

## Appendix A

THERMODYNAMIC TABLES  
(298.15 K)

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

	$\Delta H_f^\circ$ kJ/mol	$S^\circ$ J/K·mol	$\Delta G_f^\circ$ kJ/mol		$\Delta H_f^\circ$ kJ/mol	$S^\circ$ J/K·mol	$\Delta G_f^\circ$ 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
<b>Copper</b>				$\text{PbS}(s)$	-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	<b>Lithium</b>			
$\text{Cu}^{2+}(aq)$	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	<b>Magnesium</b>			
<b>Fluorine</b>				$\text{Mg}(s)$	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
<b>Hydrogen</b>				<b>Mercury</b>			
$\text{H}_2(g)$	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
<b>Iodine</b>				$\text{HgO}(s)$	-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	<b>Nitrogen</b>			
$\text{I}(g)$	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
<b>Iron</b>				$\text{N}_2\text{H}_4(aq)$	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
<b>Lead</b>				<b>Oxygen</b>			
$\text{Pb}(s)$	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

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



**Appendix D****ANSWERS TO  
END-OF-CHAPTER PROBLEMS****Chapter 1**

- FTFTFFT
- a. 104.6      b. 2,490      c. 0.204
- 98.6 °F, 310.2 K
- 993.6 mph

**Chapter 2**

- TTTTTF
- TTTFTTT
- FTTTT
- a. 116      b. 20      c. 31      d. 50      e.  $^{14}\text{C}$       f.  $^{40}\text{K}$
- a. F      b. Li      c. 5      d. Sg      e. Rb
- a. Ne      b. He      c. 2      d. Cl      e. Pu
- 107.869 u
- 39.0983 u

**Chapter 3**

- FTFTT
- a.  $\text{V}^{3+}$       b.  $\text{P}^{3-}$       c.  $\text{Ga}^{3+}$
- a. 24      b. 39      c. 36
- a. Te      b. Pd      c. Rb

**Chapter 4**

- TTTTFF
- FTFTFF
- TTTFTT
- $\text{KNO}_3$ ,  $\text{Ag}_2\text{SO}_4$ ,  $\text{NH}_4\text{F}$
- $\text{SiO}_2$ ,  $\text{ClF}_3$ ,  $\text{B}_2\text{H}_6$
- $\text{K}_2\text{O}$ ,  $\text{CaCO}_3$
- a. 2+      b. 1-      c. 2-
- a. 2      b. 25      c. 1-
- a. 18      b. 78      c. 1-
- a.  $\text{CuI}$       b.  $\text{C}_4\text{H}_{10}$       c.  $\text{K}_2\text{CrO}_4$       d.  $\text{NI}_3$
- a.  $\text{Se}_2\text{S}_6$       b.  $\text{Ni}(\text{NO}_3)_3$       c.  $\text{H}_2\text{O}_2$       d.  $\text{NaHCO}_3$
- a.  $\text{SO}_3$       b.  $\text{Co}_2(\text{SO}_4)_3$       c.  $\text{NaNO}_2$       d.  $\text{Al}_2\text{O}_3$
- a.  $\text{PCl}_5$       b.  $\text{LiH}$       c.  $\text{Ba}(\text{CH}_3\text{CO}_2)_2$       d.  $\text{Fe}(\text{CN})_3$
- a. lithium nitride      b. chromium(III) perchlorate      c. silicon dioxide      d. methane
- a. chlorine trifluoride      b. ammonium bisulfate or ammonium hydrogen sulfate  
c. copper(II) sulfite      d. mercury(II) nitrate

16. a. iron(II) oxalate      b. potassium phosphate      c. lead(IV) oxide      d. disulfur dichloride  
 17. a. hydrogen sulfide chlorate      b. calcium thiosulfate      c. nitrogen dioxide      d. manganese(III)

