

Appendix A

THERMODYNAMIC TABLES

7/11/12

	ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol		ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol
Aluminum				CCl ₄ (l)	-135.44	216.40	-65.21
Al(s)	0	28.28	0	CHCl ₃ (l)	-134.47	201.7	-73.66
Al ³⁺ (aq)	-531	-321.7	-485	Cl ₂ CO(g)	-220.08	283.80	-205.89
AlCl ₃ (s)	-705.63	109.29	-630.02	CH ₄ (g)	-74.87	186.25	-50.77
AlF ₃ (s)	-1510.4	66.48	-1431.1	C ₂ H ₂ (g)	226.73	200.96	209.20
Al ₂ O ₃ (s)	-1675.7	50.95	-1582.3	C ₂ H ₄ (g)	52.47	219.33	68.42
Arsenic				C ₂ H ₆ (g)	-84.68	229.60	-32.82
As(s)	0	35.1	0	C ₃ H ₈ (g)	-104.70	270.31	-24.31
AsH ₃ (g)	66.44	222.78	68.93	C ₄ H ₁₀ (g)	-125.60	309.91	-16.34
AsCl ₃ (l)	-305.0	216.3	-259.4	CO(g)	-110.53	197.65	-137.16
Barium				CO ₂ (g)	-393.52	213.80	-394.39
Ba(s)	0	62.48	0	CO ₂ (aq)	-413.80	117.6	-385.98
Ba ²⁺ (aq)	-537.64	9.6	-560.77	HCO ₃ ⁻ (aq)	-691.99	91.2	-586.77
BaCO ₃ (s)	-1216.3	112.1	-1137.6	CO ₃ ²⁻ (aq)	-677.14	-56.9	-527.81
BaCl ₂ (s)	-858.56	123.67	-810.29	HCO ₂ H(aq)	-425.43	163	-372.3
BaO(s)	-548.10	72.07	-520.38	HCO ₂ ⁻ (aq)	-425.55	92	-351.0
BaSO ₄ (s)	-1473.2	132.2	-1362.2	H ₂ CO(g)	-115.90	218.95	-109.92
Boron				CH ₃ OH(l)	-238.66	126.8	-166.27
B(s)	0	5.83	0	CH ₃ OH(g)	-200.66	239.81	-161.96
B ₂ H ₆ (g)	41.00	233.17	91.85	CH ₃ OH(aq)	-245.93	133.1	-175.31
BF ₃ (g)	-1135.6	254.36	-1119.0	CS ₂ (l)	89.70	151.34	65.27
B ₂ O ₃ (s)	-1271.9	53.95	-1192.8	CS ₂ (g)	116.94	237.98	66.82
H ₃ BO ₃ (s)	-1094.0	88.74	-968.52	CH ₃ CO ₂ H(aq)	-485.76	178.7	-396.46
Bromine				CH ₃ CO ₂ ⁻ (aq)	-486.01	86.6	-369.31
Br ₂ (l)	0	152.21	0	C ₂ H ₅ OH(l)	-277.69	160.7	-174.78
Br ₂ (g)	30.91	245.39	3.13	C ₂ H ₅ OH(g)	-235.10	282.70	-168.49
Br ₂ (aq)	-2.59	130.5	3.93	C ₂ H ₅ OH(aq)	-288.3	148.5	-181.64
Br(g)	111.86	175.02	82.37	HCN(g)	135.14	201.83	124.72
Br ⁻ (aq)	-121.55	82.4	-103.96	HCN(aq)	107.1	124.7	119.7
HBr(g)	-36.44	198.70	-53.51	CN ⁻ (aq)	150.6	94.1	172.4
Calcium				CH ₃ NH ₂ (g)	-22.97	243.41	32.16
Ca(s)	0	41.59	0	CH ₃ NH ₂ (aq)	-70.17	123.4	20.77
Ca ²⁺ (aq)	-542.83	-53.1	-553.58	Chlorine			
CaCO ₃ (s)	-1206.9	92.9	-1128.8	Cl ₂ (g)	0	223.08	0
CaCl ₂ (s)	-795.80	104.60	-748.07	Cl(g)	121.30	165.19	105.31
CaO(s)	-635.09	38.21	-603.50	Cl ⁻ (aq)	-167.16	56.5	-131.23
CaSO ₄ (s)	-1434.1	106.7	-1321.8	ClO ₂ (g)	97.00	256.84	114.84
Carbon				Cl ₂ O(g)	81.00	271.72	97.08
C(graphite)	0	5.74	0	HCl(g)	-92.31	186.90	-95.30
C(diamond)	1.90	2.38	2.90	HClO(aq)	-120.9	142	-79.9
				ClO ⁻ (aq)	-107.1	42	-36.8

	ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol		ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol
Copper				LiCl(s)	-408.27	59.30	-384.02
Cu(s)	0	33.16	0	Magnesium			
Cu ⁺ (aq)	71.67	40.6	49.98	Mg(s)	0	32.67	0
Cu ²⁺ (aq)	64.77	-99.6	65.49	Mg ²⁺ (aq)	-466.85	-138.1	-454.8
CuO(s)	-156.06	42.59	-128.29	MgCO ₃ (s)	-1111.7	65.85	-1028.1
CuS(s)	-53.1	66.5	-53.6	MgCl ₂ (s)	-641.62	89.63	-592.09
Cu ₂ S(s)	-79.5	120.9	-86.2	MgO(s)	-601.24	26.92	-568.94
Fluorine				Mg(OH) ₂ (s)	-924.66	63.24	-833.65
F ₂ (g)	0	202.79	0	Mercury			
F(g)	79.39	158.75	62.29	Hg(l)	0	76.03	0
F ⁻ (aq)	-332.63	-13.8	-278.79	Hg ²⁺ (aq)	171.1	-32.2	164.40
HF(g)	-272.55	173.78	-274.65	Hg ₂ ²⁺ (aq)	172.4	84.5	153.52
HF(aq)	-320.08	88.7	-296.82	HgCl ₂ (s)	-230.12	144.49	-184.02
Hydrogen				Hg ₂ Cl ₂ (s)	-264.93	192.54	-210.48
H ₂ (g)	0	130.68	0	HgO(s)	-90.79	70.27	-58.49
H(g)	218.00	114.72	203.28	HgS(s)	-58.2	82.4	-50.6
H ⁺ (aq)	0	0	0	Nitrogen			
Iodine				N ₂ (g)	0	191.61	0
I ₂ (s)	0	116.14	0	NH ₃ (g)	-45.90	192.77	-16.37
I ₂ (g)	62.42	260.68	19.32	NH ₃ (aq)	-80.29	111.3	-26.50
I(g)	106.76	180.79	70.17	NH ₄ ⁺ (aq)	-132.51	113.4	-79.31
I ⁻ (aq)	-55.19	111.3	-51.57	NH ₄ Cl(s)	-314.55	94.86	-203.09
HI(g)	26.36	206.59	1.56	N ₂ H ₄ (l)	50.63	121.54	149.44
ICl(g)	17.51	247.57	-5.74	N ₂ H ₄ (aq)	34.31	138	128.1
Iron				NO(g)	90.29	210.76	86.60
Fe(s)	0	27.32	0	N ₂ O(g)	82.05	219.96	104.18
Fe ²⁺ (aq)	-89.1	-137.7	-78.90	NO ₂ (g)	33.10	240.03	51.26
Fe ³⁺ (aq)	-48.5	-315.9	-4.7	N ₂ O ₄ (s)	-35.05	150.29	99.60
FeO(s)	-272.04	60.75	-251.43	N ₂ O ₄ (g)	9.08	304.38	97.79
Fe(OH) ₂ (s)	-574.04	87.86	-491.97	NO ₃ ⁻ (aq)	-205.0	146.4	-108.74
Fe ₂ O ₃ (s)	-825.50	87.40	-743.52	CINO(g)	51.71	261.68	66.10
FeCl ₂ (s)	-341.83	117.95	-302.34	Oxygen			
Lead				O ₂ (g)	0	205.15	0
Pb(s)	0	64.78	0	O ₂ (aq)	-11.7	110.9	16.4
Pb ²⁺ (aq)	-1.7	10.5	-24.43	O ₃ (g)	142.67	238.93	163.18
PbO(s)	-219.41	66.32	-189.28	H ₂ O(l)	-285.83	69.95	-237.14
PbO ₂ (s)	-274.47	71.80	-215.40	H ₂ O(g)	-241.83	188.83	-228.58
PbS(s)	-98.32	91.34	-96.68	OH ⁻ (aq)	-229.99	-10.75	-157.24
PbSO ₄ (s)	-919.94	148.57	-813.14	H ₂ O ₂ (aq)	-191.17	143.9	-134.03
Lithium				Phosphorus			
Li(s)	0	29.08	0	P(s) (white)	0	41.08	0
Li ⁺ (aq)	-278.49	13.4	-293.31	PH ₃ (g)	5.44	210.24	7.19

	ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol		ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol	
$\text{PCl}_3(g)$	-288.70	311.68	-269.61	Sulfur	$\text{S}(s) (\alpha)$	0	32.06	0
$\text{PCl}_5(g)$	-360.18	364.29	-290.27		$\text{S}^{2-}(aq)$	33.1	-14.6	85.8
$\text{P}_4\text{O}_{10}(s)$	-3009.9	228.78	-2723.3		$\text{HS}^-(aq)$	-17.6	62.8	12.08
$\text{H}_3\text{PO}_4(aq)$	-1288.3	158.2	-1142.5		$\text{H}_2\text{S}(g)$	-20.50	205.76	-33.33
$\text{H}_2\text{PO}_4^-(aq)$	-1296.3	90.4	-1130.3		$\text{H}_2\text{S}(aq)$	-39.7	121	-27.83
$\text{HPO}_4^{2-}(aq)$	-1292.1	-33.5	-1089.2		$\text{SO}_2(g)$	-296.84	248.21	-300.12
$\text{PO}_4^{3-}(aq)$	-1277.4	-222	-1018.7		$\text{SO}_2(aq)$	-322.98	161.9	-300.68
Potassium					$\text{HSO}_3^-(aq)$	-626.22	139.7	-527.73
$\text{K}(s)$	0	64.67	0		$\text{SO}_3^{2-}(aq)$	-635.5	-29	-486.5
$\text{K}(l)$	2.27	71.40	0.26		$\text{SO}_3(g)$	-395.76	256.77	-371.02
$\text{K}(g)$	89.00	160.34	60.48		$\text{HSO}_4^-(aq)$	-887.34	131.8	-755.91
$\text{K}^+(aq)$	-252.38	102.5	-283.27		$\text{SO}_4^{2-}(aq)$	-909.27	20.1	-744.53
$\text{KCl}(s)$	-436.68	82.55	-408.76		$\text{SO}_2\text{Cl}_2(g)$	-354.80	311.10	-310.32
$\text{KClO}_3(s)$	-397.73	143.1	-296.25		$\text{S}_2\text{Cl}_2(l)$	-58.16	223.84	-39.27
$\text{KBr}(s)$	-393.80	95.94	-380.43		Tin			
$\text{KNO}_3(s)$	-494.63	133.05	-394.86		$\text{Sn}(s)$	0	51.55	0
$\text{KOH}(s)$	-424.72	78.91	-378.90		$\text{SnO}(s)$	-285.8	56.5	-256.9
Selenium					$\text{SnO}_2(s)$	-580.7	52.3	-519.6
$\text{Se}(s)$	0	42.44	0		$\text{SnCl}_4(l)$	-511.3	258.6	-440.1
$\text{H}_2\text{Se}(g)$	29.7	219.02	15.9		Zinc			
Silicon					$\text{Zn}(s)$	0	41.72	0
$\text{Si}(s)$	0	18.82	0		$\text{Zn}^{2+}(aq)$	-153.89	-112.1	-147.06
$\text{SiH}_4(g)$	34.31	204.65	56.83		$\text{ZnCl}_2(s)$	-415.05	111.46	-369.40
$\text{SiF}_4(g)$	-1614.94	282.76	-1572.71	$\text{ZnO}(s)$	-348.28	43.64	-318.30	
$\text{SiCl}_4(g)$	-662.75	330.94	-662.78	$\text{ZnS}(s)$	-205.98	57.7	-201.29	
$\text{SiO}_2(s)$	-905.49	50.05	-853.64					
Silver								
$\text{Ag}(s)$	0	42.55	0					
$\text{Ag}^+(aq)$	105.58	72.68	77.11					
$\text{AgCl}(s)$	-127.07	96.2	-109.79					
$\text{Ag}_2\text{CO}_3(s)$	-505.8	167.4	-436.8					
$\text{Ag}_2\text{O}(s)$	-31.05	121.3	-11.20					
Sodium								
$\text{Na}(s)$	0	51.46	0					
$\text{Na}(l)$	2.41	57.86	0.50					
$\text{Na}^+(aq)$	-240.12	59.0	-261.90					
$\text{NaCl}(s)$	-411.12	72.12	-384.02					
$\text{NaBr}(s)$	-361.41	86.82	-349.27					
$\text{NaOH}(s)$	-425.93	64.44	-379.74					
$\text{Na}_2\text{CO}_3(s)$	-1130.8	138.80	-1048.0					
$\text{NaHCO}_3(s)$	-950.81	101.7	-851.0					
$\text{NaNO}_3(s)$	-467.85	116.52	-367.00					

Appendix B AQUEOUS EQUILIBRIUM CONSTANTS

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Acid Dissociation constants, K_a

