

logarithm of 100 is 4.605 and the inverse natural logarithm of 4.605 is 100. The inverse natural logarithm of a number is simply e raised to that number:

$$\text{invln } x = e^x$$

$$\text{invln } 3 = e^3 = 20.1$$

The invln of a number can be computed on your calculator. See your calculator manual for specific instructions.

Mathematical Operations Using Logarithms

Because logarithms are exponents, mathematical operations involving logarithms are similar to those involving exponents as follows:

$$\log(a \times b) = \log a + \log b \quad \ln(a \times b) = \ln a + \ln b$$

$$\log \frac{a}{b} = \log a - \log b \quad \ln \frac{a}{b} = \ln a - \ln b$$

$$\log a^n = n \log a \quad \ln a^n = n \ln a$$

C. Quadratic Equations

A quadratic equation contains at least one term in which the variable x is raised to the second power (and no terms in which x is raised to a higher power). A quadratic equation has the following general form:

$$ax^2 + bx + c = 0$$

A quadratic equation can be solved for x using the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Quadratic equations are often encountered when solving equilibrium problems. Here we show how to use the quadratic formula to solve a quadratic equation for x :

$$3x^2 - 5x + 1 = 0 \quad (\text{quadratic equation})$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-(-5) \pm \sqrt{(-5)^2 - 4(3)(1)}}{2(3)}$$

$$= \frac{5 \pm 3.6}{6}$$

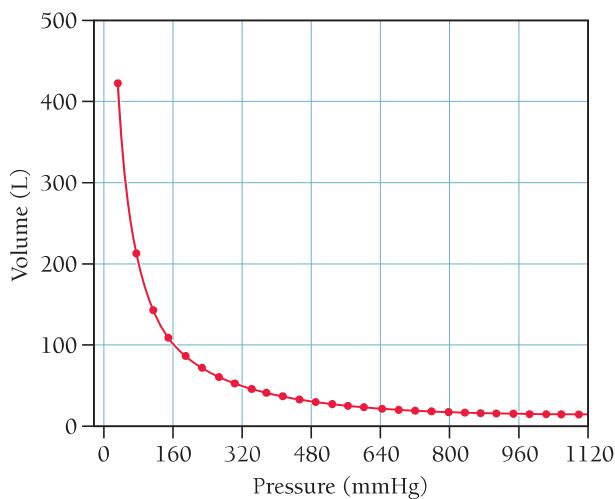
$$x = 1.43 \quad \text{or} \quad x = 0.233$$

As you can see, the solution to a quadratic equation usually has two values. In any real chemical system, one of the values can be eliminated because it has no physical significance. (For example, it may correspond to a negative concentration, which does not exist.)

D. Graphs

Graphs are often used to visually show the relationship between two variables. For example, in Chapter 5 we show

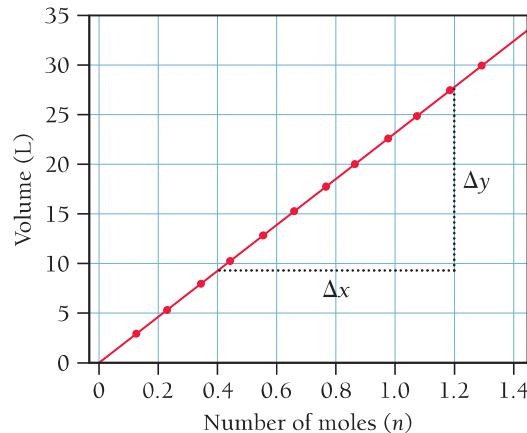
the following relationship between the volume of a gas and its pressure:



▲ **Volume versus Pressure** A plot of the volume of a gas sample—as measured in a J-tube—versus pressure. The plot shows that volume and pressure are inversely related.

The horizontal axis is the x -axis and is normally used to show the independent variable. The vertical axis is the y -axis and is normally used to show how the other variable (called the dependent variable) varies with a change in the independent variable. In this case, the graph shows that as the pressure of a gas sample increases, its volume decreases.

Many relationships in chemistry are *linear*, which means that if you change one variable by a factor of n the other variable will also change by a factor of n . For example, the volume of a gas is linearly related to the number of moles of gas. When two quantities are linearly related, a graph of one versus the other produces a straight line. For example, the graph below shows how the volume of an ideal gas sample depends on the number of moles of gas in the sample:



▲ **Volume versus Number of Moles** The volume of a gas sample increases linearly with the number of moles of gas in the sample.

A linear relationship between any two variables x and y can be expressed by the following equation:

$$y = mx + b$$

where m is the slope of the line and b is the y -intercept. The slope is the change in y divided by the change in x :

$$m = \frac{\Delta y}{\Delta x}$$

For the graph above, we can estimate the slope by simply estimating the changes in y and x for a given interval. For example, between $x = 0.4$ mol and 1.2 mol, $\Delta x = 0.80$ mol and we can estimate that $\Delta y = 18$ L. Therefore the slope is:

$$m = \frac{\Delta y}{\Delta x} = \frac{18 \text{ L}}{0.80 \text{ mol}} = 23 \text{ mol/L}$$

In several places in this book, logarithmic relationships between variables can be plotted in order to obtain a linear relationship. For example, the variables $[A]_t$ and t in the following equation are not linearly related, but the natural logarithm of $[A]_t$ and t are linearly related:

$$\ln[A]_t = -kt + \ln[A]_0$$

$$y = mx + b$$

A plot of $\ln[A]_t$ versus t will therefore produce a straight line with slope $= -k$ and y -intercept $= \ln[A]_0$.

APPENDIX II

Useful Data

A. Atomic Colors

Atomic number:

1



4



5



6



7



8



9



Atomic symbol:

H

Be

B

C

N

O

F

Atomic number:

11



12



14



15



16



17



19



Atomic symbol:

Na

Mg

Si

P

S

Cl

K

Atomic number:

20



29



30



35



53



54



Atomic symbol:

Ca

Cu

Zn

Br

I

Xe

B. Standard Thermodynamic Quantities for Selected Substances at 25 °C

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
<i>Aluminum</i>			
Al(s)	0	0	28.32
Al(g)	330.0	289.4	164.6
Al ³⁺ (aq)	-538.4	-483	-325
AlCl ₃ (s)	-704.2	-628.8	109.3
Al ₂ O ₃ (s)	-1675.7	-1582.3	50.9
<i>Barium</i>			
Ba(s)	0	0	62.5
Ba(g)	180.0	146.0	170.2
Ba ²⁺ (aq)	-537.6	-560.8	9.6
BaCO ₃ (s)	-1213.0	-1134.4	112.1
BaCl ₂ (s)	-855.0	-806.7	123.7
BaO(s)	-548.0	-520.3	72.1
Ba(OH) ₂ (s)	-944.7		
BaSO ₄ (s)	-1473.2	-1362.2	132.2

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
<i>Beryllium</i>			
Be(s)	0	0	9.5
BeO(s)	-609.4	-580.1	13.8
Be(OH) ₂ (s)	-902.5	-815.0	45.5
<i>Bismuth</i>			
Bi(s)	0	0	56.7
BiCl ₃ (s)	-379.1	-315.0	177.0
Bi ₂ O ₃ (s)	-573.9	-493.7	151.5
Bi ₂ S ₃ (s)	-143.1	-140.6	200.4
<i>Boron</i>			
B(s)	0	0	5.9
B(g)	565.0	521.0	153.4
BCl ₃ (g)	-403.8	-388.7	290.1
BF ₃ (g)	-1136.0	-1119.4	254.4
B ₂ H ₆ (g)	36.4	87.6	232.1

—(Continued on the next page)

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
$\text{B}_2\text{O}_3(s)$	-1273.5	-1194.3	54.0
$\text{H}_3\text{BO}_3(s)$	-1094.3	-968.9	90.0
Bromine			
$\text{Br}(g)$	111.9	82.4	175.0
$\text{Br}_2(l)$	0	0	152.2
$\text{Br}_2(g)$	30.9	3.1	245.5
$\text{Br}^-(aq)$	-121.4	-102.8	80.71
$\text{HBr}(g)$	-36.3	-53.4	198.7
Cadmium			
$\text{Cd}(s)$	0	0	51.8
$\text{Cd}(g)$	111.8	77.3	167.7
$\text{Cd}^{2+}(aq)$	-75.9	-77.6	-73.2
$\text{CdCl}_2(s)$	-391.5	-343.9	115.3
$\text{CdO}(s)$	-258.4	-228.7	54.8
$\text{CdS}(s)$	-161.9	-156.5	64.9
$\text{CdSO}_4(s)$	-933.3	-822.7	123.0
Calcium			
$\text{Ca}(s)$	0	0	41.6
$\text{Ca}(g)$	177.8	144.0	154.9
$\text{Ca}^{2+}(aq)$	-542.8	-553.6	-53.1
$\text{CaC}_2(s)$	-59.8	-64.9	70.0
$\text{CaCO}_3(s)$	-1207.6	-1129.1	91.7
$\text{CaCl}_2(s)$	-795.4	-748.8	108.4
$\text{CaF}_2(s)$	-1228.0	-1175.6	68.5
$\text{CaH}_2(s)$	-181.5	-142.5	41.4
$\text{Ca}(\text{NO}_3)_2(s)$	-938.2	-742.8	193.2
$\text{CaO}(s)$	-634.9	-603.3	38.1
$\text{Ca}(\text{OH})_2(s)$	-985.2	-897.5	83.4
$\text{CaSO}_4(s)$	-1434.5	-1322.0	106.5
$\text{Ca}_3(\text{PO}_4)_2(s)$	-4120.8	-3884.7	236.0
Carbon			
$\text{C}(s, \text{graphite})$	0	0	5.7
$\text{C}(s, \text{diamond})$	1.88	2.9	2.4
$\text{C}(g)$	716.7	671.3	158.1
$\text{CH}_4(g)$	-74.6	-50.5	186.3
$\text{CH}_3\text{Cl}(g)$	-81.9	-60.2	234.6
$\text{CH}_2\text{Cl}_2(g)$	-95.4		270.2
$\text{CH}_2\text{Cl}_2(l)$	-124.2	-63.2	177.8
$\text{CHCl}_3(l)$	-134.1	-73.7	201.7
$\text{CCl}_4(g)$	-95.7	-62.3	309.7
$\text{CCl}_4(l)$	-128.2	-66.4	216.4
$\text{CH}_2\text{O}(g)$	-108.6	-102.5	218.8
CH_2O_2 (<i>l</i> , formic acid)	-425.0	-361.4	129.0
CH_3NH_2 (<i>g</i> , methylamine)	-22.5	32.7	242.9
$\text{CH}_3\text{OH}(l)$	-238.6	-166.6	126.8
$\text{CH}_3\text{OH}(g)$	-201.0	-162.3	239.9