**Chapter 5**

1. a. 260.0      b. 96.09      c. 209.98  
 2. a. 301.43 u      b. 166.90 u  
 3. a. 319.1 g      b. 239.6 g      c. 153.81 g      d. 257.83 g  
 4. 9.689 g  
 5. a. 0.04444 mol      b.  $1.606 \times 10^{23}$  C atoms  
 6. a. 33.36%      b. 43.71%      c. 28.11%  
 7. a.  $\text{CHF}_2$       b.  $\text{K}_4\text{P}_2\text{O}_7$       c.  $\text{SCl}$       d.  $\text{C}_2\text{H}_5$   
 8. a.  $\text{BCl}$       b.  $\text{B}_4\text{Cl}_4$   
 9. a.  $\text{H}_2\text{SiF}$       b.  $\text{H}_4\text{Si}_2\text{F}_2$

**Chapter 6**

1. a.  $\text{B}_2\text{H}_6 + 6 \text{HF} \rightarrow 2 \text{BF}_3 + 6 \text{H}_2$   
 b.  $\text{PCl}_5 + 4 \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 5 \text{HCl}$   
 c.  $\text{Cl}_2\text{SO} + \text{H}_2\text{O} \rightarrow \text{SO}_2 + 2 \text{HCl}$   
 d.  $2 \text{K}_3\text{AsO}_4 + 3 \text{CaCO}_3 \rightarrow \text{Ca}_3(\text{AsO}_4)_2 + 3 \text{K}_2\text{CO}_3$   
 2. a.  $5 \text{F}_2\text{CO} + 2 \text{SbCl}_5 \rightarrow 5 \text{Cl}_2\text{CO} + 2 \text{SbF}_5$   
 b.  $\text{Fe}_2\text{O}_3 + 6 \text{HBr} \rightarrow 2 \text{FeBr}_3 + 3 \text{H}_2\text{O}$   
 c.  $2 \text{H}_2\text{S} + 3 \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 2 \text{SO}_2$   
 d.  $2 \text{AgNO}_3 + \text{H}_2\text{C}_2\text{O}_4 \rightarrow \text{Ag}_2\text{C}_2\text{O}_4 + 2 \text{HNO}_3$   
 3. a.  $\text{Mg}_2\text{SiO}_4 + 8 \text{HF} \rightarrow 2 \text{MgF}_2 + 4 \text{H}_2\text{O} + \text{SiF}_4$   
 b.  $2 \text{C}_2\text{H}_3\text{Cl} + 5 \text{O}_2 \rightarrow 4 \text{CO}_2 + 2 \text{HCl} + 2 \text{H}_2\text{O}$   
 c.  $\text{PbI}_2 + 2 \text{NaHSO}_4 \rightarrow \text{PbSO}_4 + 2 \text{NaI} + \text{H}_2\text{SO}_4$   
 d.  $\text{K}_2\text{Mo}_2\text{O}_7 + 8 \text{K}_2\text{S} \rightarrow 2 \text{K}_2\text{MoS}_4 + 7 \text{K}_2\text{O}$   
 4. a.  $\text{AlCl}_3 + \text{Na}_3\text{PO}_4 \rightarrow \text{AlPO}_4 + 3 \text{NaCl}$   
 b.  $\text{Co}(\text{CH}_3\text{CO}_2)_2 + (\text{NH}_4)_2\text{S} \rightarrow \text{CoS} + 2 \text{NH}_4\text{CH}_3\text{CO}_2$   
 c.  $\text{ClF}_3 + 4 \text{NaOH} \rightarrow \text{NaClO}_2 + 3 \text{NaF} + 2 \text{H}_2\text{O}$   
 5.  $2 \text{C}_3\text{H}_9\text{Al} + 12 \text{O}_2 \rightarrow 6 \text{CO}_2 + 9 \text{H}_2\text{O} + \text{Al}_2\text{O}_3$   
 6.  $\text{C}_{12}\text{H}_{22}\text{O}_{11} + 12 \text{O}_2 \rightarrow 12 \text{CO}_2 + 11 \text{H}_2\text{O}$   
 7.  $3 \text{Cl}_2 + 6 \text{NaOH} \rightarrow 5 \text{NaCl} + \text{NaClO}_3 + 3 \text{H}_2\text{O}$   
 8. First step:  $\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{CO}_3$   
 Second step:  $\text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$   
 Overall:  $\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$   
 $\text{H}_2\text{CO}_3$  is the intermediate.

