

Appendix A

THERMODYNAMIC TABLES
(298.15 K)

	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				C(<i>diamond</i>)	1.90	2.38	2.90
Al(<i>s</i>)	0	28.28	0	CCl ₄ (<i>l</i>)	-135.44	216.40	-65.21
Al ³⁺ (<i>aq</i>)	-531	-321.7	-485	CHCl ₃ (<i>l</i>)	-134.47	201.7	-73.66
AlCl ₃ (<i>s</i>)	-705.63	109.29	-630.02	Cl ₂ CO(<i>g</i>)	-220.08	283.80	-205.89
AlF ₃ (<i>s</i>)	-1510.4	66.48	-1431.1	CH ₄ (<i>g</i>)	-74.87	186.25	-50.77
Al ₂ O ₃ (<i>s</i>)	-1675.7	50.95	-1582.3	C ₂ H ₂ (<i>g</i>)	226.73	200.96	209.20
Arsenic				C ₂ H ₄ (<i>g</i>)	52.47	219.33	68.42
As(<i>s</i>)	0	35.1	0	C ₂ H ₆ (<i>g</i>)	-84.68	229.60	-32.82
AsH ₃ (<i>g</i>)	66.44	222.78	68.93	C ₃ H ₈ (<i>g</i>)	-104.70	270.31	-24.31
AsCl ₃ (<i>l</i>)	-305.0	216.3	-259.4	C ₄ H ₁₀ (<i>g</i>)	-125.60	309.91	-16.34
Barium				CO(<i>g</i>)	-110.53	197.65	-137.16
Ba(<i>s</i>)	0	62.48	0	CO ₂ (<i>g</i>)	-393.52	213.80	-394.39
Ba ²⁺ (<i>aq</i>)	-537.64	9.6	-560.77	CO ₂ (<i>aq</i>)	-413.80	117.6	-385.98
BaCO ₃ (<i>s</i>)	-1216.3	112.1	-1137.6	HCO ₃ ⁻ (<i>aq</i>)	-691.99	91.2	-586.77
BaCl ₂ (<i>s</i>)	-858.56	123.67	-810.29	CO ₃ ²⁻ (<i>aq</i>)	-677.14	-56.9	-527.81
BaO(<i>s</i>)	-548.10	72.07	-520.38	HCO ₂ H(<i>aq</i>)	-425.43	163	-372.3
BaSO ₄ (<i>s</i>)	-1473.2	132.2	-1362.2	HCO ₂ ⁻ (<i>aq</i>)	-425.55	92	-351.0
Boron				H ₂ CO(<i>g</i>)	-115.90	218.95	-109.92
B(<i>s</i>)	0	5.83	0	CH ₃ OH(<i>l</i>)	-238.66	126.8	-166.27
B ₂ H ₆ (<i>g</i>)	41.00	233.17	91.85	CH ₃ OH(<i>g</i>)	-200.66	239.81	-161.96
BF ₃ (<i>g</i>)	-1135.6	254.36	-1119.0	CH ₃ OH(<i>aq</i>)	-245.93	133.1	-175.31
B ₂ O ₃ (<i>s</i>)	-1271.9	53.95	-1192.8	CS ₂ (<i>l</i>)	89.70	151.34	65.27
H ₃ BO ₃ (<i>s</i>)	-1094.0	88.74	-968.52	CS ₂ (<i>g</i>)	116.94	237.98	66.82
Bromine				CH ₃ CO ₂ H(<i>l</i>)	-484.5	159.8	-389.9
Br ₂ (<i>l</i>)	0	152.21	0	CH ₃ CO ₂ H(<i>g</i>)	-432.25	282.5	-374.0
Br ₂ (<i>g</i>)	30.91	245.39	3.13	CH ₃ CO ₂ H(<i>aq</i>)	-485.76	178.7	-396.46
Br ₂ (<i>aq</i>)	-2.59	130.5	3.93	CH ₃ CO ₂ ⁻ (<i>aq</i>)	-486.01	86.6	-369.31
Br(<i>g</i>)	111.86	175.02	82.37	C ₂ H ₅ OH(<i>l</i>)	-277.69	160.7	-174.78
Br ⁻ (<i>aq</i>)	-121.55	82.4	-103.96	C ₂ H ₅ OH(<i>g</i>)	-235.10	282.70	-168.49
HBr(<i>g</i>)	-36.44	198.70	-53.51	C ₂ H ₅ OH(<i>aq</i>)	-288.3	148.5	-181.64
Calcium				HCN(<i>g</i>)	135.14	201.83	124.72
Ca(<i>s</i>)	0	41.59	0	HCN(<i>aq</i>)	107.1	124.7	119.7
Ca ²⁺ (<i>aq</i>)	-542.83	-53.1	-553.58	CN ⁻ (<i>aq</i>)	150.6	94.1	172.4
CaCO ₃ (<i>s</i>)	-1206.9	92.9	-1128.8	CH ₃ NH ₂ (<i>g</i>)	-22.97	243.41	32.16
CaCl ₂ (<i>s</i>)	-795.80	104.60	-748.07	CH ₃ NH ₂ (<i>aq</i>)	-70.17	123.4	20.77
Ca(IO ₃) ₂ (<i>s</i>)	-1002.5	230.	-839.2	Chlorine			
CaO(<i>s</i>)	-635.09	38.21	-603.50	Cl ₂ (<i>g</i>)	0	223.08	0
CaSO ₄ (<i>s</i>)	-1434.1	106.7	-1321.8	Cl(<i>g</i>)	121.30	165.19	105.31
Carbon				Cl ⁻ (<i>aq</i>)	-167.16	56.5	-131.23
C(<i>graphite</i>)	0	5.74	0	HCl(<i>g</i>)	-92.31	186.90	-95.30
				ClO(<i>g</i>)	101.63	225.07	98.36
				ClO ₂ (<i>g</i>)	97.00	256.84	114.84

	ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol		ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol
$\text{Cl}_2\text{O}(g)$	81.00	271.72	97.08	$\text{Pb}(\text{IO}_3)_2(s)$	-495.4	313.0	-351.4
$\text{ClO}^-(aq)$	-107.1	42	-36.8	$\text{PbO}(s)$	-219.41	66.32	-189.28
$\text{HClO}(aq)$	-120.9	142	-79.9	$\text{PbO}_2(s)$	-274.47	71.80	-215.40
Copper				$\text{PbS}(s)$	-98.32	91.34	-96.68
$\text{Cu}(s)$	0	33.16	0	$\text{PbSO}_4(s)$	-919.94	148.57	-813.14
$\text{Cu}^+(aq)$	71.67	40.6	49.98	Lithium			
$\text{Cu}^{2+}(aq)$	64.77	-99.6	65.49	$\text{Li}(s)$	0	29.08	0
$\text{CuO}(s)$	-156.06	42.59	-128.29	$\text{Li}^+(aq)$	-278.49	13.4	-293.31
$\text{CuS}(s)$	-53.1	66.5	-53.6	$\text{LiCl}(s)$	-408.27	59.30	-384.02
$\text{Cu}_2\text{S}(s)$	-79.5	120.9	-86.2	Magnesium			
Fluorine				$\text{Mg}(s)$	0	32.67	0
$\text{F}_2(g)$	0	202.79	0	$\text{Mg}^{2+}(aq)$	-466.85	-138.1	-454.8
$\text{F}(g)$	79.39	158.75	62.29	$\text{MgCO}_3(s)$	-1111.7	65.85	-1028.1
$\text{F}^-(aq)$	-332.63	-13.8	-278.79	$\text{MgCl}_2(s)$	-641.62	89.63	-592.09
$\text{HF}(g)$	-272.55	173.78	-274.65	$\text{MgO}(s)$	-601.24	26.92	-568.94
$\text{HF}(aq)$	-320.08	88.7	-296.82	$\text{Mg}(\text{OH})_2(s)$	-924.66	63.24	-833.65
Hydrogen				Mercury			
$\text{H}_2(g)$	0	130.68	0	$\text{Hg}(l)$	0	76.03	0
$\text{H}(g)$	218.00	114.72	203.28	$\text{Hg}^{2+}(aq)$	171.1	-32.2	164.40
$\text{H}^+(aq)$	0	0	0	$\text{HgCl}_2(s)$	-230.12	144.49	-184.02
Iodine				$\text{HgO}(s)$	-90.79	70.27	-58.49
$\text{I}_2(s)$	0	116.14	0	$\text{HgS}(s)$	-58.2	82.4	-50.6
$\text{I}_2(g)$	62.42	260.68	19.32	Nitrogen			
$\text{I}(g)$	106.76	180.79	70.17	$\text{N}_2(g)$	0	191.61	0
$\text{I}^-(aq)$	-55.19	111.3	-51.57	$\text{NH}_3(g)$	-45.90	192.77	-16.37
$\text{HI}(g)$	26.36	206.59	1.56	$\text{NH}_3(aq)$	-80.29	111.3	-26.50
$\text{ICl}(s)$	-35.42	97.93	-14.05	$\text{NH}_4^+(aq)$	-132.51	113.4	-79.31
$\text{ICl}(g)$	17.51	247.57	-5.74	$\text{NH}_4\text{Cl}(s)$	-314.55	94.86	-203.09
$\text{IO}_3^-(aq)$	-221.3	118.4	-128.0	$\text{N}_2\text{H}_4(l)$	50.63	121.54	149.44
$\text{HIO}_3(aq)$	-211.3	166.9	-132.6	$\text{N}_2\text{H}_4(g)$	95.35	238.72	159.23
Iron				$\text{N}_2\text{H}_4(aq)$	34.31	138	128.1
$\text{Fe}(s)$	0	27.32	0	$\text{NO}(g)$	90.29	210.76	86.60
$\text{Fe}^{2+}(aq)$	-89.1	-137.7	-78.90	$\text{N}_2\text{O}(g)$	82.05	219.96	104.18
$\text{Fe}^{3+}(aq)$	-48.5	-315.9	-4.7	$\text{NO}_2(g)$	33.10	240.03	51.26
$\text{FeO}(s)$	-272.04	60.75	-251.43	$\text{N}_2\text{O}_4(s)$	-35.05	150.29	99.60
$\text{Fe}(\text{OH})_2(s)$	-574.04	87.86	-491.97	$\text{N}_2\text{O}_4(g)$	9.08	304.38	97.79
$\text{Fe}_2\text{O}_3(s)$	-825.50	87.40	-743.52	$\text{NO}_3^-(aq)$	-205.0	146.4	-108.74
$\text{FeCl}_2(s)$	-341.83	117.95	-302.34	$\text{ClNO}(g)$	51.71	261.68	66.10
Lead				Oxygen			
$\text{Pb}(s)$	0	64.78	0	$\text{O}_2(g)$	0	205.15	0
$\text{Pb}^{2+}(aq)$	-1.7	10.5	-24.43	$\text{O}_2(aq)$	-11.7	110.9	16.4
$\text{PbCl}_2(s)$	-359.41	135.98	-314.12	$\text{O}_3(g)$	142.67	238.93	163.18

	ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol		ΔH_f° kJ/mol	S° J/K·mol	ΔG_f° kJ/mol
H ₂ O(l)	-285.83	69.95	-237.14	Na(l)	2.41	57.86	0.50
H ₂ O(g)	-241.83	188.83	-228.58	Na ⁺ (aq)	-240.12	59.0	-261.90
OH ⁻ (aq)	-229.99	-10.75	-157.24	NaCl(s)	-411.12	72.12	-384.02
H ₂ O ₂ (aq)	-191.17	143.9	-134.03	NaBr(s)	-361.41	86.82	-349.27
Phosphorus				NaOH(s)	-425.93	64.44	-379.74
P(s) (white)	0	41.08	0	Na ₂ CO ₃ (s)	-1130.8	138.80	-1048.0
PH ₃ (g)	5.44	210.24	7.19	NaHCO ₃ (s)	-950.81	101.7	-851.0
PCl ₃ (g)	-288.70	311.68	-269.61	NaNO ₃ (s)	-467.85	116.52	-367.00
PCl ₅ (g)	-360.18	364.29	-290.27	Sulfur			
P ₄ O ₁₀ (s)	-3009.9	228.78	-2723.3	S(s) (α)	0	32.06	0
H ₃ PO ₄ (aq)	-1288.3	158.2	-1142.5	S ²⁻ (aq)	33.1	-14.6	85.8
H ₂ PO ₄ ⁻ (aq)	-1296.3	90.4	-1130.3	HS ⁻ (aq)	-17.6	62.8	12.08
HPO ₄ ²⁻ (aq)	-1292.1	-33.5	-1089.2	H ₂ S(g)	-20.50	205.76	-33.33
PO ₄ ³⁻ (aq)	-1277.4	-222	-1018.7	H ₂ S(aq)	-39.7	121	-27.83
Potassium				SO ₂ (g)	-296.84	248.21	-300.12
K(s)	0	64.67	0	SO ₂ (aq)	-322.98	161.9	-300.68
K(l)	2.27	71.40	0.26	HSO ₃ ⁻ (aq)	-626.22	139.7	-527.73
K(g)	89.00	160.34	60.48	SO ₃ ²⁻ (aq)	-635.5	-29	-486.5
K ⁺ (aq)	-252.38	102.5	-283.27	SO ₃ (g)	-395.76	256.77	-371.02
KCl(s)	-436.68	82.55	-408.76	HSO ₄ ⁻ (aq)	-887.34	131.8	-755.91
KClO ₃ (s)	-397.73	143.1	-296.25	SO ₄ ²⁻ (aq)	-909.27	20.1	-744.53
KBr(s)	-393.80	95.94	-380.43	SO ₂ Cl ₂ (g)	-354.80	311.10	-310.32
KNO ₃ (s)	-494.63	133.05	-394.86	S ₂ Cl ₂ (l)	-58.16	223.84	-39.27
KOH(s)	-424.72	78.91	-378.90	Tin			
Selenium				Sn(s)	0	51.55	0
Se(s)	0	42.44	0	SnO(s)	-285.8	56.5	-256.9
H ₂ Se(g)	29.7	219.02	15.9	SnO ₂ (s)	-580.7	52.3	-519.6
Silicon				SnCl ₄ (l)	-511.3	258.6	-440.1
Si(s)	0	18.82	0	Zinc			
SiH ₄ (g)	34.31	204.65	56.83	Zn(s)	0	41.72	0
SiF ₄ (g)	-1614.94	282.76	-1572.71	Zn ²⁺ (aq)	-153.89	-112.1	-147.06
SiCl ₄ (g)	-662.75	330.94	-662.78	ZnCO ₃ (s)	-812.78	82.4	-731.52
SiO ₂ (s)	-905.49	50.05	-853.64	ZnCl ₂ (s)	-415.05	111.46	-369.40
Silver				ZnO(s)	-348.28	43.64	-318.30
Ag(s)	0	42.55	0	ZnS(s)	-205.98	57.7	-201.29
Ag ⁺ (aq)	105.58	72.68	77.11				
AgCl(s)	-127.07	96.2	-109.79				
Ag ₂ CO ₃ (s)	-505.8	167.4	-436.8				
Ag ₂ O(s)	-31.05	121.3	-11.20				
Sodium							
Na(s)	0	51.46	0				

Appendix B AQUEOUS EQUILIBRIUM CONSTANTS

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 ₃ O ₃ H	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}
aniline	C ₆ H ₅ NH ₂		4.0×10^{-10}
ethanolamine	HOC ₂ H ₄ NH ₂	HOCH ₂ CH ₂ NH ₂	3.1×10^{-5}
ethylamine	C ₂ H ₅ NH ₂	CH ₃ CH ₂ NH ₂	4.3×10^{-4}
hydrazine	N ₂ H ₄	H ₂ NNH ₂	1.0×10^{-6}
hydroxylamine	HONH ₂		9.1×10^{-9}
imidazole	C ₃ H ₄ N ₂		9.8×10^{-8}
methylamine	CH ₃ NH ₂		4.4×10^{-4}
piperidine	C ₅ H ₁₀ NH		1.3×10^{-3}
pyridine	C ₅ H ₅ N		1.7×10^{-9}
triethylamine	(C ₂ H ₅) ₃ N	(CH ₃ CH ₂) ₃ N	5.2×10^{-4}

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(II) iodate	Hg(IO ₃) ₂	3.2×10^{-13}
calcium sulfate	CaSO ₄	4.9×10^{-5}	silver bromide	AgBr	5.4×10^{-13}
copper(I) bromide	CuBr	6.3×10^{-9}	silver carbonate	Ag ₂ CO ₃	8.5×10^{-12}
copper(I) chloride	CuCl	1.7×10^{-7}	silver chloride	AgCl	1.8×10^{-10}
copper(I) iodide	CuI	1.3×10^{-12}	silver iodide	AgI	8.5×10^{-17}
gold(I) chloride	AuCl	2.0×10^{-13}	silver oxalate	Ag ₂ C ₂ O ₄	5.4×10^{-12}
iron(II) carbonate	FeCO ₃	3.1×10^{-11}	silver sulfate	Ag ₂ SO ₄	1.2×10^{-5}
iron(II) hydroxide	Fe(OH) ₂	4.9×10^{-17}	zinc carbonate	ZnCO ₃	1.5×10^{-5}

Complex Formation Constants, K_f

Formula	K_f	Formula	K_f
Ag(NH ₃) ₂ ⁺	1.1×10^7	Cu(NH ₃) ₄ ²⁺	2.1×10^{13}
Ag(SCN) ₄ ³⁻	1.2×10^{10}	Fe(CN) ₆ ⁴⁻	7.9×10^{36}
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(NH ₃) ₆ ²⁺	5.5×10^8
Cd(CN) ₄ ²⁻	6.0×10^{18}	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**

1. F T T F T
2. T F F T T
3. b and e
4. a. 38.00 kJ b. 33.9 kJ
5. a. 0.33 kJ b. 1.52 kJ c. 1.6 kJ d. 4.72 kJ e. 8.2 kJ
6. 24.5 kJ

