NORGES TEKNISK-
NATURVITENSKAPELIGE UNIVERSITET
INSTITUTT FOR KJEMI

EKSAMEN I GENERELL KJEMI, KJ1000
Mandag 7. juni 2010, 09:00 – 14:00

Eksamenssettet består av: Oppgavetekst (2 sider i tillegg til denne) og vedlegg (4 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 (må ikke kunne kommunisere med andre)

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Sensur: 28. juni 2010

1. a (2p) Hva er elektronkonfigurasjonen i grunntilstanden til atomene med atomnummer 8, 11 og 20? Er noen av disse atomene paramagnetisk? Svaret skal begrunnes

b (2p) Gjør rede for hvordan atomradiene endres innenfor:
i) en periode
ii) en hovedgruppe
Bruk dette til å sette opp grunnstoffene bor, fluor, kalium og litium i rekkefølge etter økende atomradius.

c (1p) Angi oksydasjonstallet for kloratomet i:
HCl, HOCl, HO_2Cl og $KClO_3$

d (2p) Balanser følgende reaksjonsligninger (sur vannoppløsning):

$MnO_4^-(aq) + SO_3^{2-}(aq) \rightarrow MnO_2(s) + SO_4^{2-}(aq)$
$Fe_3O_4(s) + ClO^-(aq) \rightarrow FeO_4^{2-}(aq) + Cl^-(aq)$

e (1p) Kalsium-45-isotopen er radioaktiv og spaltes under utsendelse av en β-partikkel. Hvilken isotop dannes under denne spaltingen? Skriv en reaksjonsligning for prosessen

f (2p) Etylenglykol, $C_2H_6O_2$, brukes som frostvæske i biler. Hvilket frysepunkt vil en blanding av 1.00 L vann og 1.00 L etylenglykol ha? Tettheten til vann er 1.00 kg/L og tettheten til etylenglykol er 1.11 kg/L. Oppgitt: $K_f(H_2O) = 1.86$ K kg/mol

2. a (1p) Du skal lage en buffer med pH = 7.50 og kan velge mellom følgende tre svake syrer:
HX: $K_a(HX) = 4.0 \cdot 10^{-7}$
HY: $K_a(HY) = 3.2 \cdot 10^{-8}$
HZ: $K_a(HZ) = 5.0 \cdot 10^{-9}$
Hvilken av de tre syrene vil du velge for å lage bufferen? Begrunn svaret

b (2p) 0.0100 mol HX løses opp i vann og fortynnes til 100.0 mL
Hva blir pH i denne oppløsningen?

c (2p) 0.0040 mol fast NaOH tilsettes oppløsningen i b (anta ingen volumendring)
Hva blir pH nå?

3. En galvanisk celle kan beskrives med følgende celledíagram:

$Cu(s) \mid Cu(NO_3)_2\ (aq),\ 1.00\ M \parallel AgNO_3\ (aq),\ 0.010M \mid Ag(s)$

a (2p) Hvilken reaksjon er spontan i cellen og hva er cellespenning ved 25 °C? Hvilken elektrode er anode?

b (1p) Halvcellen som inneholder $Cu(NO_3)_2$ (aq) fortynnes med vann slik at konsentrasjonen av Cu^{2+} reduseres til 0.010 M. Hva blir cellespenningen nå?

c (2p) Hvor stor er likevektskonstanten for cellereaksjonen ved 25 °C, og hva blir endringen i Gibbs fri energi for denne reaksjonen?