**Chapter 7**

1. 8.765 g  
 2. 35.34 g

- 10.2 g
- 66.10 g
- 38.40 g
- 11.6 g
- 194 g

### Chapter 8

- T T T F
- 8.963 g
- a. 19.0 g      b. 23.6 g      c. 10.5 g
- a.  $\text{H}_2\text{S} + 2 \text{H}_2\text{O} + 3 \text{Br}_2 \rightarrow \text{SO}_2 + 6 \text{HBr}$       b. 13.8 g
- 95.6%
- 73.7%

### Chapter 9

- 0.486 M
- 0.0605 M  $\text{BaCl}_2$ , 0.121 M  $\text{Cl}^-$
- 21.8 g
- 74 g
- 11.6 g
- 9.70 mL
- 0.6149 L
- 49.1 g
- 31.99 g  $\text{CaSO}_4$ , 94.4%

### Chapter 10

- T T F F F F T
- $\text{H}_3\text{O}^+$ ,  $\text{H}_5\text{O}_2^+$

### Chapter 11

- F F F F T
- T T F T F
- $\text{Al}(\text{OH})_3$ ,  $\text{CuCl}$ ,  $\text{CaC}_2\text{O}_4$
- $\text{NH}_4\text{CN}$ ,  $\text{Fe}(\text{NO}_3)_3$ ,  $\text{MgSO}_4$ ,  $\text{CuClO}_4$ ,  $\text{K}_2\text{SeO}_3$
- a.  $\text{CaSO}_4$       b.  $\text{CoCO}_3$       c.  $\text{CuC}_2\text{O}_4$       d.  $\text{NiCrO}_4$
- $2 \text{AgNO}_3(\text{aq}) + \text{ZnBr}_2(\text{aq}) \rightarrow 2 \text{AgBr}(\text{s}) + \text{Zn}(\text{NO}_3)_2(\text{aq})$   
 $\text{Ag}^+(\text{aq}) + \text{Br}^-(\text{aq}) \rightarrow \text{AgBr}(\text{s})$
- $(\text{NH}_4)_2\text{CO}_3(\text{aq}) + \text{Mg}(\text{CH}_3\text{CO}_2)_2(\text{aq}) \rightarrow 2 \text{NH}_4\text{CH}_3\text{CO}_2(\text{aq}) + \text{MgCO}_3(\text{s})$   
 $\text{CO}_3^{2-}(\text{aq}) + \text{Mg}^{2+}(\text{aq}) \rightarrow \text{MgCO}_3(\text{s})$
- $\text{Hg}(\text{ClO}_4)_2(\text{aq}) + \text{K}_2\text{S}(\text{aq}) \rightarrow 2 \text{KClO}_4(\text{aq}) + \text{HgS}(\text{s})$   
 $\text{Hg}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) \rightarrow \text{HgS}(\text{s})$
- a.  $\text{AgCl}$ ,  $\text{PbCl}_2$       b.  $\text{K}^+$ ,  $\text{ClO}_4^-$ ,  $\text{NO}_3^-$
- Strong acids:  $\text{HI}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HBr}$       Weak acids:  $\text{HClO}$ ,  $\text{HNO}_2$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{CH}_3\text{CO}_2\text{H}$