Chapter 35

1. T T T T T F
2. T T F F F T
3. 61%, 24%
4. a. 1.61 g b. 0.470 g c. 1.14 g
5. 0.70 g

Chapter 36

1. F T F T F
2. 0.0278 g
3. 1.79 Torr
4. 7.9%
5. a. E b. D c. H d. vaporization

Chapter 37

1. F T F F F F
2. F F F F T F
3. a. dispersion b. dispersion c. dispersion, dipole-dipole d. dispersion, dipole-dipole
4. a. dispersion (strongest), dipole-dipole hydrogen bonding (strongest) b. dispersion c. dispersion, dipole-dipole, d. dispersion
5. a. HF, H₃CNH₂ b. all c. HF d. PBr₃
6. a. HBr, dispersion, dipole-dipole; Br₂, dispersion; HCl, dispersion, dipole-dipole
b. dispersion: Br₂ > HBr > HCl; dipole-dipole: HCl > HBr > Br₂ (nonpolar)
c. Br₂ > HBr > HCl
7. a. H₂CBr₂ b. C₂H₄ c. C₂H₄
8. a. AsCl₃ b. Cl₂CO c. H₃CGeH₃
9. SiCl₄
10. HCl, PH₃, CH₄

Chapter 38

1. F T T F F T
2. bcc: 2 fcc: 4

D-2

- 4
- four anions, eight cations
- two cations, four anions
- a. covalent network b. molecular c. Group 18 d. ionic network
e. metallic network f. ionic network

Chapter 39

- T T T T T
- F F T F F
- a. ion-dipole b. dispersion, hydrogen bonding, dipole-dipole c. dispersion, dipole-induced dipole
d. dispersion, hydrogen bonding, dipole-dipole
- a. dispersion, dipole-dipole b. dispersion, dipole-induced dipole c. dispersion, dipole-induced dipole
d. dispersion, dipole-dipole
- MgO
- a. $\Delta H_{\text{vap}}^{\circ}$ b. $\Delta H_{\text{soln}}^{\circ}$ c. $\Delta H_{\text{hyd}}^{\circ}$ d. $\Delta H_{\text{vap}}^{\circ}$, $\Delta H_{\text{sub}}^{\circ}$, $\Delta H_{\text{lat}}^{\circ}$
- a. 33.9 kJ b. -39.8 kJ
- $\Delta H_{\text{vap}}^{\circ} = 44.72 \text{ kJ}$ $\Delta H_{\text{hyd}}^{\circ} = -61.04 \text{ kJ}$ $\Delta H_{\text{soln}}^{\circ} = -16.32 \text{ kJ}$
- $\text{ZnCl}_2(\text{s}) \rightleftharpoons \text{Zn}^{2+}(\text{aq}) + 2 \text{Cl}^{-}(\text{aq})$ $\Delta H_{\text{soln}}^{\circ} = -73.16 \text{ kJ}$ exothermic

Chapter 40

- T F F T T
- a. disfavored b. disfavored c. can be favored or disfavored
- a. $\text{CH}_3\text{OH}(\text{l})$ b. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3(\text{g})$
- a. H_2O_2 , $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ 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

- T F F F F
- 0.019 atm
- 0.91 g

Chapter 42

- 0.0018 mol
- a. 31.9% b. 27.0%
- 47.2% C_6H_6 , 33.7% C_5H_{12} , 19.1% C_2Cl_6
- 3.08 g
- 0.893 m
- a. 4.5 M b. 5.1 m c. 8.4 mol%
- a. 0.547% b. 3.50% 0.302 M

Chapter 43

- F F T T
- a. 0.52 °C b. -0.52 °C

- 4.9 g
- 0.00108 atm

Chapter 44

- FFFFTTTF
- 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
- 723.5 J/K
- 80.70 J/K
- a. 4 b. 5

Chapter 45

- TTTTFT
- FTTFT
- $\text{Ne}(g)$, $\text{H}^+(aq)$, $\text{Al}(s)$
- a. -1,104.14 kJ b. -143.21 J/K c. -1,061.44 kJ
- a. -507.45 kJ b. 29.55 J/K c. -516.26 kJ
- a. -620.6 kJ b. -203.4 J/K c. -560.0 kJ
- a
- 530.94 kJ
- 92.34 kJ
- 606.60 kJ

Chapter 46

- TTFTTT
- 113 kJ
- a. $\Delta H_{\text{vap}}^\circ = 38.00 \text{ kJ}$ $\Delta S_{\text{vap}}^\circ = 113.0 \text{ J/K}$ b. 336.3 K
- a. $\Delta H_{\text{soln}}^\circ = -20.28 \text{ kJ}$ $\Delta S_{\text{soln}}^\circ = -96.2 \text{ J/K}$ b. 13.7 kJ
- a. $Q = \frac{[\text{H}^+]^2 [\text{NO}_3^-]^2}{P(\text{N}_2\text{O}_5)}$ b. $Q = \frac{[\text{Mg}^{2+}] P(\text{CO}_2)}{[\text{H}^+]^2}$ c. $Q = \frac{P(\text{H}_2\text{S})}{[\text{HF}]^2}$
- 0.00764
- 544
- a. 4.20 kJ b. reverse
- a. 5.05 kJ b. reverse

Chapter 47

- TTTF
- b
- 9.23
- 2.61×10^{-10}
- a. $4.122 \times 10^{-4} \text{ atm}$ b. $8.098 \times 10^{-3} \text{ atm}$
- 0.0148 M

Chapter 48

1. F T T T T 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. $\text{speed} = -\frac{\Delta[\text{HS}^-]}{\Delta t} = -\frac{1}{3} \frac{\Delta[\text{ClO}^-]}{\Delta t} = \frac{\Delta[\text{HSO}_3^-]}{\Delta t} = \frac{1}{3} \frac{\Delta[\text{Cl}^-]}{\Delta t}$

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

1. F T F T F F T T

2. T F F F T

3. T T F T

4. a. $\text{rate} = k [\text{ClO}]^2$ b. The concentration of ClO is decreasing at a rate of 2.0×10^{-5} (mol/L)/s. The concentrations of Cl_2 and O_2 are each increasing at a rate of 1.0×10^{-5} (mol/L)/s.5. a. $\text{rate} = k [\text{C}_2\text{H}_5\text{Cl}]$ b. 0.42 (mol/L)/s c. 0.15 s6. a. $\text{rate} = k [\text{H}_2\text{O}] [\text{N}_2\text{O}_4]$ b. 801 (L/mol)/s

