyron Equation (11.5)

$$\ln P_{vap} = \frac{-\Delta H_{vap}}{RT} + \ln \beta$$

$$\ln\frac{P_2}{P_1} = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Henry's Law (12.4)

$$S_{gas} = k_H P_{gas}$$

Raoult's Law (12.6)

$$P_{solution} = X_{solvent}P^\circ_{solvent}$$

Freezing Point Depression (12.6)

$$\Delta T_f = m \times K_f$$

Boiling Point Elevation Constant (12.6)

$$\Delta T_b = m \times K_b$$

Osmotic Pressure (12.6)

$$\Pi = MRT$$

The Rate Law (13.3)

$$\text{Rate} = k[A]^n \quad \text{(single reactant)}$$

$$\text{Rate} = k[A]^m[B]^n \quad \text{(multiple reactants)}$$

Integrated Rate Laws and Half-Life (13.4)

Order	Integrated Rate Law	Half-Life Expression
0	$[A]_t = -kt + [A]_0$	$t_{1/2} = \frac{[A]_0}{2k}$
1	$\ln[A]_t = -kt + \ln[A]_0$	$t_{1/2} = \frac{0.693}{k}$
2	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$t_{1/2} = \frac{1}{k[A]_0}$

Arrhenius Equation (13.5)

$$k = A\,e^{\frac{-E_a}{RT}}$$

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A \quad \text{(linearized form)}$$

$$k = p\,z\,e^{\frac{-E_a}{RT}} \quad \text{(collision theory)}$$

K_c and K_p (14.4)

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

pH Scale (15.5)

$$\text{pH} = -\log[H_3O^+]$$

Henderson–Hasselbalch Equation (16.2)

$$\text{pH} = \text{p}K_a + \log\frac{[\text{base}]}{[\text{acid}]}$$

Entropy (17.3)

$$S = k\ln W$$

Change in the Entropy of the Surroundings (17.4)

$$\Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$$

Change in Gibbs Free Energy (17.5)

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

The Change in Free Energy: Nonstandard Conditions (17.8)

$$\Delta G_{rxn} = \Delta G^\circ_{rxn} + RT\ln Q$$

ΔG°_{rxn} and K (17.9)

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

Temperature Dependence of the Equilibrium Constant (17.9)

$$\ln K = -\frac{\Delta H^\circ_{rxn}}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ_{rxn}}{R}$$

ΔG° and E°_{cell} (18.5)

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

E°_{cell} and K (18.5)

$$E^\circ_{cell} = \frac{0.0592\text{ V}}{n}\log K$$

Nerst Equation (18.6)

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

Einstein's Energy-Mass Equation (19.8)