11.  $\text{H}^+(\text{aq})$  (or specifically,  $\text{H}_3\text{O}^+(\text{aq})$  and  $\text{H}_5\text{O}_2^+(\text{aq})$ ), and  $\text{NO}_3^-(\text{aq})$   
 12. Ions:  $\text{H}^+(\text{aq})$  (or specifically,  $\text{H}_3\text{O}^+(\text{aq})$  and  $\text{H}_5\text{O}_2^+(\text{aq})$ ), and  $\text{ClO}_2^-(\text{aq})$   
 Neutral molecules:  $\text{HClO}_2(\text{aq})$

**Chapter 12**

- FTTTTF
- TTTTTT
- a. HF      b.  $\text{H}_2\text{C}_2\text{O}_4$       c. HClO      d.  $\text{H}_2\text{SO}_4$
- a. hydrobromic acid      b. nitrous acid      c. arsenic acid      d. hydrocyanic acid
- a.  $\text{LiNO}_3$       b.  $\text{NH}_4\text{Cl}$       c.  $\text{NaCH}_3\text{CO}_2$       d.  $\text{CaI}_2$
- $\text{KOH}(\text{aq}) + \text{HBr}(\text{aq}) \rightarrow \text{KBr}(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
 $\text{OH}^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
- $\text{NaOH}(\text{aq}) + \text{HClO}_2(\text{aq}) \rightarrow \text{NaClO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
 $\text{OH}^-(\text{aq}) + \text{HClO}_2(\text{aq}) \rightarrow \text{ClO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- $\text{NH}_3(\text{aq}) + \text{HF}(\text{aq}) \rightarrow \text{NH}_4\text{F}(\text{aq})$   
 $\text{NH}_3(\text{aq}) + \text{HF}(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{F}^-(\text{aq})$
- a.  $\text{H}_3\text{PO}_4(\text{aq}) + \text{KOH}(\text{aq}) \rightarrow \text{KH}_2\text{PO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
 b.  $\text{H}_3\text{PO}_4(\text{aq}) + 3 \text{KOH}(\text{aq}) \rightarrow \text{K}_3\text{PO}_4(\text{aq}) + 3 \text{H}_2\text{O}(\text{l})$
- $\text{Na}_2\text{SO}_3(\text{aq}) + 2 \text{HClO}_4(\text{aq}) \rightarrow 2 \text{NaClO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{SO}_2(\text{g})$   
 $\text{SO}_3^{2-}(\text{aq}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{SO}_2(\text{g})$
- $\text{BaCO}_3(\text{s}) + 2 \text{HNO}_3(\text{aq}) \rightarrow \text{Ba}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$   
 $\text{BaCO}_3(\text{s}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{Ba}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
- $\text{CdS}(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{CdCl}_2(\text{aq}) + \text{H}_2\text{S}(\text{g})$   
 $\text{CdS}(\text{s}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{Cd}^{2+}(\text{aq}) + \text{H}_2\text{S}(\text{g})$

**Chapter 13**

- TFFTFFF
- a. H: +1    As: +3    O: -2      b. Na: +1    O: -1/2      c. Sn: +2    Cl: -1  
 d. S: +1    O: -2      e. H: +1    B: +3    F: -1
- a. Ca: +2    Si: +4    O: -2      b. C: -1/3    H: +1    Cl: -1      c. H: +1    S: -2/3  
 d. Te: +4    O: -2    F: -1      e. N: -3    H: +1    Se: +6    O: -2
- a.  $\text{Cr}^{2+}$       b.  $\text{MnO}_4^-$       c.  $\text{MnO}_4^-$       d.  $\text{Cr}^{2+}$
- a.  $\text{Br}_2$       b.  $\text{SO}_4^{2-}$       c.  $\text{SO}_4^{2-}$       d.  $\text{Br}_2$
- a.  $\text{V}^{2+}$       b.  $\text{IO}_6^{5-}$       c.  $\text{IO}_6^{5-}$       d.  $\text{V}^{2+}$