4. Fosgen, $COCl_2$, er en svært giftig gass som ble brukt som stridsgass i første verdenskrig. Den kan framstilles etter følgende reaksjon

$$C(grafitt) + CO_2(g) + 2Cl_2(g) \rightarrow 2COCl_2(g)$$

a (3p) Beregn ΔH^o, ΔS^o og ΔG^o for denne reaksjonen fra termodynamiske data Er fortegnet for ΔS^o slik du ville ventet det? Svaret skal begrunnes.

b (2p) Beregne likevektskonstanten for reaksjonen ved 298 K og ved 1000 K. Angi eventuelle antagelser du måtte gjøre under beregningene.

c (1p) Ved likevekt ved 1000 K måler vi et partialtrykk for CO_2 på 0.50 atm og for Cl_2 på 1.00 atm. Hvor stort partialtrykk har $COCl_2$ ved likevekt?

d (2p) Hvordan vil mengde $COCl_2$ som dannes endres dersom:

1. beholderens volum øker
2. mer grafitt tilsettes (se bort fra eventuelle volumendringer)
3. det tilsettes en katalysator som øker spaltingshastigheten for $COCl_2$
4. det tilsettes en inert gass (for eksempel argon)

5. N_2O_5 vil i gassfase spaltes til N_2O_4 og O_2. Dette er en første ordens reaksjon og hastighetskonstanten måles ved 55 °C til $k = 1.42 \cdot 10^{-2}\ s^{-1}$.

a (1p) Hva er halveringstiden for spaltingen av N_2O_5?

b (1p) Hvis partialtrykket av N_2O_5 ved starten av reaksjonen er 1.00 atm ved 55 °C, hvor lang tid vil det ta før partialtrykket er redusert til 0.15 atm?

c (2p) Ved 100 °C måles hastighetskonstanten for reaksjonen til $k = 1.19\ s^{-1}$. Beregn ut fra dette hvor stor aktiveringsenergien for spaltingen av N_2O_5 er.

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 65.41	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 95.94	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 173.04	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.

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)
$\chi_a = \frac{n_a}{n_{total}}$

Average Kinetic Energy (5.8)
$KE_{avg} = \frac{3}{2}RT$

Root Mean Square Velocity (5.8)
$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$

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 (6.1)
$KE = \frac{1}{2}mv^2$

Internal Energy (6.2)
$\Delta E = q + w$

Heat Capacity (6.3)
$q = m \times C_s \times \Delta T$

Pressure-Volume Work (6.3)
$w = -P\,\Delta V$

Change in Enthalpy (6.5)
$\Delta H = \Delta E + P\,\Delta V$

Standard Enthalpy of Reaction (6.8)
$\Delta H^\circ_{rxn} = \sum n_p\,\Delta H^\circ_f \text{ (products)} - \sum n_r\,\Delta H^\circ_f \text{ (reactants)}$

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 (9.2)
$E = \frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{r}$

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)
$P_{solution} = \chi_{solvent} P^\circ_{solvent}$

Freezing Point Depression (12.7)
$\Delta T_f = m \times K_f$

Boiling Point Elevation Constant (12.7)
$\Delta T_b = m \times K_b$

Osmotic Pressure (12.7)
$\Pi = MRT$

The Rate Law (13.3)
$\text{Rate} = k[A]^n$ (single reactant)
$\text{Rate} = k[A]^m[B]^n$ (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)
$k = A e^{\frac{-E_a}{RT}}$
$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$ (linearized form)
$k = pz e^{\frac{-E_a}{RT}}$ (collision theory)

K_c and K_p (14.4)
$K_p = K_c(RT)^{\Delta n}$

pH Scale (15.5)
$pH = -\log[H_3O^+]$

Henderson-Hasselbalch Equation (16.2)
$pH = pK_a + \log\frac{[\text{base}]}{[\text{acid}]}$

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 Gibb's 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)
$E^\circ_{cell} = \frac{0.0592\,\text{V}}{n}\log K$

Nernst 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)
$BCl_3(g)$	−403.8	−388.7	290.1
$BF_3(g)$	−1136.0	−1119.4	254.4
$B_2H_6(g)$	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
$C_8H_{18}(l)$	−250.1		
$C_{10}H_8$(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
$ClO_2(g)$	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		

D. Standard Reduction Half-Cell 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
$VO_2^+(aq) + 2H^+(aq) + e^- \longrightarrow VO^{2+}(aq) + H_2O(l)$	0.99
$HNO_2(aq) + H^+(aq) + e^- \longrightarrow NO(g) + 2H_2O(l)$	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