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
$\text{C}_2\text{H}_2(g)$	227.4	209.9	200.9
$\text{C}_2\text{H}_4(g)$	52.4	68.4	219.3
$\text{C}_2\text{H}_6(g)$	-84.68	-32.0	229.2
$\text{C}_2\text{H}_5\text{OH}(l)$	-277.6	-174.8	160.7
$\text{C}_2\text{H}_5\text{OH}(g)$	-234.8	-167.9	281.6
$\text{C}_2\text{H}_3\text{Cl}$ (<i>g</i> , vinyl chloride)	37.2	53.6	264.0
$\text{C}_2\text{H}_4\text{Cl}_2$ (<i>l</i> , dichloroethane)	-166.8	-79.6	208.5
$\text{C}_2\text{H}_4\text{O}$ (<i>g</i> , acetaldehyde)	-166.2	-133.0	263.8
$\text{C}_2\text{H}_4\text{O}_2$ (<i>l</i> , acetic acid)	-484.3	-389.9	159.8
$\text{C}_3\text{H}_8(g)$	-103.85	-23.4	270.3
$\text{C}_3\text{H}_6\text{O}$ (<i>l</i> , acetone)	-248.4	-155.6	199.8
$\text{C}_3\text{H}_7\text{OH}$ (<i>l</i> , isopropanol)	-318.1		181.1
$\text{C}_4\text{H}_{10}(l)$	-147.3	-15.0	231.0
$\text{C}_4\text{H}_{10}(g)$	-125.7	-15.71	310.0
$\text{C}_6\text{H}_6(l)$	49.1	124.5	173.4
$\text{C}_6\text{H}_5\text{NH}_2$ (<i>l</i> , aniline)	31.6	149.2	191.9
$\text{C}_6\text{H}_5\text{OH}$ (<i>s</i> , phenol)	-165.1	-50.4	144.0
$\text{C}_6\text{H}_{12}\text{O}_6$ (<i>s</i> , glucose)	-1273.3	-910.4	212.1
C_{10}H_8 (<i>s</i> , naphthalene)	78.5	201.6	167.4
$\text{C}_{12}\text{H}_{22}\text{O}_{11}$ (<i>s</i> , sucrose)	-2226.1	-1544.3	360.24
$\text{CO}(g)$	-110.5	-137.2	197.7
$\text{CO}_2(g)$	-393.5	-394.4	213.8
$\text{CO}_2(aq)$	-413.8	-386.0	117.6
$\text{CO}_3^{2-}(aq)$	-677.1	-527.8	-56.9
$\text{HCO}_3^-(aq)$	-692.0	-586.8	91.2
$\text{H}_2\text{CO}_3(aq)$	-699.7	-623.2	187.4
$\text{CN}^-(aq)$	151	166	118
$\text{HCN}(l)$	108.9	125.0	112.8
$\text{HCN}(g)$	135.1	124.7	201.8
$\text{CS}_2(l)$	89.0	64.6	151.3
$\text{CS}_2(g)$	116.7	67.1	237.8
$\text{COCl}_2(g)$	-219.1	-204.9	283.5
$\text{C}_{60}(s)$	2327.0	2302.0	426.0
Cesium			
$\text{Cs}(s)$	0	0	85.2
$\text{Cs}(g)$	76.5	49.6	175.6
$\text{Cs}^+(aq)$	-258.0	-292.0	132.1
$\text{CsBr}(s)$	-400	-387	117
$\text{CsCl}(s)$	-438	-414	101.2
$\text{CsF}(s)$	-553.5	-525.5	92.8
$\text{CsI}(s)$	-342	-337	127

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
Chlorine			
Cl(g)	121.3	105.3	165.2
Cl ₂ (g)	0	0	223.1
Cl ⁻ (aq)	-167.1	-131.2	56.6
HCl(g)	-92.3	-95.3	186.9
HCl(aq)	-167.2	-131.2	56.5
ClO ₂ (g)	102.5	120.5	256.8
Cl ₂ O(g)	80.3	97.9	266.2
Chromium			
Cr(s)	0	0	23.8
Cr(g)	396.6	351.8	174.5
Cr ³⁺ (aq)	-1971		
CrO ₄ ²⁻ (aq)	-872.2	-717.1	44
Cr ₂ O ₃ (s)	-1139.7	-1058.1	81.2
Cr ₂ O ₇ ²⁻ (aq)	-1476	-1279	238
Cobalt			
Co(s)	0	0	30.0
Co(g)	424.7	380.3	179.5
CoO(s)	-237.9	-214.2	53.0
Co(OH) ₂ (s)	-539.7	-454.3	79.0
Copper			
Cu(s)	0	0	33.2
Cu(g)	337.4	297.7	166.4
Cu ⁺ (aq)	51.9	50.2	-26
Cu ²⁺ (aq)	64.9	65.5	-98
CuCl(s)	-137.2	-119.9	86.2
CuCl ₂ (s)	-220.1	-175.7	108.1
CuO(s)	-157.3	-129.7	42.6
CuS(s)	-53.1	-53.6	66.5
CuSO ₄ (s)	-771.4	-662.2	109.2
Cu ₂ O(s)	-168.6	-146.0	93.1
Cu ₂ S(s)	-79.5	-86.2	120.9
Fluorine			
F(g)	79.38	62.3	158.75
F ₂ (g)	0	0	202.79
F ⁻ (aq)	-335.35	-278.8	-13.8
HF(g)	-273.3	-275.4	173.8
Gold			
Au(s)	0	0	47.4
Au(g)	366.1	326.3	180.5
Helium			
He(g)	0	0	126.2
Hydrogen			
H(g)	218.0	203.3	114.7
H ⁺ (aq)	0	0	0
H ⁻ (aq)	1536.3	1517.1	108.9
H ₂ (g)	0	0	130.7

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
Iodine			
I(g)	106.76	70.2	180.79
I ₂ (s)	0	0	116.14
I ₂ (g)	62.42	19.3	260.69
I ⁻ (aq)	-56.78	-51.57	106.45
HI(g)	26.5	1.7	206.6
Iron			
Fe(s)	0	0	27.3
Fe(g)	416.3	370.7	180.5
Fe ²⁺ (aq)	-87.9	-84.94	-113.4
Fe ³⁺ (aq)	-47.69	-10.54	-293.3
FeCO ₃ (s)	-740.6	-666.7	92.9
FeCl ₂ (s)	-341.8	-302.3	118.0
FeCl ₃ (s)	-399.5	-334.0	142.3
FeO(s)	-272.0	-255.2	60.75
Fe(OH) ₃ (s)	-823.0	-696.5	106.7
FeS ₂ (s)	-178.2	-166.9	52.9
Fe ₂ O ₃ (s)	-824.2	-742.2	87.4
Fe ₃ O ₄ (s)	-1118.4	-1015.4	146.4
Lead			
Pb(s)	0	0	64.8
Pb(g)	195.2	162.2	175.4
Pb ²⁺ (aq)	0.92	-24.4	18.5
PbBr ₂ (s)	-278.7	-261.9	161.5
PbCO ₃ (s)	-699.1	-625.5	131.0
PbCl ₂ (s)	-359.4	-314.1	136.0
PbI ₂ (s)	-175.5	-173.6	174.9
Pb(NO ₃) ₂ (s)	-451.9		
PbO(s)	-217.3	-187.9	68.7
PbO ₂ (s)	-277.4	-217.3	68.6
PbS(s)	-100.4	-98.7	91.2
PbSO ₄ (s)	-920.0	-813.0	148.5
Lithium			
Li(s)	0	0	29.1
Li(g)	159.3	126.6	138.8
Li ⁺ (aq)	-278.47	-293.3	12.24
LiBr(s)	-351.2	-342.0	74.3
LiCl(s)	-408.6	-384.4	59.3
LiF(s)	-616.0	-587.7	35.7
LiI(s)	-270.4	-270.3	86.8
LiNO ₃ (s)	-483.1	-381.1	90.0
LiOH(s)	-487.5	-441.5	42.8
Li ₂ O(s)	-597.9	-561.2	37.6
Magnesium			
Mg(s)	0	0	32.7
Mg(g)	147.1	112.5	148.6
Mg ²⁺ (aq)	-467.0	-455.4	-137
MgCl ₂ (s)	-641.3	-591.8	89.6
MgCO ₃ (s)	-1095.8	-1012.1	65.7
MgF ₂ (s)	-1124.2	-1071.1	57.2

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
MgO(s)	-601.6	-569.3	27.0
Mg(OH) ₂ (s)	-924.5	-833.5	63.2
MgSO ₄ (s)	-1284.9	-1170.6	91.6
Mg ₃ N ₂ (s)	-461	-401	88
Manganese			
Mn(s)	0	0	32.0
Mn(g)	280.7	238.5	173.7
Mn ²⁺ (aq)	-219.4	-225.6	-78.8
MnO(s)	-385.2	-362.9	59.7
MnO ₂ (s)	-520.0	-465.1	53.1
MnO ₄ ⁻ (aq)	-529.9	-436.2	190.6
Mercury			
Hg(l)	0	0	75.9
Hg(g)	61.4	31.8	175.0
Hg ²⁺ (aq)	170.21	164.4	-36.19
Hg ₂ ²⁺ (aq)	166.87	153.5	65.74
HgCl ₂ (s)	-224.3	-178.6	146.0
HgO(s)	-90.8	-58.5	70.3
HgS(s)	-58.2	-50.6	82.4
Hg ₂ Cl ₂ (s)	-265.4	-210.7	191.6
Nickel			
Ni(s)	0	0	29.9
Ni(g)	429.7	384.5	182.2
NiCl ₂ (s)	-305.3	-259.0	97.7
NiO(s)	-239.7	-211.7	37.99
NiS(s)	-82.0	-79.5	53.0
Nitrogen			
N(g)	472.7	455.5	153.3
N ₂ (g)	0	0	191.6
NF ₃ (g)	-132.1	-90.6	260.8
NH ₃ (g)	-45.9	-16.4	192.8
NH ₃ (aq)	-80.29	-26.50	111.3
NH ₄ ⁺ (aq)	-133.26	-79.31	111.17
NH ₄ Br(s)	-270.8	-175.2	113.0
NH ₄ Cl(s)	-314.4	-202.9	94.6
NH ₄ CN(s)	0.4		
NH ₄ F(s)	-464.0	-348.7	72.0
NH ₄ HCO ₃ (s)	-849.4	-665.9	120.9
NH ₄ I(s)	-201.4	-112.5	117.0
NH ₄ NO ₃ (s)	-365.6	-183.9	151.1
NH ₄ NO ₃ (aq)	-339.9	-190.6	259.8
HNO ₃ (g)	-133.9	-73.5	266.9
HNO ₃ (aq)	-207	-110.9	146
NO(g)	91.3	87.6	210.8
NO ₂ (g)	33.2	51.3	240.1
NO ₃ ⁻ (aq)	-206.85	-110.2	146.70
NOBr(g)	82.2	82.4	273.7
NOCl(g)	51.7	66.1	261.7
N ₂ H ₄ (l)	50.6	149.3	121.2
N ₂ H ₄ (g)	95.4	159.4	238.5
N ₂ O(g)	81.6	103.7	220.0