**Chapter 14**

- a.  $\text{H}_3\text{PO}_2 + 2 \text{Ni}^{2+} + 2 \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 2 \text{Ni} + 4 \text{H}^+$   
 b.  $3 \text{H}_2\text{O} + 3 \text{Sn} + 3 \text{OH}^- + \text{N}_2 \rightarrow 3 \text{HSnO}_2^- + 2 \text{NH}_3$   
 c.  $\text{PbO}_2 + 2 \text{VO}^{2+} + 4 \text{OH}^- \rightarrow \text{PbO} + \text{V}_2\text{O}_5 + 2 \text{H}_2\text{O}$   
 d.  $2 \text{HNO}_2 + 2 \text{H}^+ + 2 \text{Cl}^- \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} + 2 \text{HClO}$
- a.  $2 \text{Au}^+ + \text{NO}_2^- + \text{H}_2\text{O} \rightarrow 2 \text{Au} + \text{NO}_3^- + 2 \text{H}^+$   
 b.  $2 \text{S}_2\text{O}_6^{2-} + 2 \text{H}_2\text{O} + \text{IO}^- \rightarrow 4 \text{SO}_2 + \text{IO}_3^- + 4 \text{OH}^-$



- c.  $2 \text{BrO}_3^- + 8 \text{OH}^- + 5 \text{Zn} \rightarrow \text{Br}_2 + 4 \text{H}_2\text{O} + 5 \text{ZnO}_2^{2-}$   
 d.  $4 \text{OH}^- + 3 \text{NiO}_2 + 2 \text{Cr}(\text{OH})_3 \rightarrow 3 \text{Ni}(\text{OH})_2 + 2 \text{CrO}_4^{2-} + 2 \text{H}_2\text{O}$
3. a.  $\text{H}_2\text{C}_2\text{O}_4/\text{CO}_2$ ,  $\text{Hg}^{2+}/\text{Hg}$ , 2 electrons transferred  
 b.  $\text{MnO}_4^-/\text{MnO}_2$ ,  $\text{Tl}^+/\text{Tl}^{3+}$ , 6 electrons transferred  
 c.  $\text{Sb}/\text{SbO}^+$ ,  $\text{H}_5\text{IO}_6/\text{IO}_3^-$ , 6 electrons transferred

**Chapter 15**

- 7.14 g  $\text{CaC}_2\text{O}_4$
- 22.7 g  $\text{KNO}_3$
- 7.91 g  $\text{Ba}(\text{ClO}_3)_2$
- 64%
- 0.1669 g
- 0.5378 g, 6.72%
- 20.2 mg, 88.6%

**Chapter 16**

- T F T F T F
- 0.058 mol
- 0.585 atm, 0.593 bar
- 3.06 L
- 1.52 atm
- $\text{Cl}_2$ ,  $\text{BF}_3$ ,  $\text{SF}_4$
- 0.7598 g/L
- $\text{C}_2\text{F}_4$
- 0.787 atm total, 31.9%  $\text{SO}_2$
- 53.7%
- 0.878 g/L

**Chapter 17**

- T T T T F F
- 6.08 L
- 158 Torr
- 270 L
- 1.99 atm
- $a < d < c < b < e$
- 592 m/s
- 1,770 m/s
- 87.8 g/mol

**Chapter 18**

- T F F F T
- T T F F T
- 140 kJ

4.  $\Delta T = 12\text{ }^{\circ}\text{C}$ , final  $T = 31\text{ }^{\circ}\text{C}$