$$E = mc^2$$

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol • K)
$B_2H_6(g)$	36.4	87.6	232.1
$B_2O_3(s)$	−1273.5	−1194.3	54.0
$H_3BO_3(s)$	−1094.3	−968.9	90.0
Bromine			
$Br(g)$	111.9	82.4	175.0
$Br_2(l)$	0	0	152.2
$Br_2(g)$	30.9	3.1	245.5
$Br^-(aq)$	−121.4	−102.8	80.71
$HBr(g)$	−36.3	−53.4	198.7
Cadmium			
$Cd(s)$	0	0	51.8
$Cd(g)$	111.8	77.3	167.7
$Cd^{2+}(aq)$	−75.9	−77.6	−73.2
$CdCl_2(s)$	−391.5	−343.9	115.3
$CdO(s)$	−258.4	−228.7	54.8
$CdS(s)$	−161.9	−156.5	64.9
$CdSO_4(s)$	−933.3	−822.7	123.0
Calcium			
$Ca(s)$	0	0	41.6
$Ca(g)$	177.8	144.0	154.9
$Ca^{2+}(aq)$	−542.8	−553.6	−53.1
$CaC_2(s)$	−59.8	−64.9	70.0
$CaCO_3(s)$	−1207.6	−1129.1	91.7
$CaCl_2(s)$	−795.4	−748.8	108.4
$CaF_2(s)$	−1228.0	−1175.6	68.5
$CaH_2(s)$	−181.5	−142.5	41.4
$Ca(NO_3)_2(s)$	−938.2	−742.8	193.2
$CaO(s)$	−634.9	−603.3	38.1
$Ca(OH)_2(s)$	−985.2	−897.5	83.4
$CaSO_4(s)$	−1434.5	−1322.0	106.5
$Ca_3(PO_4)_2(s)$	−4120.8	−3884.7	236.0
Carbon			
$C(s$, graphite)	0	0	5.7
$C(s$, diamond)	1.88	2.9	2.4
$C(g)$	716.7	671.3	158.1
$CH_4(g)$	−74.6	−50.5	186.3
$CH_3Cl(g)$	−81.9	−60.2	234.6
$CH_2Cl_2(g)$	−95.4		270.2
$CH_2Cl_2(l)$	−124.2	−63.2	177.8
$CHCl_3(l)$	−134.1	−73.7	201.7
$CCl_4(g)$	−95.7	−62.3	309.7
$CCl_4(l)$	−128.2	−66.4	216.4
$CH_2O(g)$	−108.6	−102.5	218.8
CH_2O_2 (l, formic acid)	−425.0	−361.4	129.0
CH_3NH_2 (g, methylamine)	−22.5	32.7	242.9
$CH_3OH(l)$	−238.6	−166.6	126.8
$CH_3OH(g)$	−201.0	−162.3	239.9
$C_2H_2(g)$	227.4	209.9	200.9
$C_2H_4(g)$	52.4	68.4	219.3
$C_2H_6(g)$	−84.68	−32.0	229.2
$C_2H_5OH(l)$	−277.6	−174.8	160.7
$C_2H_5OH(g)$	−234.8	−167.9	281.6
C_2H_3Cl (g, vinyl chloride)	37.2	53.6	264.0
$C_2H_4Cl_2$ (l, dichloroethane)	−166.8	−79.6	208.5
C_2H_4O (g, acetaldehyde	−166.2	−133.0	263.8
$C_2H_4O_2$ (l, acetic acid)	−484.3	−389.9	159.8
$C_3H_8(g)$	−103.85	−23.4	270.3
C_3H_6O (l, acetone)	−248.4	−155.6	199.8
C_3H_7OH (l, isopropanol)	−318.1		181.1
$C_4H_{10}(l)$	−147.3	−15.0	231.0
$C_4H_{10}(g)$	−125.7	−15.71	310.0
$C_6H_6(l)$	49.1	124.5	173.4
$C_6H_5NH_2$ (l, aniline)	31.6	149.2	191.9
C_6H_5OH (s, phenol)	−165.1	−50.4	144.0
$C_6H_{12}O_6$ (s, glucose)	−1273.3	−910.4	212.1
$C_{10}H_8$ (s, naphthalene)	78.5	201.6	167.4
$C_{12}H_{22}O_{11}$ (s, sucrose)	−2226.1	−1544.3	360.24
$CO(g)$	−110.5	−137.2	197.7
$CO_2(g)$	−393.5	−394.4	213.8
$CO_2(aq)$	−413.8	−386.0	117.6
$CO_3^{2-}(aq)$	−677.1	−527.8	−56.9
$HCO_3^-(aq)$	−692.0	−586.8	91.2
$H_2CO_3(aq)$	−699.7	−623.2	187.4
$CN^-(aq)$	151	166	118
$HCN(l)$	108.9	125.0	112.8
$HCN(g)$	135.1	124.7	201.8
$CS_2(l)$	89.0	64.6	151.3
$CS_2(g)$	116.7	67.1	237.8
$COCl_2(g)$	−219.1	−204.9	283.5
$C_{60}(s)$	2327.0	2302.0	426.0
Cesium			
$Cs(s)$	0	0	85.2
$Cs(g)$	76.5	49.6	175.6
$Cs^+(aq)$	−258.0	−292.0	132.1
$CsBr(s)$	−400	−387	117
$CsCl(s)$	−438	−414	101.2
$CsF(s)$	−553.5	−525.5	92.8
$CsI(s)$	−342	−337	127
Chlorine			
$Cl(g)$	121.3	105.3	165.2
$Cl_2(g)$	0	0	223.1
$Cl^-(aq)$	−167.1	−131.2	56.6
$HCl(g)$	−92.3	−95.3	186.9
HCl(aq)	−167.2	−131.2	56.5