Name	Formula	Alternate	(Step)	K_a
acetic acid	CH ₃ CO ₂ H	CH ₃ C(O)OH		1.8×10^{-5}
arsenic acid	H ₃ AsO ₄	OAs(OH) ₃	(1) (2) (3)	4.9×10^{-3} 8.9×10^{-8} 3.2×10^{-12}
benzoic acid	C ₆ H ₅ CO ₂ H	C ₆ H ₅ C(O)OH		6.3×10^{-5}
butyric acid	C ₃ H ₇ CO ₂ H	C ₃ H ₇ C(O)OH		1.5×10^{-5}
carbon dioxide	CO ₂		(1) (2)	4.5×10^{-7} 4.7×10^{-11}
chloroacetic acid	ClCH ₂ CO ₂ H	ClCH ₂ C(O)OH		1.4×10^{-3}
chlorous acid	HClO ₂	OCIOH		1.1×10^{-2}
citric acid	C ₆ H ₈ O ₇	C ₃ H ₄ OH(C(O)OH) ₃	(1) (2) (3)	7.4×10^{-4} 1.7×10^{-5} 4.0×10^{-7}
dichloroacetic acid	Cl ₂ CHCO ₂ H	Cl ₂ CHC(O)OH		5.0×10^{-2}
dimethylphosphinic acid	(CH ₃) ₂ PO ₂ H	(CH ₃) ₂ P(O)OH		8.3×10^{-4}
formic acid	HCO ₂ H	HC(O)OH		1.8×10^{-4}
hydrocyanic acid	HCN			6.2×10^{-10}
hydrofluoric acid	HF			6.8×10^{-4}
hydrosulfuric acid	H ₂ S		(1) (2)	9.6×10^{-8} $\sim 10^{-17}$
hypobromous acid	HBrO	BrOH		2.3×10^{-9}
hypochlorous acid	HClO	ClOH		3.0×10^{-8}
hypoiodous acid	HIO	IOH		2.3×10^{-11}
iodic acid	HIO ₃	O ₂ IOH		1.7×10^{-1}
nitrous acid	HNO ₂	ONOH		7.1×10^{-4}
oxalic acid	H ₂ C ₂ O ₄	HO(O)CC(O)OH	(1) (2)	5.4×10^{-2} 5.4×10^{-5}
phosphoric acid	H ₃ PO ₄	OP(OH) ₃	(1) (2) (3)	7.1×10^{-3} 6.3×10^{-8} 4.5×10^{-13}
pyruvic acid	C ₃ H ₄ O ₃	CH ₃ C(O)C(O)OH		2.8×10^{-3}
selenous acid	H ₂ SeO ₃	OSe(OH) ₂	(1) (2)	2.4×10^{-3} 4.8×10^{-9}
sulfur dioxide	SO ₂		(1) (2)	1.4×10^{-2} 6.7×10^{-8}
sulfuric acid	H ₂ SO ₄	O ₂ S(OH) ₂	(2)	1.0×10^{-2}

Base Dissociation Constants, K_b

Name	Formula	Alternate	K_b
ammonia	NH ₃		1.8×10^{-5}
hydroxylamine	HONH ₂		9.1×10^{-9}
methylamine	CH ₃ NH ₂		4.4×10^{-4}
ethylamine	C ₂ H ₅ NH ₂	CH ₃ CH ₂ NH ₂	4.3×10^{-4}
diethylamine	(C ₂ H ₅) ₂ NH	(CH ₃ CH ₂) ₂ NH	8.6×10^{-4}
triethylamine	(C ₂ H ₅) ₃ N	(CH ₃ CH ₂) ₃ N	5.2×10^{-4}
pyridine	C ₅ H ₅ N		1.7×10^{-9}
piperidine	C ₅ H ₁₀ NH		1.3×10^{-3}
aniline	C ₆ H ₅ NH ₂		4.0×10^{-10}
hydrazine	N ₂ H ₄	H ₂ NNH ₂	1.0×10^{-6}

Solubility Products, K_{sp}

Name	Formula	K_{sp}	Name	Formula	K_{sp}
barium chromate	BaCrO ₄	1.2×10^{-10}	lead(II) chloride	PbCl ₂	1.7×10^{-5}
barium fluoride	BaF ₂	1.8×10^{-7}	lead(II) chromate	PbCrO ₄	2.8×10^{-13}
barium sulfate	BaSO ₄	1.1×10^{-10}	lead(II) iodate	Pb(IO ₃) ₂	3.7×10^{-13}
cadmium hydroxide	Cd(OH) ₂	7.2×10^{-15}	lead(II) sulfate	PbSO ₄	2.5×10^{-8}
calcium carbonate	CaCO ₃	3.4×10^{-9}	magnesium fluoride	MgF ₂	5.2×10^{-11}
calcium iodate	Ca(IO ₃) ₂	6.5×10^{-6}	mercury(I) chloride	Hg ₂ Cl ₂	1.4×10^{-18}
calcium sulfate	CaSO ₄	4.9×10^{-5}	mercury(II) iodate	Hg(IO ₃) ₂	3.2×10^{-13}
copper(I) bromide	CuBr	6.3×10^{-9}	silver bromide	AgBr	5.4×10^{-13}
copper(I) chloride	CuCl	1.7×10^{-7}	silver carbonate	Ag ₂ CO ₃	8.5×10^{-12}
copper(I) iodide	CuI	1.3×10^{-12}	silver chloride	AgCl	1.8×10^{-10}
gold(I) chloride	AuCl	2.0×10^{-13}	silver iodide	AgI	8.5×10^{-17}
iron(II) carbonate	FeCO ₃	3.1×10^{-11}	silver oxalate	Ag ₂ C ₂ O ₄	5.4×10^{-12}
iron(II) hydroxide	Fe(OH) ₂	4.9×10^{-17}	silver sulfate	Ag ₂ SO ₄	1.2×10^{-5}

Complex Formation Constants, K_f

Formula	K_f	Formula	K_f
Ag(NH ₂) ₂ ⁺	1.1×10^7	Cu(NH ₃) ₄ ²⁺	2.1×10^{13}
Ag(SCN) ₄ ³⁻	1.2×10^{10}	Hg(NH ₃) ₄ ²⁺	1.9×10^{19}
Ag(S ₂ O ₃) ₂ ³⁻	2.9×10^{13}	HgBr ₄ ²⁻	1.0×10^{21}
AlF ₆ ³⁻	6.9×10^{19}	HgCl ₄ ²⁻	1.2×10^{15}
Al(OH) ₄ ⁻	1.1×10^{33}	Ni(CN) ₄ ²⁻	1.7×10^{30}
Cd(CN) ₄ ²⁻	6.0×10^{18}	Ni(NH ₃) ₆ ²⁺	5.5×10^8
Cd(OH) ₄ ²⁻	4.2×10^8	Zn(NH ₃) ₄ ²⁺	2.9×10^9
Cu(CN) ₄ ³⁻	2.0×10^{30}	Zn(OH) ₄ ²⁻	4.6×10^{17}