**Chapter 19**

1. F T T F T T
2. For example:  $\text{He}(g)$ ,  $\text{Ne}(g)$ ,  $\text{Ar}(g)$ ,  $\text{Kr}(g)$ ,  $\text{Xe}(g)$ ,  $\text{Rn}(g)$ ,  $\text{H}_2(g)$ ,  $\text{N}_2(g)$ ,  $\text{O}_2(g)$ ,  $\text{F}_2(g)$ ,  $\text{Cl}_2(g)$ ,  $\text{Br}_2(l)$ ,  $\text{I}_2(s)$ ,  $\text{C}(\text{graph})$
3. a.  $\text{Zn}(s) + \text{N}_2(g) + 3 \text{O}_2(g) \rightarrow \text{Zn}(\text{NO}_3)_2(s)$   
 b.  $2 \text{C}(\text{graph}) + 5/2 \text{H}_2(g) + 1/2 \text{I}_2(s) \rightarrow \text{C}_2\text{H}_5\text{I}(l)$   
 c.  $1/2 \text{Br}_2(l) + 1/2 \text{N}_2(g) + 1/2 \text{O}_2(g) \rightarrow \text{BrNO}(l)$   
 d.  $\text{Hg}(l) + 1/2 \text{O}_2(g) \rightarrow \text{HgO}(s)$   
 e.  $2 \text{C}(\text{graph}) + 3 \text{F}_2(g) + \text{Xe}(g) \rightarrow \text{C}_2\text{F}_6\text{Xe}(s)$
4. 160.28 kJ, endothermic
5. -2,844.94 kJ, exothermic
6.  $\text{Ca}^{2+}(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{CaCO}_3(s)$  13.1 kJ, endothermic
7. -88.33 kJ
8. 646.24 kJ
9. -269 kJ
10. -1,786 Cal
11. -86.3 kJ
12. -193 kJ
13. 103 g

**Chapter 20**

1. F F F T T
2. F F T F T
3.  $5.45 \times 10^{-16}$  J
4. 587 kJ
5. 120. kJ
6.  $-2.42 \times 10^{-19}$  J
7.  $-3.49 \times 10^{-17}$  J
8.  $2.91 \times 10^{-19}$  J
9.  $5.01 \times 10^{-19}$  J, 397 nm
10.  $-1.55 \times 10^{-19}$  J, 1,280 nm

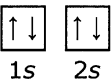
**Chapter 21**

1. T T T T T T
2. T T T T F F
3. Different colors arise from different transition energies. This will cause absorption of photons which have different energies and different wavelengths.
4. a.  $l$       b.  $m_l$
5. a. 4      b. 9      c. 5
6. a. 25      b. 6      c.  $s$
7.  $2d, 4g$

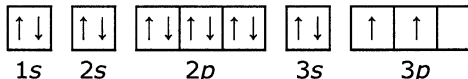
**Chapter 22**

1. T F F T T

2. F T T T F

3. a.  $1s^2 2s^2$ b.  $1s^2 2s^2 2p^6 3s^2 3p^2$ 4. a. 

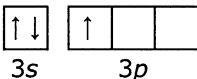
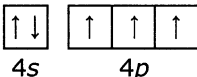
Be has zero unpaired electrons.

b. 

Si has two unpaired electrons.

**Chapter 23**

1. T T F F F F

2. S:  $1s^2 2s^2 2p^6 3s^2 3p^4$      $S^{2-}$ :  $1s^2 2s^2 2p^6 3s^2 3p^6$ 3. Ca:  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$      $Ca^{2+}$ :  $1s^2 2s^2 2p^6 3s^2 3p^6$ 4. a.  $[He]2s^2 2p^3$     b.  $[Kr]5s^2 4d^2$     c.  $[Xe]6s^2 4f^{14} 5d^6$     d.  $[Ar]4s^2 3d^5$ 5. a.  $[He]2s^2 2p^1$     b.  $[Rn]7s^2 5f^{14} 6d^9$     c.  $[Xe]6s^2 4f^{14} 5d^{10} 6p^3$     d.  $[Ar]4s^2 3d^{10} 4p^2$ 6. a.  $[Ar]$     b.  $[Kr]$     c.  $[Ar]3d^5$     d.  $[Rn]$ 7. a.  $[Xe]$     b.  $[Kr]4d^{10}$     c.  $[Xe]4f^{14} 5d^5$     d.  $[Ar]$ 8. 9. 