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
N ₂ O ₄ (l)	-19.5	97.5	209.2
N ₂ O ₄ (g)	9.16	99.8	304.4
N ₂ O ₅ (s)	-43.1	113.9	178.2
N ₂ O ₅ (g)	13.3	117.1	355.7
Oxygen			
O(g)	249.2	231.7	161.1
O ₂ (g)	0	0	205.2
O ₃ (g)	142.7	163.2	238.9
OH ⁻ (aq)	-230.02	-157.3	-10.90
H ₂ O(l)	-285.8	-237.1	70.0
H ₂ O(g)	-241.8	-228.6	188.8
H ₂ O ₂ (l)	-187.8	-120.4	109.6
H ₂ O ₂ (g)	-136.3	-105.6	232.7
Phosphorus			
P(s, white)	0	0	41.1
P(s, red)	-17.6	-12.1	22.8
P(g)	316.5	280.1	163.2
P ₂ (g)	144.0	103.5	218.1
P ₄ (g)	58.9	24.4	280.0
PCl ₃ (l)	-319.7	-272.3	217.1
PCl ₃ (g)	-287.0	-267.8	311.8
PCl ₅ (s)	-443.5		
PCl ₅ (g)	-374.9	-305.0	364.6
PF ₅ (g)	-1594.4	-1520.7	300.8
PH ₃ (g)	5.4	13.5	210.2
POCl ₃ (l)	-597.1	-520.8	222.5
POCl ₃ (g)	-558.5	-512.9	325.5
PO ₄ ³⁻ (aq)	-1277.4	-1018.7	-220.5
HPO ₄ ²⁻ (aq)	-1292.1	-1089.2	-33.5
H ₂ PO ₄ ⁻ (aq)	-1296.3	-1130.2	90.4
H ₃ PO ₄ (s)	-1284.4	-1124.3	110.5
H ₃ PO ₄ (aq)	-1288.3	-1142.6	158.2
P ₄ O ₆ (s)	-1640.1		
P ₄ O ₁₀ (s)	-2984	-2698	228.9
Platinum			
Pt(s)	0	0	41.6
Pt(g)	565.3	520.5	192.4
Potassium			
K(s)	0	0	64.7
K(g)	89.0	60.5	160.3
K ⁺ (aq)	-252.14	-283.3	101.2
KBr(s)	-393.8	-380.7	95.9
KCN(s)	-113.0	-101.9	128.5
KCl(s)	-436.5	-408.5	82.6
KClO ₃ (s)	-397.7	-296.3	143.1
KClO ₄ (s)	-432.8	-303.1	151.0
KF(s)	-567.3	-537.8	66.6
KI(s)	-327.9	-324.9	106.3
KNO ₃ (s)	-494.6	-394.9	133.1

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
KOH(s)	-424.6	-379.4	81.2
KOH(aq)	-482.4	-440.5	91.6
KO ₂ (s)	-284.9	-239.4	116.7
K ₂ CO ₃ (s)	-1151.0	-1063.5	155.5
K ₂ O(s)	-361.5	-322.1	94.14
K ₂ O ₂ (s)	-494.1	-425.1	102.1
K ₂ SO ₄ (s)	-1437.8	-1321.4	175.6
Rubidium			
Rb(s)	0	0	76.8
Rb(g)	80.9	53.1	170.1
Rb ⁺ (aq)	-251.12	-283.1	121.75
RbBr(s)	-394.6	-381.8	110.0
RbCl(s)	-435.4	-407.8	95.9
RbClO ₃ (s)	-392.4	-292.0	152
RbF(s)	-557.7		
RbI(s)	-333.8	-328.9	118.4
Scandium			
Sc(s)	0	0	34.6
Sc(g)	377.8	336.0	174.8
Selenium			
Se(s, gray)	0	0	42.4
Se(g)	227.1	187.0	176.7
H ₂ Se(g)	29.7	15.9	219.0
Silicon			
Si(s)	0	0	18.8
Si(g)	450.0	405.5	168.0
SiCl ₄ (l)	-687.0	-619.8	239.7
SiF ₄ (g)	-1615.0	-1572.8	282.8
SiH ₄ (g)	34.3	56.9	204.6
SiO ₂ (s, quartz)	-910.7	-856.3	41.5
Si ₂ H ₆ (g)	80.3	127.3	272.7
Silver			
Ag(s)	0	0	42.6
Ag(g)	284.9	246.0	173.0
Ag ⁺ (aq)	105.79	77.11	73.45
AgBr(s)	-100.4	-96.9	107.1
AgCl(s)	-127.0	-109.8	96.3
AgF(s)	-204.6	-185	84
AgI(s)	-61.8	-66.2	115.5
AgNO ₃ (s)	-124.4	-33.4	140.9
Ag ₂ O(s)	-31.1	-11.2	121.3
Ag ₂ S(s)	-32.6	-40.7	144.0
Ag ₂ SO ₄ (s)	-715.9	-618.4	200.4
Sodium			
Na(s)	0	0	51.3
Na(g)	107.5	77.0	153.7
Na ⁺ (aq)	-240.34	-261.9	58.45
NaBr(s)	-361.1	-349.0	86.8
NaCl(s)	-411.2	-384.1	72.1
NaCl(aq)	-407.2	-393.1	115.5

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
NaClO ₃ (s)	-365.8	-262.3	123.4
NaF(s)	-576.6	-546.3	51.1
NaHCO ₃ (s)	-950.8	-851.0	101.7
NaHSO ₄ (s)	-1125.5	-992.8	113.0
Nal(s)	-287.8	-286.1	98.5
NaNO ₃ (s)	-467.9	-367.0	116.5
NaNO ₃ (aq)	-447.5	-373.2	205.4
NaOH(s)	-425.8	-379.7	64.4
NaOH(aq)	-470.1	-419.2	48.2
NaO ₂ (s)	-260.2	-218.4	115.9
Na ₂ CO ₃ (s)	-1130.7	-1044.4	135.0
Na ₂ O(s)	-414.2	-375.5	75.1
Na ₂ O ₂ (s)	-510.9	-447.7	95.0
Na ₂ SO ₄ (s)	-1387.1	-1270.2	149.6
Na ₃ PO ₄ (s)	-1917	-1789	173.8
Strontium			
Sr(s)	0	0	55.0
Sr(g)	164.4	130.9	164.6
Sr ²⁺ (aq)	-545.51	-557.3	-39
SrCl ₂ (s)	-828.9	-781.1	114.9
SrCO ₃ (s)	-1220.1	-1140.1	97.1
SrO(s)	-592.0	-561.9	54.4
SrSO ₄ (s)	-1453.1	-1340.9	117.0
Sulfur			
S(s, rhombic)	0	0	32.1
S(s, monoclinic)	0.3	0.096	32.6
S(g)	277.2	236.7	167.8
S ₂ (g)	128.6	79.7	228.2
S ₈ (g)	102.3	49.7	430.9
S ²⁻ (aq)	41.8	83.7	22
SF ₆ (g)	-1220.5	-1116.5	291.5
HS ⁻ (aq)	-17.7	12.4	62.0
H ₂ S(g)	-20.6	-33.4	205.8
H ₂ S(aq)	-39.4	-27.7	122
SOCl ₂ (l)	-245.6		
SO ₂ (g)	-296.8	-300.1	248.2
SO ₃ (g)	-395.7	-371.1	256.8
SO ₄ ²⁻ (aq)	-909.3	-744.6	18.5
HSO ₄ ⁻ (aq)	-886.5	-754.4	129.5
H ₂ SO ₄ (l)	-814.0	-690.0	156.9
H ₂ SO ₄ (aq)	-909.3	-744.6	18.5
S ₂ O ₃ ²⁻ (aq)	-648.5	-522.5	67
Tin			
Sn(s, white)	0	0	51.2
Sn(s, gray)	-2.1	0.1	44.1
Sn(g)	301.2	266.2	168.5
SnCl ₄ (l)	-511.3	-440.1	258.6
SnCl ₄ (g)	-471.5	-432.2	365.8
SnO(s)	-280.7	-251.9	57.2
SnO ₂ (s)	-577.6	-515.8	49.0

—(Continued on the next page)

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
Titanium			
Ti(s)	0	0	30.7
Ti(g)	473.0	428.4	180.3
TiCl ₄ (l)	-804.2	-737.2	252.3
TiCl ₄ (g)	-763.2	-726.3	353.2
TiO ₂ (s)	-944.0	-888.8	50.6
Tungsten			
W(s)	0	0	32.6
W(g)	849.4	807.1	174.0
WO ₃ (s)	-842.9	-764.0	75.9
Uranium			
U(s)	0	0	50.2
U(g)	533.0	488.4	199.8
UF ₆ (s)	-2197.0	-2068.5	227.6

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol · K)
UF ₆ (g)	-2147.4	-2063.7	377.9
UO ₂ (s)	-1085.0	-1031.8	77.0
Vanadium			
V(s)	0	0	28.9
V(g)	514.2	754.4	182.3
Zinc			
Zn(s)	0	0	41.6
Zn(g)	130.4	94.8	161.0
Zn ²⁺ (aq)	-153.39	-147.1	-109.8
ZnCl ₂ (s)	-415.1	-369.4	111.5
ZnO(s)	-350.5	-320.5	43.7
ZnS (s, zinc blende)	-206.0	-201.3	57.7
ZnSO ₄ (s)	-982.8	-871.5	110.5

C. Aqueous Equilibrium Constants

1. Dissociation Constants for Acids at 25 °C

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Acetic	HC ₂ H ₃ O ₂	1.8×10^{-5}		
Acetylsalicylic	HC ₉ H ₇ O ₄	3.3×10^{-4}		
Adipic	H ₂ C ₆ H ₈ O ₄	3.9×10^{-5}	3.9×10^{-6}	
Arsenic	H ₃ AsO ₄	5.5×10^{-3}	1.7×10^{-7}	5.1×10^{-12}
Arsenous	H ₃ AsO ₃	5.1×10^{-10}		
Ascorbic	H ₂ C ₆ H ₆ O ₆	8.0×10^{-5}	1.6×10^{-12}	
Benzoic	HC ₇ H ₅ O ₂	6.5×10^{-5}		
Boric	H ₃ BO ₃	5.4×10^{-10}		
Butanoic	HC ₄ H ₇ O ₂	1.5×10^{-5}		
Carbonic	H ₂ CO ₃	4.3×10^{-7}	5.6×10^{-11}	
Chloroacetic	HC ₂ H ₂ O ₂ Cl	1.4×10^{-3}		
Chlorous	HClO ₂	1.1×10^{-2}		
Citric	H ₃ C ₆ H ₅ O ₇	7.4×10^{-4}	1.7×10^{-5}	4.0×10^{-7}
Cyanic	HCNO	2×10^{-4}		
Formic	HCHO ₂	1.8×10^{-4}		
Hydrazoic	HN ₃	2.5×10^{-5}		
Hydrocyanic	HCN	4.9×10^{-10}		
Hydrofluoric	HF	6.8×10^{-4}		
Hydrogen chromate ion	HCrO ₄ ⁻	3.0×10^{-7}		
Hydrogen peroxide	H ₂ O ₂	2.4×10^{-12}		
Hydrogen selenate ion	HSeO ₄ ⁻	2.2×10^{-2}		
Hydrosulfuric	H ₂ S	8.9×10^{-8}	1×10^{-19}	
Hydrotelluric	H ₂ Te	2.3×10^{-3}	1.6×10^{-11}	