7. a. 21 s b. 0.0263 mol/L c. 0.0041 mol/L d. 24%

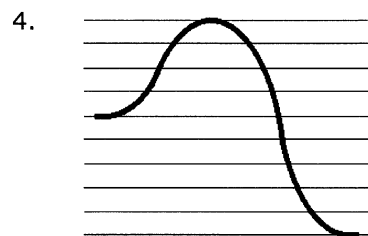
8. a. 5,350 s b. 1.27×10^{-4} mol/L c. 4.3×10^{-5} mol/L d. 25%

9. a. 0.016 mol/L b. 0.020 mol/L c. 38%

10. 683 s^{-1} **Chapter 50**

1. F F F F T

2. F T T T T

3. a. $\text{rate} = k [\text{ClNO}] [\text{NO}_2]$ b. NO, NO_2 c. both

5. a. D b. B - C c. D - C d. endothermic e. endothermic

6. 220. kJ

7. There is a very high E_a in the first step.**Chapter 51**

1. T T F T F F T

2. a. 2.92×10^{-6} b. 1.71×10^{-3}

3. 3.19

4. 4.12

5. 6.5×10^{-8}

- 314
- $P(\text{H}_2) = 0.214 \text{ atm}$; total $P = 0.541 \text{ atm}$

Chapter 52

- $P(\text{C}_2\text{H}_5\text{Cl}) = 0.481 \text{ atm}$; $P(\text{C}_2\text{H}_4) = P(\text{HCl}) = 8.50 \times 10^{-4} \text{ atm}$
- $P(\text{Cl}_2) = 0.83 \text{ atm}$; $P(\text{BrCl}) = 1.34 \text{ atm}$
- $[\text{Mg}^{2+}] = 0.00484 \text{ M}$; $[\text{Ba}^{2+}] = 0.00116 \text{ M}$
- $[\text{CO}_2] = 0.028 \text{ M}$; $[\text{F}^-] = 0.017 \text{ M}$; $[\text{CO}_3^{2-}] = 4.4 \times 10^{-6} \text{ M}$; $[\text{HF}] = 8.8 \times 10^{-6} \text{ M}$
- $P(\text{N}_2\text{O}) = 0.194 \text{ atm}$; $P(\text{Cl}_2) = 0.294 \text{ atm}$; $P(\text{Cl}_2\text{O}) = 0.91 \text{ atm}$; $P(\text{N}_2) = 1.11 \text{ atm}$

Chapter 53

- T F F F
- a. left b. left c. right d. no effect
- a. no effect b. left c. no effect d. right
- a. left b. left c. no effect d. no effect
- a and c

Chapter 54

- T T F F T
- F T F T F
- F F T F T
- T T F T T
- $\Delta G^\circ = 80.8 \text{ kJ}$; $K_w = 2.43 \times 10^{-14}$; pH 6.81
- a. F^- b. HBr c. H_2PO_4^-
- a. ClO_2^- b. HCN c. NH_3
- water, hydrogen oxalate ion, dihydrogen arsenate ion
- a. 0.00334 M b. 2.48 c. 11.52
- a. $8.50 \times 10^{-4} \text{ M}$ b. 3.07 c. 10.93
- 2.03
- 11.26
- 0.21 g
- 0.038 L

Chapter 55

- T F T T F
- $\text{HBrO}(aq) \rightleftharpoons \text{H}^+(aq) + \text{BrO}^-(aq)$ $K_a = \frac{[\text{H}^+][\text{BrO}^-]}{[\text{HBrO}]}$
 - $\text{HN}_3(aq) \rightleftharpoons \text{H}^+(aq) + \text{N}_3^-(aq)$ $K_a = \frac{[\text{H}^+][\text{N}_3^-]}{[\text{HN}_3]}$
- $\text{H}_3\text{AsO}_4(aq) \rightleftharpoons \text{H}^+(aq) + \text{H}_2\text{AsO}_4^-(aq)$
 $\text{H}_2\text{AsO}_4^-(aq) \rightleftharpoons \text{H}^+(aq) + \text{HAsO}_4^{2-}(aq)$
 $\text{HAsO}_4^{2-}(aq) \rightleftharpoons \text{H}^+(aq) + \text{AsO}_4^{3-}(aq)$
- nitric acid, chlorous acid

5. $\text{HP}_2\text{O}_7^{3-}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{P}_2\text{O}_7^{4-}(\text{aq}) \quad K_{a4} = \frac{[\text{H}^+][\text{P}_2\text{O}_7^{4-}]}{[\text{HP}_2\text{O}_7^{3-}]}$
6. $[\text{C}_3\text{H}_7\text{CO}_2\text{H}] = 0.131 \text{ M}$; $[\text{H}^+] = [\text{C}_3\text{H}_7\text{CO}_2^-] = 0.0014 \text{ M}$; pH 2.85; 1.1% diss
7. $[\text{ClCH}_2\text{CO}_2\text{H}] = 0.0273 \text{ M}$; $[\text{H}^+] = [\text{ClCH}_2\text{CO}_2^-] = 0.0062 \text{ M}$; pH 2.21; 19% diss
8. 2.41
9. $K_{a1} = 6.8 \times 10^{-5}$ $\Delta G^\circ = 24 \text{ kJ}$
10. $[\text{H}_2\text{C}_2\text{O}_4] = 0.065 \text{ M}$; $[\text{H}^+] = [\text{HC}_2\text{O}_4^-] = 0.059 \text{ M}$; 48% diss; $[\text{C}_2\text{O}_4^{2-}] = 5.4 \times 10^{-5} \text{ M}$
11. 1.33
12. Strongest, HClO_3 ; weakest, HIO
13. $\Delta H^\circ = 43.5 \text{ kJ}$ $\Delta S^\circ = -30.6 \text{ J/K}$ endothermic: Expect K_a greater at 70. °C.
 $\Delta G^\circ (70. \text{ }^\circ\text{C}) = 54.0 \text{ kJ}$ $K_a (70. \text{ }^\circ\text{C}) = 5.97 \times 10^{-9}$ K_a is greater at 70. °C compared to
the value at 25 °C (6.2×10^{-10}), as expected.
14. $[\text{H}^+] = 2.4 \times 10^{-4}$ pH = 3.62