10. a. 2 valence, 18 core    b. 5 valence, 46 core    c. 4 valence, 78 core    d. 7 valence, 2 core

11. a. Ga    b. 4    c. Rh

12. a. Sn    b. Te    c. P

13. a. 6    b. I    c. Pd

14. a. He    b. K    c. Cl

15. a. N    b. Be    c. O

16. Cl

17.  $Na^+$ **Chapter 24**

1. T T F T F

2. T F T F F

3. Ca,  $Ca^{2+}$ ,  $Mg^{2+}$ 4.  $Al^{3+}$ ,  $Zn^{2+}$ 

5. a. 3    b. 2    c. 5    d. 1    e. 0

6. a. 4    b. 2    c. 0    d. 3    e. 1

7. a. Mo, Ru    b. Ba    c. Mg

8. a. 6    b.  $Bi^{3+}$     c. Ti, Ni, Ge, Se

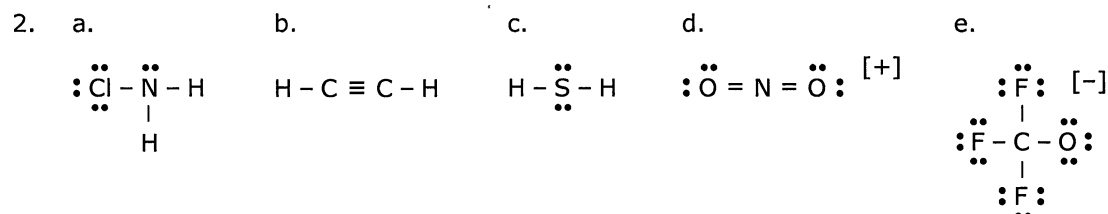
9. Br

10.  $\text{Te}^{2-}$ **Chapter 25**

1. F F T T T F T
2. MgO
3. Si-P
4. N=O
5. a. 153 pm      b. 233 pm      c. 183 pm
6. P
7. As-F
8. Te-I

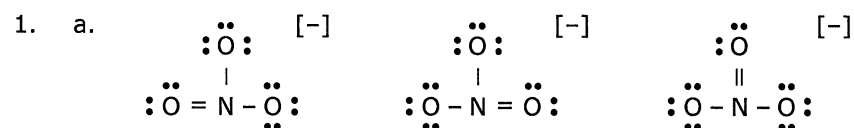
**Chapter 26**

1. T F F F

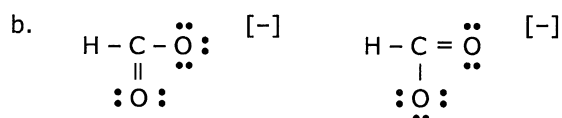


- a. One NCl single bond, two NH single bonds. Three lone pairs on Cl, one lone pair on N.  
 b. Two CH single bonds, one CC triple bond. No lone pairs.  
 c. Two HS single bonds. Two lone pairs on S.  
 d. Two NO double bonds. Two lone pairs on each O.  
 e. Three CF single bonds, one CO single bond. Three lone pairs on each F, three lone pairs on O.
3. a.  $\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{C}=\ddot{\text{O}} \end{array}$       b.  $\begin{array}{c} \text{H}-\ddot{\text{P}}\cdot \\ | \\ \text{H} \end{array}$       c.  $\begin{array}{c} \text{:}\ddot{\text{O}}\text{:}^{[3-]} \\ | \\ \text{:}\ddot{\text{O}}-\text{B}-\ddot{\text{O}}\text{:} \end{array}$       d.  $\begin{array}{c} \text{:}\ddot{\text{F}}\text{:} \quad \text{:}\ddot{\text{F}}\text{:} \\ \diagdown \quad / \\ \text{:}\ddot{\text{F}}-\text{Si}-\ddot{\text{F}}\text{:} \\ / \quad \diagdown \\ \text{:}\ddot{\text{F}}\text{:} \quad \text{:}\ddot{\text{F}}\text{:} \end{array}^{[2-]}$       e.  $\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{C}-\text{C}\equiv\text{N}\text{:} \\ | \\ \text{H} \end{array}$

$\text{PH}_2$  has an odd number of electrons.  $\text{BO}_3^{3-}$  is electron deficient.  $\text{SiF}_6^{2-}$  displays expanded valence.