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Hypobromous	HBrO	2.8×10^{-9}		
Hypochlorous	HClO	2.9×10^{-8}		
Hypoiodous	HIO	2.3×10^{-11}		
Iodic	HIO ₃	1.7×10^{-1}		
Lactic	HC ₃ H ₅ O ₃	1.4×10^{-4}		
Maleic	H ₂ C ₄ H ₂ O ₄	1.2×10^{-2}	5.9×10^{-7}	
Malonic	H ₂ C ₃ H ₂ O ₄	1.5×10^{-3}	2.0×10^{-6}	
Nitrous	HNO ₂	4.6×10^{-4}		
Oxalic	H ₂ C ₂ O ₄	6.0×10^{-2}	6.1×10^{-5}	
Paraperiodic	H ₅ IO ₆	2.8×10^{-2}	5.3×10^{-9}	
Phenol	HC ₆ H ₅ O	1.3×10^{-10}		
Phosphoric	H ₃ PO ₄	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
Phosphorous	H ₃ PO ₃	5×10^{-2}	2.0×10^{-7}	
Propanoic	HC ₃ H ₅ O ₂	1.3×10^{-5}		
Pyruvic	HC ₃ H ₃ O ₃	4.1×10^{-3}		
Pyrophosphoric	H ₄ P ₂ O ₇	1.2×10^{-1}	7.9×10^{-3}	2.0×10^{-7}
Selenous	H ₂ SeO ₃	2.4×10^{-3}	4.8×10^{-9}	
Succinic	H ₂ C ₄ H ₄ O ₄	6.2×10^{-5}	2.3×10^{-6}	
Sulfuric	H ₂ SO ₄	Strong acid	1.2×10^{-2}	
Sulfurous	H ₂ SO ₃	1.6×10^{-2}	6.4×10^{-8}	
Tartaric	H ₂ C ₄ H ₄ O ₆	1.0×10^{-3}	4.6×10^{-5}	
Trichloroacetic	HC ₂ Cl ₃ O ₂	2.2×10^{-1}		
Trifluoroacetic acid	HC ₂ F ₃ O ₂	3.0×10^{-1}		

2. Dissociation Constants for Hydrated Metal Ions at 25 °C

Cation	Hydrated Ion	K_a
Al^{3+}	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	1.4×10^{-5}
Be^{2+}	$\text{Be}(\text{H}_2\text{O})_6^{2+}$	3×10^{-7}
Co^{2+}	$\text{Co}(\text{H}_2\text{O})_6^{2+}$	1.3×10^{-9}
Cr^{3+}	$\text{Cr}(\text{H}_2\text{O})_6^{3+}$	1.6×10^{-4}
Cu^{2+}	$\text{Cu}(\text{H}_2\text{O})_6^{2+}$	3×10^{-8}
Fe^{2+}	$\text{Fe}(\text{H}_2\text{O})_6^{2+}$	3.2×10^{-10}

Cation	Hydrated Ion	K_a
Fe^{3+}	$\text{Fe}(\text{H}_2\text{O})_6^{3+}$	6.3×10^{-3}
Ni^{2+}	$\text{Ni}(\text{H}_2\text{O})_6^{2+}$	2.5×10^{-11}
Pb^{2+}	$\text{Pb}(\text{H}_2\text{O})_6^{2+}$	3×10^{-8}
Sn^{2+}	$\text{Sn}(\text{H}_2\text{O})_6^{2+}$	4×10^{-4}
Zn^{2+}	$\text{Zn}(\text{H}_2\text{O})_6^{2+}$	2.5×10^{-10}

3. Dissociation Constants for Bases at 25 °C

Name	Formula	K_b
Ammonia	NH_3	1.76×10^{-5}
Aniline	$\text{C}_6\text{H}_5\text{NH}_2$	3.9×10^{-10}
Bicarbonate ion	HCO_3^-	2.3×10^{-8}
Carbonate ion	CO_3^{2-}	1.8×10^{-4}
Codeine	$\text{C}_{18}\text{H}_{21}\text{NO}_3$	1.6×10^{-6}
Diethylamine	$(\text{C}_2\text{H}_5)_2\text{NH}$	6.9×10^{-4}
Dimethylamine	$(\text{CH}_3)_2\text{NH}$	5.4×10^{-4}
Ethylamine	$\text{C}_2\text{H}_5\text{NH}_2$	5.6×10^{-4}
Ethylenediamine	$\text{C}_2\text{H}_8\text{N}_2$	8.3×10^{-5}
Hydrazine	H_2NNH_2	1.3×10^{-6}
Hydroxylamine	HONH_2	1.1×10^{-8}

Name	Formula	K_b
Ketamine	$\text{C}_{13}\text{H}_{16}\text{ClNO}$	3×10^{-7}
Methylamine	CH_3NH_2	4.4×10^{-4}
Morphine	$\text{C}_{17}\text{H}_{19}\text{NO}_3$	1.6×10^{-6}
Nicotine	$\text{C}_{10}\text{H}_{14}\text{N}_2$	1.0×10^{-6}
Piperidine	$\text{C}_5\text{H}_{10}\text{NH}$	1.33×10^{-3}
Propylamine	$\text{C}_3\text{H}_7\text{NH}_2$	3.5×10^{-4}
Pyridine	$\text{C}_5\text{H}_5\text{N}$	1.7×10^{-9}
Strychnine	$\text{C}_{21}\text{H}_{22}\text{N}_2\text{O}_2$	1.8×10^{-6}
Triethylamine	$(\text{C}_2\text{H}_5)_3\text{N}$	5.6×10^{-4}
Trimethylamine	$(\text{CH}_3)_3\text{N}$	6.4×10^{-5}

4. Solubility Product Constants for Compounds at 25 °C

Compound	Formula	K_{sp}
Aluminum hydroxide	$\text{Al}(\text{OH})_3$	1.3×10^{-33}
Aluminum phosphate	AlPO_4	9.84×10^{-21}
Barium carbonate	BaCO_3	2.58×10^{-9}
Barium chromate	BaCrO_4	1.17×10^{-10}
Barium fluoride	BaF_2	2.45×10^{-5}
Barium hydroxide	$\text{Ba}(\text{OH})_2$	5.0×10^{-3}
Barium oxalate	BaC_2O_4	1.6×10^{-6}
Barium phosphate	$\text{Ba}_3(\text{PO}_4)_2$	6×10^{-39}
Barium sulfate	BaSO_4	1.07×10^{-10}
Cadmium carbonate	CdCO_3	1.0×10^{-12}
Cadmium hydroxide	$\text{Cd}(\text{OH})_2$	7.2×10^{-15}
Cadmium sulfide	CdS	8×10^{-28}
Calcium carbonate	CaCO_3	4.96×10^{-9}
Calcium chromate	CaCrO_4	7.1×10^{-4}
Calcium fluoride	CaF_2	1.46×10^{-10}
Calcium hydroxide	$\text{Ca}(\text{OH})_2$	4.68×10^{-6}

Compound	Formula	K_{sp}
Calcium hydrogen phosphate	CaHPO_4	1×10^{-7}
Calcium oxalate	CaC_2O_4	2.32×10^{-9}
Calcium phosphate	$\text{Ca}_3(\text{PO}_4)_2$	2.07×10^{-33}
Calcium sulfate	CaSO_4	7.10×10^{-5}
Chromium(III) hydroxide	$\text{Cr}(\text{OH})_3$	6.3×10^{-31}
Cobalt(II) carbonate	CoCO_3	1.0×10^{-10}
Cobalt(II) hydroxide	$\text{Co}(\text{OH})_2$	5.92×10^{-15}
Cobalt(II) sulfide	CoS	5×10^{-22}
Copper(I) bromide	CuBr	6.27×10^{-9}
Copper(I) chloride	CuCl	1.72×10^{-7}
Copper(I) cyanide	CuCN	3.47×10^{-20}
Copper(II) carbonate	CuCO_3	2.4×10^{-10}
Copper(II) hydroxide	$\text{Cu}(\text{OH})_2$	2.2×10^{-20}
Copper(II) phosphate	$\text{Cu}_3(\text{PO}_4)_2$	1.40×10^{-37}
Copper(II) sulfide	CuS	1.27×10^{-36}
Iron(II) carbonate	FeCO_3	3.07×10^{-11}

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Compound	Formula	K_{sp}
Iron(II) hydroxide	Fe(OH) ₂	4.87×10^{-17}
Iron(II) sulfide	FeS	3.72×10^{-19}
Iron(III) hydroxide	Fe(OH) ₃	2.79×10^{-39}
Lanthanum fluoride	LaF ₃	2×10^{-19}
Lanthanum iodate	La(IO ₃) ₃	7.50×10^{-12}
Lead(II) bromide	PbBr ₂	4.67×10^{-6}
Lead(II) carbonate	PbCO ₃	7.40×10^{-14}
Lead(II) chloride	PbCl ₂	1.17×10^{-5}
Lead(II) chromate	PbCrO ₄	2.8×10^{-13}
Lead(II) fluoride	PbF ₂	3.3×10^{-8}
Lead(II) hydroxide	Pb(OH) ₂	1.43×10^{-20}
Lead(II) iodide	PbI ₂	9.8×10^{-9}
Lead(II) phosphate	Pb ₃ (PO ₄) ₂	1×10^{-54}
Lead(II) sulfate	PbSO ₄	1.82×10^{-8}
Lead(II) sulfide	PbS	9.04×10^{-29}
Magnesium carbonate	MgCO ₃	6.82×10^{-6}
Magnesium fluoride	MgF ₂	5.16×10^{-11}
Magnesium hydroxide	Mg(OH) ₂	2.06×10^{-13}
Magnesium oxalate	MgC ₂ O ₄	4.83×10^{-6}
Manganese(II) carbonate	MnCO ₃	2.24×10^{-11}
Manganese(II) hydroxide	Mn(OH) ₂	1.6×10^{-13}
Manganese(II) sulfide	MnS	2.3×10^{-13}
Mercury(I) bromide	Hg ₂ Br ₂	6.40×10^{-23}
Mercury(I) carbonate	Hg ₂ CO ₃	3.6×10^{-17}
Mercury(I) chloride	Hg ₂ Cl ₂	1.43×10^{-18}
Mercury(I) chromate	Hg ₂ CrO ₄	2×10^{-9}
Mercury(I) cyanide	Hg ₂ (CN) ₂	5×10^{-40}