Chapter 56

1. T T T F F T
2. a. $\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{CH}_3\text{NH}_3^+(\text{aq}) \quad K_b = \frac{[\text{OH}^-][\text{CH}_3\text{NH}_3^+]}{[\text{CH}_3\text{NH}_2]}$
b. $\text{C}_6\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{C}_6\text{H}_5\text{NH}_3^+(\text{aq}) \quad K_b = \frac{[\text{OH}^-][\text{C}_6\text{H}_5\text{NH}_3^+]}{[\text{C}_6\text{H}_5\text{NH}_2]}$
3. $[\text{C}_5\text{H}_5\text{N}] = 0.0143 \text{ M}$; $[\text{OH}^-] = 4.9 \times 10^{-6} \text{ M}$; $[\text{C}_5\text{H}_5\text{NH}^+] = 4.9 \times 10^{-6} \text{ M}$; pOH = 5.31; pH = 8.69 or 8.70
4. $[(\text{C}_2\text{H}_5)_3\text{N}] = 0.0267 \text{ M}$; $[\text{OH}^-] = 0.0037 \text{ M}$; $[(\text{C}_2\text{H}_5)_3\text{NH}^+] = 0.0037 \text{ M}$; pH = 11.57; 12% diss
5. 6.7 g
6. a. $\text{HONH}_3^+(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HONH}_2(\text{aq}) \quad K_a = \frac{[\text{H}^+][\text{HONH}_2]}{[\text{HONH}_3^+]}$
b. $\text{CN}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{HCN}(\text{aq}) \quad K_b = \frac{[\text{OH}^-][\text{HCN}]}{[\text{CN}^-]}$
7. a. 1.4×10^{-11} b. 1.0×10^{-12} c. 2.3×10^{-11} d. 7.7×10^{-12}
8. a. $K_a = 8.9 \times 10^{-8}$; $K_b = 2.0 \times 10^{-12}$
b. $K_a = 4.8 \times 10^{-9}$; $K_b = 4.2 \times 10^{-12}$
c. $K_a = 4.5 \times 10^{-13}$; $K_b = 1.6 \times 10^{-7}$
9. $[\text{ClO}^-] = 0.00544 \text{ M}$; $[\text{OH}^-] = 4.2 \times 10^{-5} \text{ M}$; $[\text{HClO}] = 4.2 \times 10^{-5} \text{ M}$; pOH = 4.38; pH = 9.62
10. $[\text{C}_6\text{H}_5\text{NH}_3^+] = 0.00683 \text{ M}$; $[\text{H}^+] = 4.1 \times 10^{-4} \text{ M}$; $[\text{C}_6\text{H}_5\text{NH}_2] = 4.1 \times 10^{-4} \text{ M}$; pH = 3.39
11. 0.0027 atm
12. $\text{Cr}(\text{H}_2\text{O})_6^{3+}(\text{aq}) \rightleftharpoons \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}(\text{aq}) + \text{H}^+(\text{aq})$ OR
 $\text{Cr}(\text{H}_2\text{O})_6^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
13. a. neutral b. acidic c. basic d. basic e. acidic
14. a. neutral b. basic c. acidic d. neutral e. acidic
15. a. acidic b. basic c. acidic d. acidic

Chapter 57

1. T T T F F

- 2.82
- 10.76
- 0.028 mol
- 9.86
- $C_6H_5CO_2H$
- a. 4.89 b. 4.84 c. 4.99
- a. 6.87 b. 6.50 c. 7.21

Chapter 58

- T T F T F
- a. 16.17 mL b. 1.14 c. 1.62 d. 7.00
- a. 1.50 b. 1.81 c. 11.70
- a. 41.44 mL b. 2.42 c. 3.69 d. 8.11
- a. 4.39 b. 8.40 c. 11.84

Chapter 59

- F T F F
- $Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3 OH^{-}(aq)$ $K_{sp} = [Fe^{3+}] [OH^{-}]^3$
 - $CuCrO_4(s) \rightleftharpoons Cu^{2+}(aq) + CrO_4^{2-}(aq)$ $K_{sp} = [Cu^{2+}] [CrO_4^{2-}]$
- $PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2 Br^{-}(aq)$ $K_{sp} = [Pb^{2+}] [Br^{-}]^2$
 - $Ni_3(PO_4)_2(s) \rightleftharpoons 3 Ni^{2+}(aq) + 2 PO_4^{3-}(aq)$ $K_{sp} = [Ni^{2+}]^3 [PO_4^{3-}]^2$
- 1.0×10^{-5} M for MX , 2.9×10^{-4} M for MX_2 , and 0.0014 M for MX_3 . Overall, $MX < MX_2 < MX_3$.
- $\Delta G^\circ = 64.4$ kJ $K_{sp} = 5.14 \times 10^{-12}$
- $$\begin{array}{l} Ag_2C_2O_4(s) \rightleftharpoons 2 Ag^{+}(aq) + C_2O_4^{2-}(aq) \\ C_2O_4^{2-}(aq) + H_2O(l) \rightleftharpoons HC_2O_4^{-}(aq) + OH^{-}(aq) \\ \hline Ag_2C_2O_4(s) + H_2O(l) \rightleftharpoons 2 Ag^{+}(aq) + HC_2O_4^{-}(aq) + OH^{-}(aq) \end{array}$$
 $K = 1.0 \times 10^{-21}$

Chapter 60

- F F F F F T
- a. 5.3×10^{-7} M b. 1.1×10^{-4} M
- a. 3.5×10^{-8} M b. 2.6×10^{-6} M
- $[Pb^{2+}] = 5.3 \times 10^{-5}$ M; $[SO_4^{2-}] = 4.70 \times 10^{-4}$ M
- 2.0×10^{-7} M
- 0.01 M HNO_3
- $Cd^{2+}(aq) + 4 OH^{-}(aq) \rightleftharpoons Cd(OH)_4^{2-}(aq)$ $K_f = \frac{[Cd(OH)_4^{2-}]}{[Cd^{2+}] [OH^{-}]^4}$
 - $Ni^{2+}(aq) + 6 NH_3(aq) \rightleftharpoons Ni(NH_3)_6^{2+}(aq)$ $K_f = \frac{[Ni(NH_3)_6^{2+}]}{[Ni^{2+}] [NH_3]^6}$
- 5.7×10^{-11} M
- 0.0017 M
- $$\begin{array}{l} CuCl(s) \rightleftharpoons Cu^{+}(aq) + Cl^{-}(aq) \\ Cu^{+}(aq) + 4 CN^{-}(aq) \rightleftharpoons Cu(CN)_4^{3-}(aq) \\ \hline CuCl(s) + 4 CN^{-}(aq) \rightleftharpoons Cu(CN)_4^{3-}(aq) + Cl^{-}(aq) \end{array}$$
 $K = 3.4 \times 10^{23}$