Appendix C

HALF-CELL POTENTIALS

	$E_{1/2}^{\circ}$ in V
1. $\text{O}_3(g) + 2 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{O}_2(g) + \text{H}_2\text{O}(l)$	2.08
2. $\text{Co}^{3+}(aq) + e^- \rightleftharpoons \text{Co}^{2+}(aq)$	1.92
3. $\text{Au}^+(aq) + e^- \rightleftharpoons \text{Au}(s)$	1.69
4. $\text{MnO}_4^-(aq) + 8 \text{H}^+(aq) + 5 e^- \rightleftharpoons \text{Mn}^{2+}(aq) + 4 \text{H}_2\text{O}(l)$	1.51
5. $\text{HClO}(aq) + \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{Cl}^-(aq) + \text{H}_2\text{O}(l)$	1.48
6. $\text{ClO}_3^-(aq) + 6 \text{H}^+(aq) + 6 e^- \rightleftharpoons \text{Cl}^-(aq) + 3 \text{H}_2\text{O}(l)$	1.45
7. $\text{Au}^{3+}(aq) + 2 e^- \rightleftharpoons \text{Au}^+(aq)$	1.40
8. $\text{Cl}_2(g) + 2 e^- \rightleftharpoons 2 \text{Cl}^-(aq)$	1.36
9. $\text{HCrO}_4^-(aq) + 7 \text{H}^+(aq) + 3 e^- \rightleftharpoons \text{Cr}^{3+}(aq) + 4 \text{H}_2\text{O}(l)$	1.35
10. $2 \text{HNO}_2(aq) + 4 \text{H}^+(aq) + 4 e^- \rightleftharpoons \text{N}_2\text{O}(g) + 3 \text{H}_2\text{O}(l)$	1.30
11. $\text{O}_2(g) + 4 \text{H}^+(aq) + 4 e^- \rightleftharpoons 2 \text{H}_2\text{O}(l)$	1.23
12. $\text{MnO}_2(s) + 4 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{Mn}^{2+}(aq) + 2 \text{H}_2\text{O}(l)$	1.22
13. $\text{SeO}_4^{2-}(aq) + 4 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{H}_2\text{SeO}_3(aq) + \text{H}_2\text{O}(l)$	1.15
14. $\text{IO}_3^-(aq) + 6 \text{H}^+(aq) + 6 e^- \rightleftharpoons \text{I}^-(aq) + 3 \text{H}_2\text{O}(l)$	1.08
15. $\text{Br}_2(l) + 2 e^- \rightleftharpoons 2 \text{Br}^-(aq)$	1.07
16. $\text{NO}_3^-(aq) + 4 \text{H}^+(aq) + 3 e^- \rightleftharpoons \text{NO}(g) + 2 \text{H}_2\text{O}(l)$	0.96
17. $\text{Ag}^+(aq) + e^- \rightleftharpoons \text{Ag}(s)$	0.80
18. $\text{Fe}^{3+}(aq) + e^- \rightleftharpoons \text{Fe}^{2+}(aq)$	0.77
19. $\text{O}_2(g) + 2 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{H}_2\text{O}_2(aq)$	0.70
20. $\text{ClO}_3^-(aq) + 3 \text{H}_2\text{O}(l) + 6 e^- \rightleftharpoons \text{Cl}^-(aq) + 6 \text{OH}^-(aq)$	0.62
21. $\text{MnO}_4^-(aq) + 2 \text{H}_2\text{O}(l) + 3 e^- \rightleftharpoons \text{MnO}_2(s) + 4 \text{OH}^-(aq)$	0.60
22. $\text{I}_2(s) + 2 e^- \rightleftharpoons 2 \text{I}^-(aq)$	0.54
23. $\text{Cu}^+(aq) + e^- \rightleftharpoons \text{Cu}(s)$	0.52
24. $\text{O}_2(g) + 2 \text{H}_2\text{O}(l) + 4 e^- \rightleftharpoons 4 \text{OH}^-(aq)$	0.40
25. $\text{Cu}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Cu}(s)$	0.34
26. $\text{ClO}_3^-(aq) + \text{H}_2\text{O}(l) + 2 e^- \rightleftharpoons \text{ClO}_2^-(aq) + 2 \text{OH}^-(aq)$	0.33
27. $\text{AgCl}(s) + e^- \rightleftharpoons \text{Ag}(s) + \text{Cl}^-(aq)$	0.22
28. $\text{Cu}^{2+}(aq) + e^- \rightleftharpoons \text{Cu}^+(aq)$	0.15
29. $\text{Sn}^{4+}(aq) + 2 e^- \rightleftharpoons \text{Sn}^{2+}(aq)$	0.15
30. $2 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{H}_2(g)$	0.00
31. $\text{Fe}^{3+}(aq) + 3 e^- \rightleftharpoons \text{Fe}(s)$	-0.04
32. $\text{SnO}_2(s) + 4 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{Sn}^{2+}(aq) + 2 \text{H}_2\text{O}(l)$	-0.09
33. $\text{Sn}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Sn}(s)$	-0.14
34. $\text{Ni}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Ni}(s)$	-0.26
35. $\text{Cr}^{3+}(aq) + e^- \rightleftharpoons \text{Cr}^{2+}(aq)$	-0.41
36. $\text{Fe}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Fe}(s)$	-0.45
37. $\text{NO}_2^-(aq) + \text{H}_2\text{O}(l) + e^- \rightleftharpoons \text{NO}(g) + 2 \text{OH}^-(aq)$	-0.46
38. $\text{H}_3\text{PO}_3(aq) + 2 \text{H}^+(aq) + 2 e^- \rightleftharpoons \text{H}_3\text{PO}_2(aq) + \text{H}_2\text{O}(l)$	-0.50
39. $2 \text{SO}_3^{2-}(aq) + 3 \text{H}_2\text{O}(l) + 4 e^- \rightleftharpoons \text{S}_2\text{O}_3^{2-}(aq) + 6 \text{OH}^-(aq)$	-0.57
40. $\text{Cr}^{3+}(aq) + 3 e^- \rightleftharpoons \text{Cr}(s)$	-0.74
41. $\text{Zn}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Zn}(s)$	-0.76
42. $\text{SO}_4^{2-}(aq) + \text{H}_2\text{O}(l) + 2 e^- \rightleftharpoons \text{SO}_3^{2-}(aq) + 2 \text{OH}^-(aq)$	-0.93
43. $\text{Al}^{3+}(aq) + 3 e^- \rightleftharpoons \text{Al}(s)$	-1.66
44. $\text{Al}(\text{OH})_4^-(aq) + 3 e^- \rightleftharpoons \text{Al}(s) + 4 \text{OH}^-(aq)$	-2.33
45. $\text{Mg}^{2+}(aq) + 2 e^- \rightleftharpoons \text{Mg}(s)$	-2.37

Appendix D**ANSWERS TO
END-OF-CHAPTER PROBLEMS****Chapter 34**

- FTTFT
- TTFTT
- b and e
- a. 38.00 kJ b. 33.9 kJ
- a. 0.33 kJ b. 1.52 kJ c. 1.6 kJ d. 4.72 kJ e. 8.2 kJ
- 24.5 kJ

Chapter 35

- TTTTTF
- TTFFFF
- 61%, 24%
- 0.019 g
- 0.70 g

Chapter 36

- FTTF
- 0.0278 g
- 1.79 Torr
- 7.9%

Chapter 37

- FTFFFF
- FFFFTF
- a. dispersion b. dispersion c. dispersion, dipole-dipole d. dispersion, dipole-dipole
- a. dispersion (strongest), dipole-dipole hydrogen bonding (strongest) b. dispersion c. dispersion, dipole-dipole, d. dispersion
- a. HF, H₃CNH₂ b. all c. HF d. PBr₃
- HCl < HBr < Br₂
- a. H₂CBr₂ b. C₂H₆ c. C₂H₆
- SiCl₄
- HCl, PH₃, CH₄

Chapter 38

- FTTFFT
- bcc: 2 fcc: 4
- 4
- four anions, eight cations
- a. covalent network b. molecular c. molecular d. ionic network e. metallic
network f. ionic network

Chapter 39

- TTTTT
- FTFFF
- a. ion-dipole induced dipole b. dispersion, hydrogen bonding, dipole-dipole c. dispersion, dipole-induced dipole
- a. dispersion, dipole-dipole hydrogen bonding, dipole-dipole b. dispersion, dipole-induced dipole c. dispersion,
- MgO
- a. 2 b. 3 c. 1
- a. 33.9 kJ b. -39.8 kJ
- $\text{ZnCl}_2(s) \rightleftharpoons \text{Zn}^{2+}(aq) + 2 \text{Cl}^{-}(aq)$ $\Delta H_{\text{soln}}^{\circ} = -73.16 \text{ kJ}$ exothermic