Compound	Formula	K_{sp}
Mercury(I) iodide	Hg ₂ I ₂	5.2×10^{-29}
Mercury(II) hydroxide	Hg(OH) ₂	3.1×10^{-26}
Mercury(II) sulfide	HgS	1.6×10^{-54}
Nickel(II) carbonate	NiCO ₃	1.42×10^{-7}
Nickel(II) hydroxide	Ni(OH) ₂	5.48×10^{-16}
Nickel(II) sulfide	NiS	3×10^{-20}
Silver bromate	AgBrO ₃	5.38×10^{-5}
Silver bromide	AgBr	5.35×10^{-13}
Silver carbonate	Ag ₂ CO ₃	8.46×10^{-12}
Silver chloride	AgCl	1.77×10^{-10}
Silver chromate	Ag ₂ CrO ₄	1.12×10^{-12}
Silver cyanide	AgCN	5.97×10^{-17}
Silver iodide	Agl	8.51×10^{-17}
Silver phosphate	Ag ₃ PO ₄	8.89×10^{-17}
Silver sulfate	Ag ₂ SO ₄	1.20×10^{-5}
Silver sulfide	Ag ₂ S	6×10^{-51}
Strontium carbonate	SrCO ₃	5.60×10^{-10}
Strontium chromate	SrCrO ₄	3.6×10^{-5}
Strontium phosphate	Sr ₃ (PO ₄) ₂	1×10^{-31}
Strontium sulfate	SrSO ₄	3.44×10^{-7}
Tin(II) hydroxide	Sn(OH) ₂	5.45×10^{-27}
Tin(II) sulfide	SnS	1×10^{-26}
Zinc carbonate	ZnCO ₃	1.46×10^{-10}
Zinc hydroxide	Zn(OH) ₂	3×10^{-17}
Zinc oxalate	ZnC ₂ O ₄	2.7×10^{-8}
Zinc sulfide	ZnS	2×10^{-25}

5. Complex Ion Formation Constants in Water at 25 °C

Complex Ion	K_f
[Ag(CN) ₂] ⁻	1×10^{21}
[Ag(EDTA)] ³⁻	2.1×10^7
[Ag(en) ₂] ⁺	5.0×10^7
[Ag(NH ₃) ₂] ⁺	1.7×10^7
[Ag(SCN) ₄] ³⁻	1.2×10^{10}
[Ag(S ₂ O ₃) ₂] ³⁻	2.8×10^{13}
[Al(EDTA)] ⁻	1.3×10^{16}
[AlF ₆] ³⁻	7×10^{19}
[Al(OH) ₄] ⁻	3×10^{33}
[Al(ox) ₃] ³⁻	2×10^{16}
[CdBr ₄] ²⁻	5.5×10^3
[Cd(CN) ₄] ²⁻	3×10^{18}

Complex Ion	K_f
[CdCl ₄] ²⁻	6.3×10^2
[Cd(en) ₃] ²⁺	1.2×10^{12}
[CdI ₄] ²⁻	2×10^6
[Co(EDTA)] ²⁻	2.0×10^{16}
[Co(EDTA)] ⁻	1×10^{36}
[Co(en) ₃] ²⁺	8.7×10^{13}
[Co(en) ₃] ³⁺	4.9×10^{48}
[Co(NH ₃) ₆] ²⁺	1.3×10^5
[Co(NH ₃) ₆] ³⁺	2.3×10^{33}
[Co(OH) ₄] ²⁻	5×10^9
[Co(ox) ₃] ⁴⁻	5×10^9
[Co(ox) ₃] ³⁻	1×10^{20}

Complex Ion	K_f
$[\text{Co}(\text{SCN})_4]^{2-}$	1×10^{23}
$[\text{Cr}(\text{EDTA})]^{2-}$	1×10^{23}
$[\text{Cr}(\text{OH})_4]^{-}$	8.0×10^{29}
$[\text{CuCl}_3]^{2-}$	5×10^5
$[\text{Cu}(\text{CN})_4]^{2-}$	1.0×10^{25}
$[\text{Cu}(\text{EDTA})]^{2-}$	5×10^{18}
$[\text{Cu}(\text{en})_2]^{2+}$	1×10^{20}
$[\text{Cu}(\text{NH}_3)_4]^{2+}$	1.7×10^{13}
$[\text{Cu}(\text{ox})_2]^{2-}$	3×10^8
$[\text{Fe}(\text{CN})_6]^{4-}$	1.5×10^{35}
$[\text{Fe}(\text{CN})_6]^{3-}$	2×10^{43}
$[\text{Fe}(\text{EDTA})]^{2-}$	2.1×10^{14}
$[\text{Fe}(\text{EDTA})]^{-}$	1.7×10^{24}
$[\text{Fe}(\text{en})_3]^{2+}$	5.0×10^9
$[\text{Fe}(\text{ox})_3]^{4-}$	1.7×10^5
$[\text{Fe}(\text{ox})_3]^{3-}$	2×10^{20}
$[\text{Fe}(\text{SCN})]^{2+}$	8.9×10^2
$[\text{Hg}(\text{CN})_4]^{2-}$	1.8×10^{41}
$[\text{HgCl}_4]^{2-}$	1.1×10^{16}
$[\text{Hg}(\text{EDTA})]^{2-}$	6.3×10^{21}
$[\text{Hg}(\text{en})_2]^{2+}$	2×10^{23}
$[\text{HgI}_4]^{2-}$	2×10^{30}

Complex Ion	K_f
$[\text{Hg}(\text{ox})_2]^{2-}$	9.5×10^6
$[\text{Ni}(\text{CN})_4]^{2-}$	2×10^{31}
$[\text{Ni}(\text{EDTA})]^{2-}$	3.6×10^{18}
$[\text{Ni}(\text{en})_3]^{2+}$	2.1×10^{18}
$[\text{Ni}(\text{NH}_3)_6]^{2+}$	2.0×10^8
$[\text{Ni}(\text{ox})_3]^{4-}$	3×10^8
$[\text{PbCl}_3]^{-}$	2.4×10^1
$[\text{Pb}(\text{EDTA})]^{2-}$	2×10^{18}
$[\text{PbI}_4]^{2-}$	3.0×10^4
$[\text{Pb}(\text{OH})_3]^{-}$	8×10^{13}
$[\text{Pb}(\text{ox})_2]^{2-}$	3.5×10^6
$[\text{Pb}(\text{S}_2\text{O}_3)_3]^{4-}$	2.2×10^6
$[\text{PtCl}_4]^{2-}$	1×10^{16}
$[\text{Pt}(\text{NH}_3)_6]^{2+}$	2×10^{35}
$[\text{Sn}(\text{OH})_3]^{-}$	3×10^{25}
$[\text{Zn}(\text{CN})_4]^{2-}$	2.1×10^{19}
$[\text{Zn}(\text{EDTA})]^{2-}$	3×10^{16}
$[\text{Zn}(\text{en})_3]^{2+}$	1.3×10^{14}
$[\text{Zn}(\text{NH}_3)_4]^{2+}$	2.8×10^9
$[\text{Zn}(\text{OH})_4]^{2-}$	2×10^{15}
$[\text{Zn}(\text{ox})_3]^{4-}$	1.4×10^8

D. Standard Electrode Potentials at 25 °C

Half-Reaction	$E^\circ(\text{V})$
$\text{F}_2(g) + 2 \text{e}^- \longrightarrow 2 \text{F}^-(\text{aq})$	2.87
$\text{O}_3(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{O}_2(\text{g}) + \text{H}_2(\text{l})$	2.08
$\text{Ag}^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}^+(\text{aq})$	1.98
$\text{Co}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Co}^{2+}(\text{aq})$	1.82
$\text{H}_2\text{O}_2(\text{aq}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}(\text{l})$	1.78
$\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{PbSO}_4(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$	1.69
$\text{MnO}_4^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{MnO}_2(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$	1.68
$2 \text{HClO}(\text{aq}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cl}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$	1.61
$\text{MnO}_4^-(\text{aq}) + 8 \text{H}^+(\text{aq}) + 5 \text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4 \text{H}_2\text{O}(\text{l})$	1.51
$\text{Au}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Au}(\text{s})$	1.50
$2 \text{BrO}_3^-(\text{aq}) + 12 \text{H}^+(\text{aq}) + 10 \text{e}^- \longrightarrow \text{Br}_2(\text{l}) + 6 \text{H}_2\text{O}(\text{l})$	1.48
$\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pb}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$	1.46
$\text{Cl}_2(\text{g}) + 2 \text{e}^- \longrightarrow 2 \text{Cl}^-(\text{aq})$	1.36

Half-Reaction	$E^\circ(\text{V})$
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14 \text{H}^+(\text{aq}) + 6 \text{e}^- \longrightarrow 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O}(\text{l})$	1.33
$\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}(\text{l})$	1.23
$\text{MnO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$	1.21
$\text{IO}_3^-(\text{aq}) + 6 \text{H}^+(\text{aq}) + 5 \text{e}^- \longrightarrow \frac{1}{2} \text{I}_2(\text{aq}) + 3 \text{H}_2\text{O}(\text{l})$	1.20
$\text{Br}_2(\text{l}) + 2 \text{e}^- \longrightarrow 2 \text{Br}^-(\text{aq})$	1.09
$\text{AuCl}_4^-(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Au}(\text{s}) + 4 \text{Cl}^-(\text{aq})$	1.00
$\text{VO}_2^+(\text{aq}) + 2 \text{H}^+(\text{aq}) + \text{e}^- \longrightarrow \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	1.00
$\text{HNO}_2(\text{aq}) + \text{H}^+(\text{aq}) + \text{e}^- \longrightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$	0.98
$\text{NO}_3^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$	0.96
$\text{ClO}_2(\text{g}) + \text{e}^- \longrightarrow \text{ClO}_2^-(\text{aq})$	0.95
$2 \text{Hg}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}_2^{2+}(\text{aq})$	0.92
$\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$	0.80
$\text{Hg}_2^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}(\text{l})$	0.80

—(Continued on the next page)