Chapter 61

- $\text{S}_2\text{O}_3^{2-}/\text{SO}_4^{2-}$ and HBrO/Br^-
 - $\text{S}_2\text{O}_3^{2-} + 5 \text{H}_2\text{O} \rightarrow 2 \text{SO}_4^{2-} + 10 \text{H}^+ + 8 \text{e}^-$
 $\text{HBrO} + \text{H}^+ + 2 \text{e}^- \rightarrow \text{Br}^- + \text{H}_2\text{O}$
 - $\text{S}_2\text{O}_3^{2-} + 4 \text{HBrO} + \text{H}_2\text{O} \rightarrow 2 \text{SO}_4^{2-} + 6 \text{H}^+ + 4 \text{Br}^-$
 - $\text{S}_2\text{O}_3^{2-}$ is oxidized. HBrO is reduced.
- $\text{Cd}/\text{Cd}(\text{OH})_2$ and $\text{NiO}(\text{OH})/\text{Ni}(\text{OH})_2$
 - $\text{Cd} + 2 \text{OH}^- \rightarrow \text{Cd}(\text{OH})_2 + 2 \text{e}^-$
 $\text{NiO}(\text{OH}) + \text{e}^- + \text{H}_2\text{O} \rightarrow \text{Ni}(\text{OH})_2 + \text{OH}^-$
 - $\text{Cd} + 2 \text{NiO}(\text{OH}) + 2 \text{H}_2\text{O} \rightarrow \text{Cd}(\text{OH})_2 + 2 \text{Ni}(\text{OH})_2$
 - Cd is oxidized. $\text{NiO}(\text{OH})$ is reduced.
- $\text{N}_2\text{O} + 3 \text{H}_2\text{O} \rightarrow 2 \text{HNO}_2 + 4 \text{H}^+ + 4 \text{e}^-$
 $\text{Co}^{3+} + \text{e}^- \rightarrow \text{Co}^{2+}$
 - $\text{N}_2\text{O} + 3 \text{H}_2\text{O} + 4 \text{Co}^{3+} \rightarrow 2 \text{HNO}_2 + 4 \text{H}^+ + 4 \text{Co}^{2+}$
 - Co^{3+} is the oxidizing agent. N_2O is the reducing agent.
- $3 \text{PO}_4^{3-} + 2 \text{Cr} + 2 \text{H}_2\text{O} \rightarrow 2 \text{CrO}_2^- + 3 \text{HPO}_3^{2-} + \text{OH}^-$
 - PO_4^{3-} is the oxidizing agent. Cr is the reducing agent.

Chapter 62

- T F T T T F
- $\text{Co}(\text{s}) \rightarrow \text{Co}^{2+}(\text{aq}) + 2 \text{e}^-$ ---anode
 $\text{AuCl}_4^-(\text{aq}) + 3 \text{e}^- \rightarrow \text{Au}(\text{s}) + 4 \text{Cl}^-(\text{aq})$ ---cathode
 Co is oxidized; AuCl_4^- is reduced.
 - $3 \text{Co}(\text{s}) + 2 \text{AuCl}_4^-(\text{aq}) \rightarrow 3 \text{Co}^{2+}(\text{aq}) + 2 \text{Au}(\text{s}) + 8 \text{Cl}^-(\text{aq})$
 - $\text{Co}(\text{s}) | \text{Co}^{2+}(\text{aq}) || \text{AuCl}_4^-(\text{aq}), \text{Cl}^-(\text{aq}) | \text{Au}(\text{s})$
- Fe/Fe^{3+} and Ag^+/Ag
 - $\text{Fe}(\text{s}) \rightarrow \text{Fe}^{3+}(\text{aq}) + 3 \text{e}^-$ ---anode
 $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$ ---cathode
 Fe is oxidized; Ag^+ is reduced.
 - $\text{Fe}(\text{s}) + 3 \text{Ag}^+(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + 3 \text{Ag}(\text{s})$
- $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2 \text{e}^-$ ---anode
 $2 \text{HClO}_2(\text{aq}) + 6 \text{H}^+(\text{aq}) + 6 \text{e}^- \rightarrow \text{Cl}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{l})$ ---cathode
 Cu is oxidized; HClO_2 is reduced.
 - $3 \text{Cu}(\text{s}) + 2 \text{HClO}_2(\text{aq}) + 6 \text{H}^+(\text{aq}) \rightarrow 3 \text{Cu}^{2+}(\text{aq}) + \text{Cl}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{l})$
- $\text{SO}_3^{2-}(\text{aq}) + 2 \text{OH}^-(\text{aq}) \rightarrow \text{SO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2 \text{e}^-$ ---anode
 $\text{HSnO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \rightarrow \text{Sn}(\text{s}) + 3 \text{OH}^-(\text{aq})$ ---cathode
 - $\text{SO}_3^{2-}(\text{aq}) + \text{HSnO}_2^-(\text{aq}) \rightarrow \text{SO}_4^{2-}(\text{aq}) + \text{Sn}(\text{s}) + \text{OH}^-(\text{aq})$
- $2 \text{CrO}_4^{2-}(\text{aq}) + 8 \text{H}_2\text{O}(\text{l}) + 3 \text{Zn}(\text{s}) + 2 \text{OH}^-(\text{aq}) \rightarrow 2 \text{Cr}(\text{OH})_3(\text{s}) + 3 \text{Zn}(\text{OH})_4^{2-}(\text{aq})$
 - $\text{Zn}(\text{s}) | \text{OH}^-(\text{aq}), \text{Zn}(\text{OH})_4^{2-}(\text{aq}) || \text{OH}^-(\text{aq}), \text{CrO}_4^{2-}(\text{aq}) | \text{Cr}(\text{OH})_3(\text{s}) | \text{Pt}(\text{s})$
- $\text{Hg}(\text{l}) \rightarrow \text{Hg}^{2+}(\text{aq}) + 2 \text{e}^-$ ---anode
 $\text{ClO}_2(\text{g}) + 3 \text{H}^+(\text{aq}) + 3 \text{e}^- \rightarrow \text{HClO}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ ---cathode
 - $\text{Hg}(\text{l}) | \text{Hg}^{2+}(\text{aq}) || \text{H}^+(\text{aq}), \text{HClO}(\text{aq}) | \text{ClO}_2(\text{g}) | \text{Pt}(\text{s})$
- T F F F
- $\Delta G_{1/2}^\circ = -207.92 \text{ kJ}; E_{1/2}^\circ = 1.0775 \text{ V}$