Chapter 40

- TFFFF
- a. disfavored b. disfavored c. can be favored or disfavored
- a. $\text{CH}_3\text{OH}(l)$ b. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3(g)$
- a. H_2O_2 , HNO_3 b. CH_2Cl_2 c. C_8H_{18}
- $\text{CH}_3\text{CO}_2\text{H}$ (miscible)
- a. hydrophobic b. amphiphilic c. hydrophilic

Chapter 41

- TFFF
- 0.019 atm
- 0.79 g

Chapter 42

- $1.8 \times 10^{-3} \text{ mol}$
- 0.455
- 47.2% C_6H_6 , 33.7% C_5H_{12} , 19.1% C_2Cl_6
- 3.08 g
- 0.893 m
- a. 4.3 M b. 4.8 m c. 8.0 mol%

Chapter 43

- FFTT
- 1.20 °C
- 95.2 g/mol
- 17,000 g/mol

Chapter 44

- FFFTTTF
- a. $\text{Br}_2(g)$ b. $\text{CH}_3\text{OH}(g)$
- a. $\text{PF}_5(g)$ b. $\text{AsH}_3(g)$
- 287.51 J/K

5. -723.5 J/K
 6. a. 4 b. 5

Chapter 45

1. T T T F T F
 2. F T T F T T
 3. $\text{Ne}(g), \text{H}^+(aq), \text{Al}(s)$
 4. a. -1104.14 kJ b. -143.21 J/K c. -1061.44 kJ
 5. a. -507.45 kJ b. 29.55 J/K c. -516.26 kJ
 6. a. -620.6 kJ b. -203.4 J/K c. -560.0 kJ
 7. a
 8. -9.10 kJ
 9. -92.34 kJ
 10. -606.60 kJ

Chapter 46

1. T T F T
 2. -113 kJ
 3. 336.3 K
 4. a.
$$Q = \frac{[\text{H}^+]^2 [\text{NO}_3^-]^2}{P(\text{N}_2\text{O}_5)}$$
 b.
$$Q = \frac{[\text{Mg}^{2+}] P(\text{CO}_2)}{[\text{H}^+]^2}$$

 5. 0.00764
 6. 544
 7. 4.20 kJ
 8. 5.05 kJ

Chapter 47

1. T F T
 2. b
 3. 2.127×10^{-4}
 4. 2.61×10^{-10}
 5. 1.64×10^{-3}
 6. 4.122×10^{-4}
 7. 6.81 kJ

Chapter 48

1. F T T F F F
 2. a.
$$\text{speed} = -\frac{1}{2} \frac{\Delta[\text{NO}]}{\Delta t} = -\frac{\Delta[\text{O}_2]}{\Delta t} = \frac{1}{2} \frac{\Delta[\text{NO}_2]}{\Delta t}$$

 b.
$$\text{speed} = -\frac{\Delta[(\text{NH}_2)_2\text{CO}]}{\Delta t} = -\frac{1}{2} \frac{\Delta[\text{OH}^-]}{\Delta t} = \frac{\Delta[\text{CO}_3^{2-}]}{\Delta t} = \frac{1}{2} \frac{\Delta[\text{NH}_3]}{\Delta t}$$

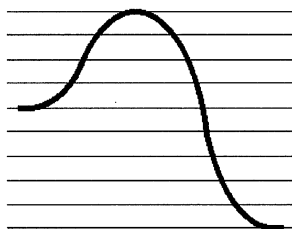
$$c. \text{ speed} = -\frac{\Delta[\text{CH}_2\text{Cl}_2]}{\Delta t} = -\frac{1}{2} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t} = \frac{\Delta[\text{CO}_2]}{\Delta t} = \frac{1}{2} \frac{\Delta[\text{HCl}]}{\Delta t} = \frac{1}{2} \frac{\Delta[\text{H}_2]}{\Delta t}$$

Chapter 49

- FTTFFTT
- TFFFT
- TTFT
- a. rate = $k [\text{C}_2\text{H}_5\text{Cl}]$ b. 0.42 (mol/L)/s c. 0.15 s
- a. rate = $k [\text{H}_2\text{O}] [\text{N}_2\text{O}_4]$ b. 5.92 (mol/L)/s
- a. 2.2×10^{-4} mol/L b. 1.1×10^{-4} mol/L c. 33%
- a. 21 s b. 0.00901 mol/L c. 0.0127 mol/L d. 73.8%
- a. 0.016 mol/L b. 0.020 mol/L c. 38%
- 20,600 (L/mol)/s
- 2.7

Chapter 50

- FFFFT
- FTTTT
-



- a. D b. B - C c. D - C d. endothermic e. endothermic
220. kJ
- Very high E_a in the first step

Chapter 51

- FTTTF
- TTTTT
- a. 2.92×10^{-6} b. 1.71×10^{-3}
- 3.19
- 4.12
- 6.5×10^{-8}
- 314

Chapter 52

- $P(\text{Cl}_2) = 0.53$ atm; $P(\text{SCl}_2) = 1.93$ atm or 1.94 atm
- $P(\text{C}_2\text{H}_5\text{Cl}) = 0.481$ atm; $P(\text{C}_2\text{H}_4) = 8.50 \times 10^{-4}$ atm
- $P(\text{Cl}_2) = 0.83$ atm; $P(\text{BrCl}) = 1.34$ atm
- $[\text{CO}_2] = 0.028$ M; $[\text{F}^-] = 0.017$ M; $[\text{CO}_3^{2-}] = 4.4 \times 10^{-6}$ M; $[\text{HF}] = 8.8 \times 10^{-6}$ M
- a. -10.13 kJ b. 59.7 c. $[\text{NH}_3(aq)] = 0.0462$ M; $P(\text{NH}_3(g)) = 7.70 \times 10^{-4}$ atm

Chapter 53

1. T F F F
2. a. left b. left c. right d. no effect
3. a. no effect b. left c. no effect d. right
4. a. left b. left c. no effect d. no effect
5. a and c

Chapter 54

1. T T F F T
2. T T F T F
3. F F T F T
4. T T T T T
5. $\Delta G^\circ = 80.9 \text{ kJ}$; $K_w = 2.33 \times 10^{-14}$; pH 6.82
6. a. F^- b. H_2CO_3 c. H_2PO_4^-
7. a. ClO_2^- b. HCN c. NH_3
8. water, hydrogen oxalate ion, dihydrogen arsenate ion
9. a. 0.0334 M b. 1.48 c. 12.52
10. a. 0.00850 M b. 2.07 c. 11.93
11. 2.03
12. 12.26
13. 0.21 g
14. 0.038 L