**Chapter 27**

The average NO bond order is  $4/3$  (1.33).



The average CO bond order is  $3/2$  (1.5).



- c. Two  $\sigma$  bonds and two  $\pi$  bonds.                      d. Three  $\sigma$  bonds and two  $\pi$  bonds.
3. a. The CO triple bond results from one  $\sigma$  and two  $\pi$  interactions. The  $\sigma$  bond arises from (C) $sp$  + (O) $sp$  while the  $\pi$  bonds arise from (C) $2p$  + (O) $2p$ .
- b. The SiH single bonds are  $\sigma$  type and each arises from (Si) $sp^3$  + (H) $1s$ . The SiCl single bond is  $\sigma$  type and arises from (Si) $sp^3$  + (Cl) $3p$ .
- c. The HN single bonds are  $\sigma$  type and each arises from (H) $1s$  + (N) $sp^2$ . The NN double bond results from one  $\sigma$  and one  $\pi$  interaction. The  $\sigma$  bond arises from (N) $sp^2$  + (N) $sp^2$  while the  $\pi$  bond arises from (N) $2p$  + (N) $2p$ .
4. a. The C's are trigonal planar, trigonal planar and linear (left-to-right).
- b. The hybridizations are C  $sp^2$ ; C  $sp^2$ ; C  $sp$  and N  $sp$ .
- c. The CC double bond is composed of one  $\sigma$  bond (from (C) $sp^2$  + (C) $sp^2$ ) and one  $\pi$  bond (from (C) $2p$  + (C) $2p$ ). The CC single bond is  $\sigma$  type and it arises from (C) $sp^2$  + (C) $sp$ . All CH bonds are  $\sigma$  type and arise from (C) $sp^2$  + (H) $1s$ . The CN bond is composed of one  $\sigma$  bond (from (C) $sp$  + (N) $sp$ ) and two  $\pi$  bonds (from (C) $2p$  + (N) $2p$ ).
- d. The lone pair on N is in an  $sp$  hybrid orbital.

### Chapter 32

- $(\sigma_{1s})^2(\sigma_{1s}^*)^1$ , bond order = 0.5, one unpaired electron
- The configuration is  $(\sigma_{2s})^1$  and the bond order is one-half, so it can exist.

### Chapter 33

- F T F T F F T
- $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^3$                       Bond order = 1.5; paramagnetic; one unpaired electron
  - $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p})^2(\pi_{2p})^4(\pi_{2p}^*)^2$                       Bond order = 2; paramagnetic; two unpaired electrons
  - $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^4(\sigma_{2p})^2(\pi_{2p}^*)^1$                       Bond order = 2.5; paramagnetic; one unpaired electron
- $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p})^4(\sigma_{2p})^1$                       Bond order = 2.5; paramagnetic; one unpaired electron
  - $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p})^2(\pi_{2p})^4(\pi_{2p}^*)^4$                       Bond order = 1; diamagnetic; zero unpaired electrons
- Bond order = 2; zero unpaired electrons                      b. Bond order = 0.5; one unpaired electron
  - Bond order = 3; zero unpaired electrons                      d. Bond order = 2.5; one unpaired electron



## 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	$6.022 \times 10^{23}$
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	$C = 6.242 \times 10^{18}$ charges
Faraday constant	96,485 C/mol
Mass-energy	$u = 931.5$ MeV