Chapter 63

- a. 0.43 V b. 0.45 V c. 0.81 V
- a. 0.24 V b. 2.73 V c. 0.27 V
- b or d
- a. 2 mol b. 12 mol c. 6 mol
- $E^\circ = 0.38 \text{ V}$ and $\Delta G^\circ = -73 \text{ kJ}$
- 1.50 V
- 0.59 V

Chapter 64

- F T F T T
- a. 1.07 V b. 2 mol c. 1.27 V
- a. 0.92 V b. 3 mol c. 0.90 V
- a. 0.43 V b. 0.30 V c. 1.2×10^{29}
- a. 0.28 V b. 0.47 V c. 2.5×10^{28}
- 0.014 M
- a. decrease b. increase c. increase d. same
- a. same b. increase c. decrease d. increase e. decrease
- a. increase b. increase c. increase d. decrease
- $\Delta G^\circ = -373.34 \text{ kJ}$ and $E^\circ = 1.9347 \text{ V}$

Chapter 65

- F F T F T
- a. exergonic b. exergonic c. endergonic d. endergonic e. exergonic
- a. -0.45 V b. -0.35 V c. 2.4×10^{-46}
- a. -0.04 V, endergonic b. 0.06 V, exergonic
- a. 0.0010 mol b. 0.11 g
- 0.126 g
- 12.2 min

Chapter 66

- T T T F F
- F F T T F
- ${}_{14}^{26}\text{Si} \rightarrow {}_{13}^{26}\text{Al} + {}_1^0\beta$
 - ${}_{109}^{256}\text{Mt} \rightarrow {}_{107}^{252}\text{Bh} + {}_2^4\alpha$
 - ${}_{31}^{67}\text{Ga} + {}_{-1}^0\text{e} \rightarrow {}_{30}^{67}\text{Zn}$
 - ${}_{16}^{35}\text{S} \rightarrow {}_{17}^{35}\text{Cl} + {}_{-1}^0\beta$
 - ${}_{44}^{93m}\text{Ru} \rightarrow {}_{44}^{93}\text{Ru} + \gamma$
 - ${}_{92}^{238}\text{U} \rightarrow {}_{52}^{134}\text{Te} + {}_{40}^{102}\text{Zr} + 2 {}_0^1\text{n}$
- a. ${}^{217}\text{Rn}$ b. ${}^{119}\text{Sn}$ c. ${}^{209}\text{Pb}$ d. ${}^{62}\text{Cu}$
- a. β^- b. α c. β^+ or EC
- a. ${}^{228}\text{Ra}$, ${}^{224}\text{Ra}$ b. ${}^{208}\text{Pb}$

Chapter 67

- a. 2.35×10^{12} Bq b. 63.5 Ci
- 3.09×10^{12} dis/min
- 4.95×10^{-5} g
- a. 115 Ci b. 1.32 Ci
- 1.42 μ g
- 4.86 MBq
- 4.17×10^9 y

Chapter 68

- T F T F
- a. ${}_{86}^{222}\text{Rn} \rightarrow {}_{84}^{218}\text{Po} + {}_2^4\alpha$ b. 540. GJ c. 5.592 MeV
- a. ${}_{6}^{14}\text{C} \rightarrow {}_{7}^{14}\text{N} + {}_{-1}^0\beta$ b. 15.1 GJ c. 0.156 MeV
- a. ${}_{74}^{178}\text{W} + {}_{-1}^0\text{e} \rightarrow {}_{73}^{178}\text{Ta}$ b. 18.5 GJ c. 0.192 MeV
- a. ${}_{35}^{79\text{m}}\text{Br} \rightarrow {}_{35}^{79}\text{Br} + \gamma$ b. 20.1 GJ c. 0.208 MeV
- EC, 1.504 MeV; β^- , 1.311 MeV

Chapter 69

- T F F F T T T
- a. 0.081810 u 76.21 MeV 6.928 MeV/nucleon
b. 0.611075 u 569.2 MeV 8.757 MeV/nucleon
- a. ${}_{92}^{238}\text{U}: {}_{92}^{238}\text{U} + {}_2^4\alpha \rightarrow {}_{94}^{242}\text{Pu} + \gamma$
b. ${}_{19}^{39}\text{K}: {}_{20}^{48}\text{Ca} + \gamma \rightarrow {}_1^1\text{p} + {}_{19}^{39}\text{K}$
- a. ${}_{10}^{\text{B}}: {}_{10}^{\text{B}}(\alpha, \text{p}){}_{13}^{\text{C}}$ b. ${}_{79}^{196}\text{Au}: {}_{79}^{197}\text{Au}(\gamma, \text{n}){}_{79}^{196}\text{Au}$
- a. ${}_{21}^{44}\text{Sc}$ b. ${}_{15}^{32}\text{P}$ c. ${}_{71}^{177}\text{Lu}$
- 180.6 MeV, 17.4 TJ
- ${}_{48}^{110}\text{Cd}$

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 $u = 1.6605 \times 10^{-24}$ g
Avogadro's number	6.022×10^{23}
Pressure units	atm = 760 Torr (exact) bar = 100 kPa (exact) atm = 760 Torr = 1.01325 bar = 101.325 kPa (all exact) atm = 14.7 psi
Gas constant	$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}$
Energy units	$\text{J} = \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} = \text{V} \cdot \text{C}$ cal = 4.184 J (exact) Cal (nutritional) = 4.184 kJ (exact)
Speed of light (in a vacuum)	$c = 3.00 \times 10^8$ m/s
Planck's constant	$h = 6.626 \times 10^{-34}$ J·s
Coulomb	C = 6.242×10^{18} charges
Faraday constant	96,485 C/mol
Mass-energy	$u = 931.5$ MeV