Chapter 55

1. T F T T T
2. a. $\text{HBrO}(aq) \rightleftharpoons \text{H}^+(aq) + \text{BrO}^-(aq)$ $K_a = \frac{[\text{H}^+][\text{BrO}^-]}{[\text{HBrO}]}$
 b. $\text{HCN}(aq) \rightleftharpoons \text{H}^+(aq) + \text{CN}^-(aq)$ $K_a = \frac{[\text{H}^+][\text{CN}^-]}{[\text{HCN}]}$
3. a. $\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}(aq) \rightleftharpoons \text{H}^+(aq) + \text{HO}_2\text{CCH}_2\text{CO}_2^-(aq)$
 $\text{HO}_2\text{CCH}_2\text{CO}_2^-(aq) \rightleftharpoons \text{H}^+(aq) + ^-\text{O}_2\text{CCH}_2\text{CO}_2^-(aq)$
 b. $\text{H}_3\text{AsO}_4(aq) \rightleftharpoons \text{H}^+(aq) + \text{H}_2\text{AsO}_4^-(aq)$
 $\text{H}_2\text{AsO}_4^-(aq) \rightleftharpoons \text{H}^+(aq) + \text{HAsO}_4^{2-}(aq)$
 $\text{HAsO}_4^{2-}(aq) \rightleftharpoons \text{H}^+(aq) + \text{AsO}_4^{3-}(aq)$
4. nitric acid, chlorous acid
5. $\text{HP}_2\text{O}_7^{3-}(aq) \rightleftharpoons \text{H}^+(aq) + \text{P}_2\text{O}_7^{4-}(aq)$ $K_{a4} = \frac{[\text{H}^+][\text{P}_2\text{O}_7^{4-}]}{[\text{HP}_2\text{O}_7^{3-}]}$
6. $[\text{C}_3\text{H}_7\text{CO}_2\text{H}] = 0.131 \text{ M}$; $[\text{H}^+] = 0.0014 \text{ M}$; $[\text{C}_3\text{H}_7\text{CO}_2^-] = 0.0014 \text{ M}$; pH 2.85; 1.1% diss
7. $[\text{ClCH}_2\text{CO}_2\text{H}] = 0.0273 \text{ M}$; $[\text{H}^+] = 0.0062 \text{ M}$; $[\text{ClCH}_2\text{CO}_2^-] = 0.0062 \text{ M}$; pH 2.21; 19% diss
8. 2.41
9. $[\text{H}_2\text{C}_2\text{O}_4] = 0.065 \text{ M}$; $[\text{H}^+] = 0.059 \text{ M}$; $[\text{HC}_2\text{O}_4^-] = 0.059 \text{ M}$; 48% diss; $[\text{C}_2\text{O}_4^{2-}] = 5.4 \times 10^{-5} \text{ M}$
10. 1.33

- Strongest, HClO_3 ; weakest, HIO
- $[\text{H}^+] = 2.4 \times 10^{-4} \text{ M}$; pH 3.62

Chapter 56

- T T T F F T
- $\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{CH}_3\text{NH}_3^+(\text{aq})$ $K_b = \frac{[\text{OH}^-][\text{CH}_3\text{NH}_3^+]}{[\text{CH}_3\text{NH}_2]}$
 - $\text{C}_6\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{C}_6\text{H}_5\text{NH}_3^+(\text{aq})$ $K_b = \frac{[\text{OH}^-][\text{C}_6\text{H}_5\text{NH}_3^+]}{[\text{C}_6\text{H}_5\text{NH}_2]}$
- $[\text{C}_5\text{H}_5\text{N}] = 0.0143 \text{ M}$; $[\text{OH}^-] = 4.9 \times 10^{-6} \text{ M}$; $[\text{C}_5\text{H}_5\text{NH}^+] = 4.9 \times 10^{-6} \text{ M}$; pOH = 5.31; pH = 8.69
- $[(\text{C}_2\text{H}_5)_3\text{N}] = 0.0267 \text{ M}$; $[\text{OH}^-] = 0.0037 \text{ M}$; $[(\text{C}_2\text{H}_5)_3\text{NH}^+] = 0.0037 \text{ M}$; pH = 11.57; 12% diss
- 6.7 g
- $\text{HONH}_3^+(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HONH}_2(\text{aq})$ $K_a = \frac{[\text{H}^+][\text{HONH}_2]}{[\text{HONH}_3^+]}$
 - $\text{CN}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{HCN}(\text{aq})$ $K_b = \frac{[\text{OH}^-][\text{HCN}]}{[\text{CN}^-]}$
- 1.4×10^{-11}
 - 1.0×10^{-12}
 - 2.3×10^{-11}
 - 7.7×10^{-12}
- $K_a = 3.2 \times 10^{-12}$; $K_b = 1.1 \times 10^{-7}$
 - $K_a = 4.8 \times 10^{-9}$; $K_b = 4.2 \times 10^{-12}$
- $[\text{ClO}^-] = 0.0241 \text{ M}$; $[\text{OH}^-] = 8.9 \times 10^{-5} \text{ M}$; $[\text{HClO}] = 8.9 \times 10^{-5} \text{ M}$; pOH = 4.05; pH = 9.95
- $[\text{CH}_3\text{NH}_3^+] = 0.0669 \text{ M}$; $[\text{H}^+] = 1.2 \times 10^{-6} \text{ M}$; $[\text{CH}_3\text{NH}_2] = 1.2 \times 10^{-6} \text{ M}$; pH = 5.92
- 0.0027 atm
- neutral
 - acidic
 - basic
 - basic
 - acidic
- neutral
 - basic
 - acidic
 - neutral
 - acidic
- acidic
 - basic
 - acidic
 - acidic

Chapter 57

- T T T F F
- 2.82
- 10.76
- 9.85
- $\text{C}_6\text{H}_5\text{CO}_2\text{H}$
- 4.89
 - 4.84
 - 4.99
- 6.87
 - 6.50
 - 7.21

Chapter 58

- T T F T F
- 16.17 mL
 - 1.14
 - 1.62
 - 7.00
 - 12.00
- 1.50
 - 1.81
 - 7.00
 - 11.70
- 41.44 mL
 - 2.42
 - 3.69
 - 8.11
 - 11.59
- 4.39
 - 8.40
 - 11.84
 - 12.14

Chapter 59

- T T F F

2. a. $\text{Fe}(\text{OH})_3(\text{s}) \rightleftharpoons \text{Fe}^{3+}(\text{aq}) + 3 \text{OH}^{-}(\text{aq})$ $K_{\text{sp}} = [\text{Fe}^{3+}] [\text{OH}^{-}]^3$
 b. $\text{Hg}_2\text{SO}_4(\text{s}) \rightleftharpoons \text{Hg}_2^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$ $K_{\text{sp}} = [\text{Hg}_2^{2+}] [\text{SO}_4^{2-}]$
3. a. $\text{PbBr}_2(\text{s}) \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + 2 \text{Br}^{-}(\text{aq})$ $K_{\text{sp}} = [\text{Pb}^{2+}] [\text{Br}^{-}]^2$
 b. $\text{Ni}_3(\text{PO}_4)_2(\text{s}) \rightleftharpoons 3 \text{Ni}^{2+}(\text{aq}) + 2 \text{PO}_4^{3-}(\text{aq})$ $K_{\text{sp}} = [\text{Ni}^{2+}]^3 [\text{PO}_4^{3-}]^2$
4. $\text{MX} < \text{MX}_2 < \text{MX}_3$
5. $\Delta G^\circ = 64.4 \text{ kJ}$ $K_{\text{sp}} = 5.1 \times 10^{-12}$
6. $\text{Ag}_2\text{C}_2\text{O}_4(\text{s}) \rightleftharpoons 2 \text{Ag}^{+}(\text{aq}) + \text{C}_2\text{O}_4^{2-}(\text{aq})$
 $\text{C}_2\text{O}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HC}_2\text{O}_4^{-}(\text{aq}) + \text{OH}^{-}(\text{aq})$
 $\text{Ag}_2\text{C}_2\text{O}_4(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons 2 \text{Ag}^{+}(\text{aq}) + \text{HC}_2\text{O}_4^{-}(\text{aq}) + \text{OH}^{-}(\text{aq})$ $K = 1.0 \times 10^{-21}$