Half-Reaction	$E^\circ(V)$	Half-Reaction	$E^\circ(V)$
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$	0.77	$\text{N}_2(\text{g}) + 5 \text{H}^+(\text{aq}) + 4 \text{e}^- \longrightarrow \text{N}_2\text{H}_5^+(\text{aq})$	-0.23
$\text{PtCl}_4^{2-}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pt}(\text{s}) + 4 \text{Cl}^-(\text{aq})$	0.76	$\text{Ni}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ni}(\text{s})$	-0.23
$\text{O}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$	0.70	$\text{Co}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Co}(\text{s})$	-0.28
$\text{MnO}_4^-(\text{aq}) + \text{e}^- \longrightarrow \text{MnO}_4^{2-}(\text{aq})$	0.56	$\text{PbSO}_4(\text{s}) + 2 \text{e}^- \longrightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$	-0.36
$\text{I}_2(\text{s}) + 2 \text{e}^- \longrightarrow 2 \text{I}^-(\text{aq})$	0.54	$\text{Cd}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cd}(\text{s})$	-0.40
$\text{Cu}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}(\text{s})$	0.52	$\text{Fe}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Fe}(\text{s})$	-0.45
$\text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l}) + 4 \text{e}^- \longrightarrow 4 \text{OH}^-(\text{aq})$	0.40	$2 \text{CO}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{C}_2\text{O}_4(\text{aq})$	-0.49
$\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cu}(\text{s})$	0.34	$\text{Cr}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cr}^{2+}(\text{aq})$	-0.50
$\text{BiO}^+(\text{aq}) + 2 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Bi}(\text{s}) + \text{H}_2\text{O}(\text{l})$	0.32	$\text{Cr}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Cr}(\text{s})$	-0.73
$\text{Hg}_2\text{Cl}_2(\text{s}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}(\text{l}) + 2 \text{Cl}^-(\text{aq})$	0.27	$\text{Zn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Zn}(\text{s})$	-0.76
$\text{AgCl}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{Cl}^-(\text{aq})$	0.22	$2 \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2 \text{OH}^-(\text{aq})$	-0.83
$\text{SO}_4^{2-}(\text{aq}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	0.20	$\text{Mn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mn}(\text{s})$	-1.18
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}^+(\text{aq})$	0.16	$\text{Al}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Al}(\text{s})$	-1.66
$\text{Sn}^{4+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Sn}^{2+}(\text{aq})$	0.15	$\text{H}_2(\text{g}) + 2 \text{e}^- \longrightarrow 2 \text{H}^-(\text{aq})$	-2.23
$\text{S}(\text{s}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{S}(\text{g})$	0.14	$\text{Mg}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mg}(\text{s})$	-2.37
$\text{AgBr}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{Br}^-(\text{aq})$	0.071	$\text{La}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{La}(\text{s})$	-2.38
$2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2(\text{g})$	0.00	$\text{Na}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Na}(\text{s})$	-2.71
$\text{Fe}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Fe}(\text{s})$	-0.036	$\text{Ca}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ca}(\text{s})$	-2.76
$\text{Pb}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pb}(\text{s})$	-0.13	$\text{Ba}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ba}(\text{s})$	-2.90
$\text{Sn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Sn}(\text{s})$	-0.14	$\text{K}^+(\text{aq}) + \text{e}^- \longrightarrow \text{K}(\text{s})$	-2.92
$\text{AgI}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{I}^-(\text{aq})$	-0.15	$\text{Li}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Li}(\text{s})$	-3.04

E. Vapor Pressure of Water at Various Temperatures

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

Chapter 1

- 33.** a. theory
c. law
- 35.** Several answers possible
- 37.** a. mixture, homogeneous
b. pure substance, compound
c. pure substance, element
d. mixture, heterogeneous
- | 39. Substance | Pure or Mixture | Type |
|-------------------|-----------------|---------------|
| Aluminum | Pure | Element |
| Apple juice | Mixture | Homogeneous |
| Hydrogen peroxide | Pure | Compound |
| Chicken soup | Mixture | Heterogeneous |
- 41.** a. pure substance, compound
b. mixture, heterogeneous
c. mixture, homogeneous
d. pure substance, element
- 43.** physical, chemical, physical, physical, physical
- 45.** a. chemical
c. physical
- 47.** a. chemical
c. chemical
- 49.** a. physical b. chemical
- 51.** a. 0°C
c. -78.3°F
- 53.** -89.2°C , 184.0 K
- 55.** a. 1.2 nm
c. 1.5 Gg
- 57.** a. $4.5 \times 10^{-9}\text{ s}$
c. $1.28 \times 10^{-10}\text{ m}$
- 59.** 1245 kg $1.245 \times 10^6\text{ g}$ $1.245 \times 10^9\text{ mg}$
 515 km $5.15 \times 10^6\text{ dm}$ $5.15 \times 10^7\text{ cm}$
 122.355 s $1.22355 \times 10^5\text{ ms}$ 0.122355 ks
 3.345 kJ $3.345 \times 10^3\text{ J}$ $3.345 \times 10^6\text{ mJ}$
- 61.** e. 254.998 km
g. $254998 \times 10^3\text{ mm}$
- 63.** 10,000 1 cm squares
- 65.** no
- 67.** 1.26 g/cm^3
- 69.** a. 463 g
- 71.** $201. \times 10^3\text{ g}$
- 73.** a. 73.7 mL b. 88.2°C
- 75.** a. 1,050,501
c. 0.00000000002
- 77.** a. 3 b. ambiguous; without more information, assume three significant figures.
c. 3 d. 5
- 79.** a. not exact
c. not exact
- 81.** a. 156.9 b. 156.8 c. 156.8 d. 156.9
- 83.** a. 1.84
c. 0.500
- 85.** a. 41.4
c. 73.0
- 87.** a. 391.3
c. 5.96
- 89.** 0.74 g/mL
- 91.** a. $2.78 \times 10^4\text{ cm}^3$
c. $1.98 \times 10^7\text{ cm}$
- 93.** a. 60.6 in
c. 3.7 qt
- 95.** $5.0 \times 10^1\text{ min}$
- 97.** $4.0 \times 10^1\text{ mi/gal}$
- 99.** a. $1.95 \times 10^{-4}\text{ km}^2$
c. $1.95 \times 10^6\text{ cm}^2$
- 101.** 0.680 mi^2
- 103.** 0.95 mL
- 105.** $3.1557 \times 10^7\text{ s/solar year}$
- 107.** a. extensive
c. intensive
e. extensive
- 109.** -34°F
- 111.** $F = \text{kg}(\text{m/s}^2) = \text{N}$ (for newton), kN , pN
- 113.** a. 2.2×10^{-6} b. 0.0159 c. 6.9×10^4
- 115.** a. mass of can of gold = $1.9 \times 10^4\text{ g}$
mass of can of sand = $3.0 \times 10^3\text{ g}$
b. Yes, the thief sets off the trap because the can of sand is lighter than the gold cylinder.
- 117.** 22 in^3
- 119.** 7.6 g/cm^3
- 121.** $3.11 \times 10^5\text{ lb}$
- 123.** $3.3 \times 10^2\text{ km}$
- 125.** 6.8×10^{-15}
- 127.** $2.4 \times 10^{19}\text{ km}$
- 129.** 488 grams
- 131.** $0.661\text{ }\Omega$
- 133.** 0.492
- 135.** 18.2 atm
- 137.** $1\text{ J} = 1\text{ kg m}^2/\text{s}^2$
 $m = \text{kg}$, $v^2 = (\text{m/s})^2$ $mv = \text{kg m}^2/\text{s}^2$
 $P = \text{N/m}^2 = \text{kg m/s}^2/\text{m}^2 = \text{kg/m s}^2$
 $V = \text{m}^2 PV = \text{kg m}^3/\text{m s}^2 = \text{kg m}^2/\text{s}^2$
- 139.** $9.0 \times 10^1\text{ mg CO}$
- 141.** 13% increase
- 143.** No. Since the container is sealed, the atoms and molecules can move around, but they cannot leave. If no atoms or molecules can leave, the mass must be constant.

- 145.** 343 1 cm cubes
147. a. the dark block **b.** the light-colored block
c. cannot tell
149. a. law **b.** theory **c.** observation **d.** law
155. a. 8.2% **c.** 24.4 million cubic kilometers

Chapter 2

- 29.** 13.5 g
31. These results are not consistent with the law of definite proportions because sample 1 is composed of 11.5 parts Cl to 1 part C and sample 2 is composed of 9.05 parts Cl to 1 part C. The law of definite proportions states that a given compound always contains exactly the same proportion of elements by mass.
33. 23.8 g
35. For the law of multiple proportions to hold, the ratio of the masses of O combining with 1 g of O's in the compound should be a small whole number.
 $0.3369/0.168 = 2.00$
37. Sample 1: 1.00 g O₂/1.00 g S;
 Sample 2: 1.50 g O₂/1.00 g S
 $\text{Sample 2/sample 1} = 1.50/1.00 = 1.50$
 $3 \text{ O atoms}/2 \text{ O atoms} = 1.5$
39. a. not consistent
b. consistent: Dalton's atomic theory states that the atoms of a given element are identical.
c. consistent: Dalton's atomic theory states that atoms combine in simple whole-number ratios to form compounds.
d. not consistent
41. a. consistent: Rutherford's nuclear model states that the atom is largely empty space.
b. consistent: Rutherford's nuclear model states that most of the atom's mass is concentrated in a tiny region called the nucleus.
c. not consistent **d.** not consistent
43. -2.3×10^{-19} C
45. 9.4×10^{13} excess electrons, 8.5×10^{-17} kg
47. a, b, c
49. 1.83×10^3 e⁻
51. a. Ag-107 **b.** Ag-109 **c.** U-238 **d.** H-2
53. a. 7_1^1p and 7_1^0n
c. 86_1^1p and 136_1^0n
55. 6_1^1p and 8_0^1n , $^{14}_6C$
57. a. 28_1^1p and 26 e⁻
c. 35_1^1p and 36 e⁻
59. a. 2- **b.** 1+ **c.** 3+ **d.** 1+
61.

Symbol	Ion Formed	Number of Electrons in Ion	Number of Protons in Ion
Ca	Ca ²⁺	18	20
Be	Be ²⁺	2	4
Se	Se ²⁻	36	34
In	In ³⁺	46	49

63. a. potassium, metal
c. iodine, nonmetal
e. antimony, metalloid
65. a and **b** are main-group elements.
67. a. alkali metal
b. halogen
c. alkaline earth metal
d. alkaline earth metal
e. noble gas
69. Cl and F because they are in the same group or family. Elements in the same group or family have similar chemical properties.

71.