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
$ClO_2(g)$	102.5	120.5	256.8
$Cl_2O(g)$	80.3	97.9	266.2
Chromium			
$Cr(s)$	0	0	23.8
$Cr(g)$	396.6	351.8	174.5
$Cr^{3+}(aq)$	−1971		
$CrO_4^{2-}(aq)$	−872.2	−717.1	44
$Cr_2O_3(s)$	−1139.7	−1058.1	81.2
$Cr_2O_7^{2-}(aq)$	−1476	−1279	238
Cobalt			
$Co(s)$	0	0	30.0
$Co(g)$	424.7	380.3	179.5
$CoO(s)$	−237.9	−214.2	53.0
$Co(OH)_2(s)$	−539.7	−454.3	79.0
Copper			
$Cu(s)$	0	0	33.2
$Cu(g)$	337.4	297.7	166.4
$Cu^+(aq)$	51.9	50.2	−26
$Cu^{2+}(aq)$	64.9	65.5	−98
$CuCl(s)$	−137.2	−119.9	86.2
$CuCl_2(s)$	−220.1	−175.7	108.1
$CuO(s)$	−157.3	−129.7	42.6
$CuS(s)$	−53.1	−53.6	66.5
$CuSO_4(s)$	−771.4	−662.2	109.2
$Cu_2O(s)$	−168.6	−146.0	93.1
$Cu_2S(s)$	−79.5	−86.2	120.9
Fluorine			
$F(g)$	79.38	62.3	158.75
$F_2(g)$	0	0	202.79
$F^-(aq)$	−335.35	−278.8	−13.8
$HF(g)$	−273.3	−275.4	173.8
Gold			
$Au(s)$	0	0	47.4
$Au(g)$	366.1	326.3	180.5
Helium			
$He(g)$	0	0	126.2
Hydrogen			
$H(g)$	218.0	203.3	114.7
$H^+(aq)$	0	0	0
$H^+(g)$	1536.3	1517.1	108.9
$H_2(g)$	0	0	130.7
Iodine			
$I(g)$	106.76	70.2	180.79
$I_2(s)$	0	0	116.14
$I_2(g)$	62.42	19.3	260.69
$I^-(aq)$	−56.78	−51.57	106.45
$HI(g)$	26.5	1.7	206.6
Iron			
$Fe(s)$	0	0	27.3
$Fe(g)$	416.3	370.7	180.5
$Fe^{2+}(aq)$	−87.9	−84.94	113.4
$Fe^{3+}(aq)$	−47.69	−10.54	293.3
$FeCO_3(s)$	−740.6	−666.7	92.9
$FeCl_2(s)$	−341.8	−302.3	118.0
$FeCl_3(s)$	−399.5	−334.0	142.3
$FeO(s)$	−272.0	−255.2	60.75
$Fe(OH)_3(s)$	−823.0	−696.5	106.7
$FeS_2(s)$	−178.2	−166.9	52.9
$Fe_2O_3(s)$	−824.2	−742.2	87.4
$Fe_3O_4(s)$	−1118.4	−1015.4	146.4
Lead			
$Pb(s)$	0	0	64.8
$Pb(g)$	195.2	162.2	175.4
$Pb^{2+}(aq)$	0.92	−24.4	18.5
$PbBr_2(s)$	−278.7	−261.9	161.5
$PbCO_3(s)$	−699.1	−625.5	131.0
$PbCl_2(s)$	−359.4	−314.1	136.0
$PbI_2(s)$	−175.5	−173.6	174.9
$Pb(NO_3)_2(s)$	−451.9		
$PbO(s)$	−217.3	−187.9	68.7
$PbO_2(s)$	−277.4	−217.3	68.6
$PbS(s)$	−100.4	−98.7	91.2
$PbSO_4(s)$	−920.0	−813.0	148.5
Lithium			
$Li(s)$	0	0	29.1
$Li(g)$	159.3	126.6	138.8
$Li^+(aq)$	−278.47	−293.3	12.24
$LiBr(s)$	−351.2	−342.0	74.3
$LiCl(s)$	−408.6	−384.4	59.3
$LiF(s)$	−616.0	−587.7	35.7
$LiI(s)$	−270.4	−270.3	86.8
$LiNO_3(s)$	−483.1	−381.1	90.0
$LiOH(s)$	−487.5	−441.5	42.8
$Li_2O(s)$	−597.9	−561.2	37.6
Magnesium			
$Mg(s)$	0	0	32.7
$Mg(g)$	147.1	112.5	148.6
$Mg^{2+}(aq)$	−467.0	−455.4	−137
$MgCl_2(s)$	−641.3	−591.8	89.6
$MgCO_3(s)$	−1095.8	−1012.1	65.7
$MgF_2(s)$	−1124.2	−1071.1	57.2
$MgO(s)$	−601.6	−569.3	27.0
$Mg(OH)_2(s)$	−924.5	−833.5	63.2
$MgSO_4(s)$	−1284.9	−1170.6	91.6
$Mg_3N_2(s)$	−461	−401	88
Manganese			
$Mn(s)$	0	0	32.0
$Mn(g)$	280.7	238.5	173.7
$Mn^{2+}(aq)$	−219.4	−225.6	−78.8
$MnO(s)$	−385.2	−362.9	59.7