Chapter 60

1. F F F T
2. a. $5.3 \times 10^{-7} \text{ M}$ b. $1.3 \times 10^{-4} \text{ M}$
3. a. $3.5 \times 10^{-8} \text{ M}$ b. $2.6 \times 10^{-6} \text{ M}$
4. $[\text{Pb}^{2+}] = 5.3 \times 10^{-5} \text{ M}$; $[\text{SO}_4^{2-}] = 4.70 \times 10^{-4} \text{ M}$
5. $2.0 \times 10^{-7} \text{ M}$
6. 0.01 M HNO_3
7. a. $\text{Cd}^{2+}(\text{aq}) + 4 \text{OH}^{-}(\text{aq}) \rightleftharpoons \text{Cd}(\text{OH})_4^{2-}(\text{aq})$ $K_{\text{f}} = \frac{[\text{Cd}(\text{OH})_4^{2-}]}{[\text{Cd}^{2+}] [\text{OH}^{-}]^4}$
 b. $\text{Ni}^{2+}(\text{aq}) + 6 \text{NH}_3(\text{aq}) \rightleftharpoons \text{Ni}(\text{NH}_3)_6^{2+}(\text{aq})$ $K_{\text{f}} = \frac{[\text{Ni}(\text{NH}_3)_6^{2+}]}{[\text{Ni}^{2+}] [\text{NH}_3]^6}$
8. a. $[\text{Cu}^{2+}] = 2.3 \times 10^{-4} \text{ M}$; $[\text{NH}_3] = 9.2 \times 10^{-4} \text{ M}$; $[\text{Cu}(\text{NH}_3)_4^{2+}] = 0.00342 \text{ M}$
 b. $[\text{Cu}^{2+}] = 8.4 \times 10^{-9} \text{ M}$; $[\text{NH}_3] = 0.0120 \text{ M}$; $[\text{Cu}(\text{NH}_3)_4^{2+}] = 0.00365 \text{ M}$
9. $[\text{Al}^{3+}] = 5.9 \times 10^{-10} \text{ M}$; $[\text{F}^{-}] = 0.0064 \text{ M}$; $[\text{AlF}_6^{3-}] = 0.00280 \text{ M}$
10. $\text{CuCl}(\text{s}) \rightleftharpoons \text{Cu}^{+}(\text{aq}) + \text{Cl}^{-}(\text{aq})$
 $\text{Cu}^{+}(\text{aq}) + 4 \text{CN}^{-}(\text{aq}) \rightleftharpoons \text{Cu}(\text{CN})_4^{3-}(\text{aq})$
 $\text{CuCl}(\text{s}) + 4 \text{CN}^{-}(\text{aq}) \rightleftharpoons \text{Cu}(\text{CN})_4^{3-}(\text{aq}) + \text{Cl}^{-}(\text{aq})$ $K = 3.4 \times 10^{23}$

Chapter 61

1. a. $\text{S}_2\text{O}_3^{2-}/\text{SO}_4^{2-}$ and $\text{HBrO}/\text{Br}^{-}$
 b. $\text{S}_2\text{O}_3^{2-} + 5 \text{H}_2\text{O} \rightarrow 2 \text{SO}_4^{2-} + 10 \text{H}^{+} + 8 \text{e}^{-}$
 $\text{HBrO} + \text{H}^{+} + 2 \text{e}^{-} \rightarrow \text{Br}^{-} + \text{H}_2\text{O}$
 c. $\text{S}_2\text{O}_3^{2-} + 4 \text{HBrO} + \text{H}_2\text{O} \rightarrow 2 \text{SO}_4^{2-} + 6 \text{H}^{+} + 4 \text{Br}^{-}$
 d. $\text{S}_2\text{O}_3^{2-}$ is oxidized. HBrO is reduced.
2. a. $\text{Cd}/\text{Cd}(\text{OH})_2$ and $\text{NiO}(\text{OH})/\text{Ni}(\text{OH})_2$
 b. $\text{Cd} + 2 \text{OH}^{-} \rightarrow \text{Cd}(\text{OH})_2 + 2 \text{e}^{-}$
 $\text{NiO}(\text{OH}) + \text{e}^{-} + \text{H}_2\text{O} \rightarrow \text{Ni}(\text{OH})_2 + \text{OH}^{-}$
 c. $\text{Cd} + 2 \text{NiO}(\text{OH}) + 2 \text{H}_2\text{O} \rightarrow \text{Cd}(\text{OH})_2 + 2 \text{Ni}(\text{OH})_2$
 d. Cd is oxidized. $\text{NiO}(\text{OH})$ is reduced.
3. a. $\text{N}_2\text{O} + 3 \text{H}_2\text{O} \rightarrow 2 \text{HNO}_2 + 4 \text{H}^{+} + 4 \text{e}^{-}$
 $\text{Co}^{3+} + \text{e}^{-} \rightarrow \text{Co}^{2+}$
 b. $\text{N}_2\text{O} + 3 \text{H}_2\text{O} + 4 \text{Co}^{3+} \rightarrow 2 \text{HNO}_2 + 4 \text{H}^{+} + 4 \text{Co}^{2+}$
 c. Co^{3+} is the oxidizing agent. N_2O is the reducing agent.
4. a. $3 \text{PO}_4^{3-} + 2 \text{Cr} + 2 \text{H}_2\text{O} \rightarrow 2 \text{CrO}_2^{-} + 3 \text{HPO}_3^{2-} + \text{OH}^{-}$

b. PO_4^{3-} is the oxidizing agent. Cr is the reducing agent.

Chapter 62

- T F T T T F
- Fe/Fe^{3+} and Ag^+/Ag
 - $$\text{Fe}(s) \rightarrow \text{Fe}^{3+}(aq) + 3 e^- \quad \text{---anode}$$

$$\text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s) \quad \text{---cathode}$$
 Fe is oxidized; Ag^+ is reduced.
 - $\text{Fe}(s) + 3 \text{Ag}^+(aq) \rightarrow \text{Fe}^{3+}(aq) + 3 \text{Ag}(s)$
- $$\text{Cu}(s) \rightarrow \text{Cu}^{2+}(aq) + 2 e^- \quad \text{---anode}$$

$$2 \text{HClO}_2(aq) + 6 \text{H}^+(aq) + 6 e^- \rightarrow \text{Cl}_2(g) + 4 \text{H}_2\text{O}(l) \quad \text{---cathode}$$
 Cu is oxidized; HClO_2 is reduced.
 - $3 \text{Cu}(s) + 2 \text{HClO}_2(aq) + 6 \text{H}^+(aq) \rightarrow 3 \text{Cu}^{2+}(aq) + \text{Cl}_2(g) + 4 \text{H}_2\text{O}(l)$
- $$\text{SO}_3^{2-}(aq) + 2 \text{OH}^-(aq) \rightarrow \text{SO}_4^{2-}(aq) + \text{H}_2\text{O}(l) + 2 e^- \quad \text{---anode}$$