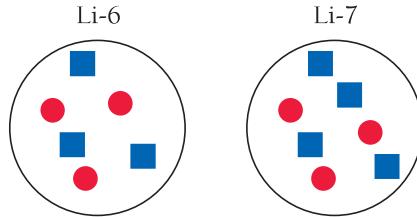
Mass (amu)	Intensity (%)
68.92558	100%
70.92470	~66%

73. The fluorine-19 isotope must have a large percent abundance, which would make fluorine produce a large peak at this mass. Chlorine has two isotopes (Cl-35 and Cl-37). The atomic mass is simply the weighted average of these two, which means that there is no chlorine isotope with a mass of 35.45 amu.
75. 121.8 amu, Sb
77. Br-79 78.92, amu 50.96%
79. 152 amu
81. 3.32×10^{24} atoms
83. a. 0.295 mol Ar **b.** 0.0543 mol Zn
c. 0.144 mol Ta
85. 2.11×10^{22} atoms
87. a. 1.01×10^{23} atoms
c. 5.39×10^{21} atoms
89. a. 36 grams
c. 62 grams
91. 2.6×10^{21} atoms
93. 3.239×10^{-22} g
95. 1.50 g
97. C₂O₃
99. 4.82241×10^7 C/kg
101. 207 amu
103. ²³⁷Pa, ²³⁸U, ²³⁹Np, ²⁴⁰Pu, ²³⁵Ac, ²³⁴Ra, etc.

105. Symbol	Z	A	#p	#e ⁻	#n	Charge
O	8	16	8	10	8	2-
Ca ²⁺	20	40	20	18	20	2+
Mg ²⁺	12	25	12	10	13	2+
N ³⁻	7	14	7	10	7	3-

107. $V_n = 8.2 \times 10^{-8}$ pm³, $V_a = 1.4 \times 10^6$ pm³, $5.9 \times 10^{-12}\%$
109. 6.022×10^{21} dollars total, 8.6×10^{11} dollars per person, billionaires
111. 15.985 amu
113. 4.76×10^{24} atoms

- 115.** 3.56 cm
117. Li-6 = 7.494%, Li-7 = 92.506%
119. 75.0% gold
121. 106.91 amu
123. 1.66×10^{22} gold atoms
125. 1×10^{78} atoms/universe
127. 0.423
129. 63.67 g/mol
131. 25.06 g/mol
133. Li-6



- 135.** If the amu and mole were not based on the same isotope, the numerical values obtained for an atom of material and a mole of material would not be the same. If, for example, the mole were based on the number of particles in C-12 but the amu were changed to a fraction of the mass of an atom of Ne-20, the number of particles and the number of amu that make up one mole of material would no longer be the same. We would no longer have the relationship in which the mass of an atom in amu is numerically equal to the mass of a mole of those atoms in grams.
137. The different isotopes of the same element have the same number of protons and electrons, so the attractive forces between the nucleus and the electrons are constant and there is no difference in the radii of the isotopes. Ions, on the other hand, have a different number of electrons than the parent atom from which they are derived. Cations have fewer electrons than the parent atom. The attractive forces are greater because there is a larger positive charge in the nucleus than the negative charge in the electron cloud. So, cations are smaller than the atom they are derived from. Anions have more electrons than the parent. The electron cloud has a greater negative charge than the nucleus, so the anions have larger radii than the parent.
142. **a.** 2000, 0.24 $\mu\text{g}/\text{m}^3$; 2016, 0.017 $\mu\text{g}/\text{m}^3$
c. 2.9×10^{14} Pb atoms

Chapter 3

- 23.** **a.** 3 Mg, 2 P, 8 O
c. 1 Fe, 2 N, 4 O
25. **a.** NH₃ **b.** C₂H₆
27. **a.** atomic
c. atomic
29. **a.** molecular
c. ionic
31. **a.** molecular element
c. atomic element
33. **a.** CaO **b.** ZnS
35. **a.** Ca(OH)₂
c. Ca₃(PO₄)₂
- b.** 1 Ba, 2 Cl
d. 1 Ca, 2 O, 2 H
c. SO₃
b. molecular
d. molecular
b. ionic
d. molecular
b. molecular compound
c. RbBr **d.** Al₂O₃
b. CaCrO₄
d. Ca(CN)₂

- 37.** **a.** magnesium nitride
c. sodium oxide
e. cesium fluoride
39. **a.** tin(II) oxide
c. rubidium iodide
41. **a.** copper(I) nitrite
c. barium nitrate
43. **a.** NaHSO₃
c. AgNO₃
e. RbHSO₄
45. **a.** cobalt(II) sulfate heptahydrate
b. IrBr₃ × 4 H₂O
c. magnesium bromate hexahydrate
d. K₂CO₃ × 2 H₂O
47. **a.** carbon monoxide
c. silicon tetrachloride
d. tetranitrogen tetraselenide
49. **a.** PCl₃
c. S₂F₄
51. **a.** hydroiodic acid
c. carbonic acid
53. **a.** HF **b.** HBr **c.** H₂SO₃
55. **a.** strontium chloride
b. tin(IV) oxide
c. diphosphorus pentasulfide
d. acetic acid
57. **a.** potassium chlorate
c. lead(II) sulfate
59. **a.** 46.01 amu
c. 180.16 amu
61. **a.** 0.471 mol
c. 968 mol
63. **a.** 0.554 mol
c. 0.378 mol
65. **a.** 2.2×10^{23} molecules
c. 4.16×10^{23} molecules
67. **a.** 0.0790 g **b.** 0.84 g
69. 0.10 mg
71. **a.** 74.87% C
c. 92.24% C
73. NH₃: 82.27% N
CO(NH₂)₂: 46.65% N
NH₄NO₃: 35.00% N
(NH₄)₂SO₄: 21.20% N
NH₃ has the highest N content.
75. 20.8 g F
77. 196 μg KI
79. **a.** 2: 1 **b.** 4: 1
81. **a.** 0.885 mol H
c. 29 mol H
83. **a.** 3.3 g Na
c. 1.4 g Na
85. 1.41×10^{23} F atoms
87. **a.** Ag₂O **b.** Co₃As₂O₈ **c.** SeBr₄
89. **a.** C₅H₇N
91. C₁₃H₁₈O₂
93. NCl₃
95. **a.** C₁₂H₁₄N₂ **b.** C₆H₃Cl₃ **c.** C₁₀H₂₀N₂S₄
- b.** potassium fluoride
d. lithium sulfide
f. potassium iodide
b. chromium(III) sulfide
d. barium bromide
b. magnesium acetate
d. lead(II) acetate
b. LiMnO₄
d. K₂SO₄
f. KHCO₃
b. nitrogen triiodide
b. ClO
d. PF₅
b. nitric acid
b. H₂SO₃
b. tin(IV) oxide
c. diphosphorus pentasulfide
b. acetic acid
b. diiodine pentoxyde
b. 58.12 amu
d. 238.03 amu
b. 0.0362 mol
d. 0.279 mol
b. 28.4 mol
d. 1093 mol
b. 7.06 $\times 10^{23}$ molecules
d. 1.09 $\times 10^{23}$ molecules
c. 2.992×10^{-22} g
b. 79.88% C
d. 37.23% C
c. 6: 2: 1
b. 5.2 mol H
d. 33.7 mol H
b. 3.6 g Na
d. 1.7 g Na

- 97.** CH₂
- 99.** C₂H₄O
- 101. a.** inorganic **b.** organic
c. organic **d.** inorganic
- 103. a.** alkene **b.** alkane
c. alkyne **d.** alkane
- 105. a.** CH₃CH₂CH₃
b. propane
c. CH₃CH₂CH₂CH₂CH₂CH₂CH₃
d. pentane
- 107. a.** functionalized hydrocarbon, alcohol
b. hydrocarbon
c. functionalized hydrocarbon, ketone
d. functionalized hydrocarbon, amine
- 109.** 1.50 × 10²⁴ molecules EtOH
- 111. a.** K₂CrO₄, 40.27% K, 26.78% Cr, 32.95% O
b. Pb₃(PO₄)₂, 76.60% Pb, 7.63% P, 15.77% O
c. H₂SO₃, 2.46% H, 39.07% S, 58.47% O
d. CoBr₂, 26.94% Co, 73.06% Br
- 113.** 1.80 × 10² g Cl₂/yr
- 115.** M = Fe
- 117.** estradiol = C₁₈H₂₄O₂
- 119.** C₁₈H₂₀O₂
- 121.** 7 H₂O
- 123.** C₆H₉BrO
- 125.** 1.87 × 10²¹ atoms
- 127.** 92.93 amu
- 129.** x = 1, y = 2
- 131.** 41.7 mg
- 133.** 0.224 g
- 135.** 22.0% by mass
- 137.** 1.6 × 10⁷ kg Cl
- 139.** 7.8 × 10³ kg rock
- 141.** C₅H₁₀SI
- 143.** X₃Y₂
- 145.** The sphere in the molecular models represents the electron cloud of the atom. On this scale, the nucleus would be too small to see.
- 147.** The statement is incorrect because a chemical formula is based on the ratio of atoms combined, not the ratio of grams combined. The statement should read, "The chemical formula for ammonia (NH₃) indicates that ammonia contains three hydrogen atoms to each nitrogen atom."
- 149.** O, S, H
- 154. a.** Yes. **c.** 50.05 %
- Chapter 4**
- 13.** 2 SO₂(g) + O₂(g) + 2 H₂O(l) → 2 H₂SO₄(aq)
- 15.** 2 Na(s) + 2 H₂O(l) → H₂(g) + 2 NaOH(aq)
- 17.** C₁₂H₂₂O₁₁(s) + H₂O(l) → 4 C₂H₅OH(aq) + 4 CO₂(g)
- 19. a.** PbS(s) + 2 HBr(aq) → PbBr₂(s) + H₂S(g)
b. CO(g) + 3 H₂(g) → CH₄(g) + H₂O(l)
c. 4 HCl(aq) + MnO₂(g) → MnCl₂(aq) + 2 H₂O(l) + Cl₂(g)
d. C₅H₁₂(l) + 8 O₂(g) → 5 CO₂(g) + 6 H₂O(g)
- 21.** Na₂CO₃(aq) + CuCl₂(aq) → CuCO₃(s) + 2 NaCl(aq)
- 23. a.** 2 CO₂(g) + CaSiO₃(s) + H₂O(l) → SiO₂(s) + Ca(HCO₃)₂(aq)
b. 2 Co(NO₃)₃(aq) + 3 (NH₄)₂S(aq) → Co₂S₃(s) + 6 NH₄NO₃(aq)
c. Cu₂O(s) + C(s) → 2 Cu(s) + CO(g)
d. H₂(g) + Cl₂(g) → 2 HCl(g)
- 25.** 2 C₆H₁₄(g) + 19 O₂(g) → 12 CO₂(g) + 14 H₂O(g), 68 mol O₂
- 27. a.** 5.0 mol NO₂ **b.** 14. mol NO₂
c. 0.281 mol NO₂ **d.** 53.1 mol NO₂
- | mol SiO ₂ | mol C | mol SiC | mol CO |
|----------------------|-------|---------|--------|
| 3 | 9 | 3 | 6 |
| 2 | 6 | 2 | 4 |
| 5 | 15 | 5 | 10 |
| 2.8 | 8.4 | 2.8 | 5.6 |
| 0.517 | 1.55 | 0.517 | 1.03 |
- 31.** 9.3 g HBr, 0.12 g H₂
- 33. a.** 5.56 g BaCl₂
b. 6.55 g CaCO₃
c. 6.09 g Mg O
d. 6.93 g Al₂O₃
- 35. a.** Na **b.** Na **c.** Br₂ **d.** Na
- 37.** 3 molecules Cl₂
- 39. a.** 2 mol **b.** 7 mol **c.** 9.40 mol
- 41.** 0.5 mol O₂
- 43. a.** 2.5 g **b.** 31.1 g **c.** 1.16 g
- 45.** 2.91 grams CO remaining
- 47.** limiting reactant: Pb²⁺ theoretical yield: 34.5 g PbCl₂
percent yield: 85.3%
- 49.** limiting reactant: NH₃ theoretical yield: 240.5 kg
CH₄N₂O, percent yield: 70.01%
- 51. a.** S(s) + O₂(g) → SO₂(g)
b. 2 C₃H₆(g) + 9 O₂(g) → 6 CO₂(g) + 6 H₂O(g)
c. 2 Ca(s) + O₂(g) → 2 CaO(g)
d. C₅H₁₂S(l) + 9 O₂(g) → 5 CO₂(g) + SO₂(g) + 6 H₂O(g)
- 53.** Sr(s) + I₂(g) → SrI₂(s)
- 55. 2** Li(s) + 2 H₂O(l) → 2 Li⁺(aq) + 2 OH⁻(aq) + H₂(g)
- 57.** H₂(g) + Br₂(g) → 2 HBr(g)
- 59.** 3.1 kg
- 61.** limiting reactant: C₇H₆O₃, theoretical yield: 1.63 g
C₉H₈O₄ percent yield: 74.8%
- 63. b**
- 65.** 0.333 g PH₃
- 67.** 30.8 kg CO₂
- 69.** 1.6 g C₂H₂
- 71.** 2.8 mol A
- 73.** 96.6 g Mn
- 75.** d. 1.5 g K, 0.38 g O₂
- 77. a)**
- 81. a.** Experiments 1, 2, and 3
c. 2 A + 1 B **e.** 2 C