(continued on the next page)

D. Standard Electrode Potentials at 25 °C

Half-Reaction	$E°$ (V)
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	2.87
$O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O(l)$	2.08
$Ag^{2+}(aq) + e^- \longrightarrow Ag^+(aq)$	1.98
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	1.82
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O(l)$	1.78
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O(l)$	1.69
$MnO_4^-(aq) + 4H^+(aq) + 3e^- \longrightarrow MnO_2(s) + 2H_2O(l)$	1.68
$2HClO(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(g) + 2H_2O(l)$	1.61
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$	1.51
$Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$	1.50
$2BrO_3^-(aq) + 12H^+(aq) + 10e^- \longrightarrow Br_2(l) + 6H_2O(l)$	1.48
$PbO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Pb^{2+}(aq) + 2H_2O(l)$	1.46
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	1.33
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$	1.23
$MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O(l)$	1.21
$IO_3^-(aq) + 6H^+(aq) + 5e^- \longrightarrow \frac{1}{2}I_2(aq) + 3H_2O(l)$	1.20
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	1.09
$AuCl_4^-(aq) + 3e^- \longrightarrow Au(s) + 4Cl^-(aq)$	1.00
$VO_2^+(aq) + 2H^+(aq) + e^- \longrightarrow VO^{2+}(aq) + H_2O(l)$	1.00
$HNO_2(aq) + H^+(aq) + e^- \longrightarrow NO(g) + 2H_2O(l)$	0.98
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O(l)$	0.96
$ClO_2(g) + e^- \longrightarrow ClO_2^-(aq)$	0.95
$2Hg^{2+}(aq) + 2e^- \longrightarrow 2Hg_2^{2+}(aq)$	0.92
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	0.80
$Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$	0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	0.77
$PtCl_4^{2-}(aq) + 2e^- \longrightarrow Pt(s) + 4Cl^-(aq)$	0.76
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	0.70
$MnO_4^-(aq) + e^- \longrightarrow MnO_4^{2-}(aq)$	0.56
$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$	0.54
$Cu^+(aq) + e^- \longrightarrow Cu(s)$	0.52
$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	0.40
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	0.34
$BiO^+(aq) + 2H^+(aq) + 3e^- \longrightarrow Bi(s) + H_2O(l)$	0.32
$Hg_2Cl_2(s) + 2e^- \longrightarrow 2Hg(l) + 2Cl^-(aq)$	0.27
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	0.22
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow H_2SO_3(aq) + H_2O(l)$	0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	0.16
$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$	0.15
$S(s) + 2H^+(aq) + 2e^- \longrightarrow H_2S(g)$	0.14
$AgBr(s) + e^- \longrightarrow Ag(s) + Br^-(aq)$	0.071
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Fe^{3+}(aq) + 3e^- \longrightarrow Fe(s)$	−0.036
$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$AgI(s) + e^- \longrightarrow Ag(s) + I^-(aq)$	−0.15
$N_2(g) + 5H^+(aq) + 4e^- \longrightarrow N_2H_5^+(aq)$	−0.23
$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$	−0.23
$Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.36
$Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.45
$2CO_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2C_2O_4(aq)$	−0.49
$Cr^{3+}(aq) + e^- \longrightarrow Cr^{2+}(aq)$	−0.50
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	−0.73
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$	−1.66
$H_2(g) + 2e^- \longrightarrow 2H^-(aq)$	−2.23
$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$	−2.37
$La^{3+}(aq) + 3e^- \longrightarrow La(s)$	−2.38
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$	−2.76
$Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.92
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.04

E. Vapor Pressure of Water at Various Temperatures

T (°C)	P (torr)	T (°C)	P (torr)	T (°C)	P (torr)	T (°C)	P (torr)
0	4.58	21	18.65	35	42.2	92	567.0
5	6.54	22	19.83	40	55.3	94	610.9
10	9.21	23	21.07	45	71.9	96	657.6
12	10.52	24	22.38	50	92.5	98	707.3
14	11.99	25	23.76	55	118.0	100	760.0
16	13.63	26	25.21	60	149.4	102	815.9
17	14.53	27	26.74	65	187.5	104	875.1
18	15.48	28	28.35	70	233.7	106	937.9
19	16.48	29	30.04	80	355.1	108	1004.4
20	17.54	30	31.82	90	525.8	110	1074.6