$$\text{HSnO}_2^-(aq) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{Sn}(s) + 3 \text{OH}^-(aq) \quad \text{---cathode}$$
 SO_3^{2-} is oxidized; HSnO_2^- is reduced.
 - $\text{SO}_3^{2-}(aq) + \text{HSnO}_2^-(aq) \rightarrow \text{SO}_4^{2-}(aq) + \text{Sn}(s) + \text{OH}^-(aq)$
- $\text{Ni}(s) | \text{Ni}^{2+}(aq) || \text{H}^+(aq) | \text{H}_2(g) | \text{Pt}(s)$
- $2 \text{CrO}_4^{2-}(aq) + 8 \text{H}_2\text{O}(l) + 3 \text{Zn}(s) + 2 \text{OH}^-(aq) \rightarrow 2 \text{Cr}(\text{OH})_3(s) + 3 \text{Zn}(\text{OH})_4^{2-}(aq)$
 - $\text{Zn}(s) | \text{OH}^-(aq), \text{Zn}(\text{OH})_4^{2-}(aq) || \text{OH}^-(aq), \text{CrO}_4^{2-}(aq) | \text{Cr}(\text{OH})_3(s) | \text{Pt}(s)$
- $$\text{ClO}_2(g) + 3 \text{H}^+(aq) + 3 e^- \rightarrow \text{HClO}(aq) + \text{H}_2\text{O}(l) \quad \text{---cathode}$$

$$\text{Hg}(l) \rightarrow \text{Hg}^{2+}(aq) + 2 e^- \quad \text{---anode}$$
 - $\text{Hg}(l) | \text{Hg}^{2+}(aq) || \text{H}^+(aq), \text{HClO}(aq) | \text{ClO}_2(g) | \text{Pt}(s)$
- T F F F
- $\Delta G_{1/2}^\circ = -207.92 \text{ kJ}; E_{1/2}^\circ = 1.0775 \text{ V}$

Chapter 63

- 0.43 V b. 0.45 V c. 0.81 V
- 0.24 V b. 2.73 V c. 0.27 V
- b or d
- 2 mol b. 12 mol c. 6 mol
- $E^\circ = 0.38 \text{ V}$ and $\Delta G^\circ = -73 \text{ kJ}$
- 1.50 V
- $$\begin{array}{l} \text{MnO}_4^-(aq) + 8 \text{H}^+(aq) + 5 e^- \rightleftharpoons \text{Mn}^{2+}(aq) + 4 \text{H}_2\text{O}(l) \\ \text{Mn}^{2+}(aq) + 2 \text{H}_2\text{O}(l) \rightleftharpoons \text{MnO}_2(s) + 4 \text{H}^+(aq) + 2 e^- \\ \hline \text{MnO}_4^-(aq) + 4 \text{H}^+(aq) + 3 e^- \rightleftharpoons \text{MnO}_2(s) + 2 \text{H}_2\text{O}(l) \end{array} \quad E_{1/2}^\circ = 1.70 \text{ V}$$

Chapter 64

- F T F T T T
- 1.07 V b. 2 c. 1.27 V
- 0.92 V b. 3 c. 0.90 V
- 0.43 V b. 0.30 V c. 1.2×10^{29}
- 0.28 V b. 0.47 V c. 2.5×10^{28}
- 0.014 M
- decrease b. increase c. increase d. same

8. a. same b. increase c. decrease d. increase e. decrease
 9. a. increase b. increase c. increase d. decrease
 10. $\Delta G^\circ = -373.34 \text{ kJ}$ and $E^\circ = 1.9347 \text{ V}$

Chapter 65

1. F F T F T
 2. a. exergonic b. exergonic c. endergonic d. endergonic e. exergonic
 3. a. -0.45 V b. -0.35 V c. 2.4×10^{-46}
 4. a. -0.04 V , endergonic b. 0.06 V , exergonic
 5. 0.126 g
 6. 12.2 min

Chapter 66

1. T T T F F
 2. F F T T F
 3. a. ${}_{14}^{26}\text{Si} \rightarrow {}_{13}^{26}\text{Al} + {}_1^0\beta$
 b. ${}_{84}^{212}\text{Po} \rightarrow {}_{82}^{208}\text{Pb} + {}_2^4\alpha$
 c. ${}_{31}^{67}\text{Ga} + {}_{-1}^0\text{e} \rightarrow {}_{30}^{67}\text{Zn}$
 d. ${}_{16}^{35}\text{S} \rightarrow {}_{17}^{35}\text{Cl} + {}_{-1}^0\beta$
 e. ${}_{44}^{93\text{m}}\text{Ru} \rightarrow {}_{44}^{93}\text{Ru} + \gamma$
 4. a. ${}^{217}\text{Rn}$ b. ${}^{119}\text{Sn}$ c. ${}^{209}\text{Pb}$ d. ${}^{25}\text{Al}$
 5. a. β^- b. α c. β^+ or EC
 6. a. ${}^{228}\text{Ra}$, ${}^{224}\text{Ra}$ b. ${}^{208}\text{Pb}$

Chapter 67

1. a. $2.35 \times 10^{12} \text{ Bq}$ b. 63.5 Ci
 2. $3.09 \times 10^{12} \text{ dis/min}$
 3. a. 0.214 mol b. 49.6 g
 4. $5.06 \times 10^{-5} \text{ g}$
 5. a. 115 Ci b. 1.32 Ci
 6. $1.42 \mu\text{g}$
 7. 4.86 MBq
 8. $4.04 \times 10^9 \text{ y}$

Chapter 68

1. T F T F
 2. a. ${}_{86}^{222}\text{Rn} \rightarrow {}_{84}^{218}\text{Po} + {}_2^4\alpha$ b. $540. \text{ GJ}$ c. 5.591 MeV
 3. a. ${}_{6}^{14}\text{C} \rightarrow {}_{7}^{14}\text{N} + {}_{-1}^0\beta$ b. 15.1 GJ c. 0.156 MeV
 4. a. ${}_{74}^{178}\text{W} + {}_{-1}^0\text{e} \rightarrow {}_{73}^{178}\text{Ta}$ b. 8.8 GJ c. 0.091 MeV
 5. a. ${}_{35}^{79\text{m}}\text{Br} \rightarrow {}_{35}^{79}\text{Br} + \gamma$ b. 20.0 GJ c. 0.207 MeV
 6. EC, 1.504 MeV ; β^- , 1.311 MeV

CONVERSIONS AND CONSTANTS

Length units	inch (in) = 2.54 cm (exact) mile (mi) = 1.609 km
Volume units	L = 1.057 qt
Mass units	lb = 453.6 g u = 1.6605×10^{-24} g
Pressure units	atm = 760 Torr = 14.7 psi
Energy units	J = $\text{kg} \cdot \text{m}^2/\text{s}^2 = \text{V} \cdot \text{C}$ cal = 4.184 J (exact) Cal (nutritional) = 4.184 kJ (exact)
Avogadro's number	6.022×10^{23}
Gas constant	$R = 0.08206 \text{ L} \cdot \text{atm}/(\text{mol} \cdot \text{K}) = 8.314 \text{ J}/(\text{mol} \cdot \text{K})$
Speed of light (in vacuum)	$c = 3.00 \times 10^8 \text{ m/s}$
Planck's constant	$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$
Coulomb	$C = 6.242 \times 10^{18} \text{ charges}$
Faraday constant	96,485 C/mol