Chapter 5

- 21.** **a.** 1.17 M LiCl
c. 0.00453 M NaCl
- 23.** **a.** 0.150 M NO_3^-
c. 0.450 M NO_3^-
- 25.** **a.** 1.3 mol
c. 0.211 mol
- 27.** 37 g
- 29.** 0.27 M
- 31.** 6.0 L
- 33.** 37.1 mL
- 35.** 2.1 L
- 37.** lead nitrate, 3.75 g, 65.3%
- 39.** **a.** yes **b.** no **c.** yes **d.** no
- 41.** **a.** soluble Ag^+ , NO_3^-
b. soluble Pb^{2+} , $\text{C}_2\text{H}_3\text{O}_2^-$
c. soluble K^+ , NO_3^-
d. soluble NH_4^+ , S^{2-}
- 43.** **a.** NO REACTION
b. NO REACTION
c. $\text{CrBr}_2(aq) + \text{Na}_2\text{CO}_3(aq) \longrightarrow \text{CrCO}_3(s) + 2 \text{NaBr}(aq)$
d. $3 \text{NaOH}(aq) + \text{FeCl}_3(aq) \longrightarrow \text{Fe(OH)}_3(s) + 3 \text{NaCl}(aq)$
- 45.** **a.** $\text{K}_2\text{CO}_3(aq) + \text{Pb}(\text{NO}_3)_2(aq) \longrightarrow \text{PbCO}_3(s) + 2 \text{KNO}_3(aq)$
b. $\text{Li}_2\text{SO}_4(aq) + \text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2(aq) \longrightarrow \text{PbSO}_4(s) + 2 \text{LiC}_2\text{H}_3\text{O}_2(aq)$
c. $\text{Cu}(\text{NO}_3)_2(aq) + \text{MgS}(aq) \longrightarrow \text{CuS}(s) + \text{Mg}(\text{NO}_3)_2(aq)$
d. NO REACTION
- 47.** **a.** Complete:

$$\text{H}^+(aq) + \text{Cl}^-(aq) + \text{Li}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{Li}^+(aq) + \text{Cl}^-(aq)$$
Net: $\text{H}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l)$
- b.** Complete:

$$\text{Ca}^{2+}(aq) + \text{S}^{2-}(aq) + \text{Cu}^{2+}(aq) + 2 \text{Cl}^-(aq) \longrightarrow \text{CuS}(s) + \text{Ca}^{2+}(aq) + 2 \text{Cl}^-(aq)$$
Net: $\text{Cu}^{2+}(aq) + \text{S}^{2-}(aq) \longrightarrow \text{CuS}(s)$
- c.** Complete:

$$\text{Na}^+(aq) + \text{OH}^-(aq) + \text{HC}_2\text{H}_3\text{O}_2(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{Na}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$$
Net: $\text{OH}^-(aq) + \text{HC}_2\text{H}_3\text{O}_2(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$
- d.** Complete:

$$6 \text{Na}^+(aq) + 2 \text{PO}_4^{3-}(aq) + 3 \text{Ni}^{2+}(aq) + 6 \text{Cl}^-(aq) \longrightarrow \text{Ni}_3(\text{PO}_4)_2(s) + 6 \text{Na}^+(aq) + 6 \text{Cl}^-(aq)$$
Net: $3 \text{Ni}^{2+}(aq) + 2 \text{PO}_4^{3-}(aq) \longrightarrow \text{Ni}_3(\text{PO}_4)_2(s)$
- 49.** Complete:

$$\text{Hg}_2^{2+}(aq) + 2 \text{NO}_3^-(aq) + 2 \text{Na}^+(aq) + 2 \text{Cl}^-(aq) \longrightarrow \text{Hg}_2\text{Cl}_2(s) + 2 \text{Na}^+(aq) + 2 \text{NO}_3^-(aq)$$
Net: $\text{Hg}_2^{2+}(aq) + 2 \text{Cl}^-(aq) \longrightarrow \text{Hg}_2\text{Cl}_2(s)$
- 51.** Molecular:

$$\text{HBr}(aq) + \text{KOH}(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{KBr}(aq)$$
Net ionic: $\text{H}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l)$

- 53.** **a.** $\text{H}_2\text{SO}_4(aq) + \text{Ca}(\text{OH})_2(aq) \longrightarrow 2 \text{H}_2\text{O}(l) + \text{CaSO}_4(s)$
b. $\text{HClO}_4(aq) + \text{KOH}(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{KClO}_4(aq)$
c. $\text{H}_2\text{SO}_4(aq) + 2 \text{NaOH}(aq) \longrightarrow 2 \text{H}_2\text{O}(l) + \text{Na}_2\text{SO}_4(aq)$
- 55.** **a.** Complete ionic:

$$\text{H}^+(aq) + \text{Br}^-(aq) + \text{Na}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{Na}^+(aq) + \text{Br}^-(aq)$$
Net ionic: $\text{H}^+(aq) \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l)$
- b.** Complete ionic:

$$\text{HF}(aq) + \text{Na}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{Na}^+(aq) + \text{F}^-(aq)$$
Net ionic:

$$\text{HF}(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{F}^-(aq)$$
- c.** Complete ionic:

$$\text{HC}_2\text{H}_3\text{O}_2(aq) + \text{Rb}^+(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{Rb}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$$
Net ionic:

$$\text{HC}_2\text{H}_3\text{O}_2(aq) + \text{OH}^-(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$$
- 57.** 0.1810 M HClO_4
- 59.** **a.** $2 \text{HBr}(aq) + \text{NiS}(s) \longrightarrow \text{H}_2\text{S}(g) + \text{NiBr}_2(aq)$
b. $\text{NH}_4\text{I}(aq) + \text{NaOH}(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{NH}_3(g) + \text{NaI}(aq)$
c. $2 \text{HBr}(aq) + \text{Na}_2\text{S}(aq) \longrightarrow \text{H}_2\text{S}(g) + 2 \text{NaBr}(aq)$
d. $2 \text{HClO}_4(aq) + \text{Li}_2\text{CO}_3(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{CO}_2(g) + 2 \text{LiClO}_4(aq)$
- 61.** **a.** Ag: 0 **b.** Ag: +1
c. Ca: +2, F: -1 **d.** H: +1, S: -2
e. C: +4, O: -2 **f.** Cr: +6, O: -2
- 63.** **a.** +2 **b.** +6 **c.** +3
- 65.** **a.** redox reaction, oxidizing agent: O_2 reducing agent: Li
b. redox reaction, oxidizing agent: Fe^{2+} reducing agent: Mg
c. not a redox reaction **d.** not a redox reaction
- 67.** b and c occur spontaneously in the forward direction.
- 69.** Fe, Cr, Zn, Mn, Al, Mg, Na, Ca, K, Li
- 71.** Mg
- 73.** 3.32 M
- 75.** 1.1 g
- 77.** **a.** $2 \text{HCl}(aq) + \text{Hg}_2(\text{NO}_3)_2(aq) \longrightarrow \text{Hg}_2\text{Cl}_2(s) + 2 \text{HNO}_3(aq)$
b. $\text{KHSO}_3(aq) + \text{HNO}_3(aq) \longrightarrow \text{H}_2\text{O}(l) + \text{SO}_2(g) + \text{KNO}_3(aq)$
c. $2 \text{NH}_4\text{Cl}(aq) + \text{Pb}(\text{NO}_3)_2(aq) \longrightarrow \text{PbCl}_2(s) + 2 \text{NH}_4\text{NO}_3(aq)$
d. $2 \text{NH}_4\text{Cl}(aq) + \text{Ca}(\text{OH})_2(aq) \longrightarrow 2 \text{NH}_3(g) + 2 \text{H}_2\text{O}(g) + \text{CaCl}_2(aq)$
- 79.** 22 g
- 81.** 6.9 g
- 83.** Br is the oxidizing agent, Au is the reducing agent, 38.8 g KAuF_4 .
- 85.** Ca^{2+} and Cu^{2+} present in the original solution.
Net ionic for first precipitate:

$$\text{Ca}^{2+}(aq) + \text{SO}_4^{2-}(aq) \longrightarrow \text{CaSO}_4(s)$$
Net ionic for second precipitate:

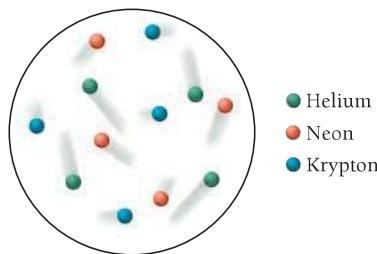
$$\text{Cu}^{2+}(aq) + \text{CO}_3^{2-}(aq) \longrightarrow \text{CuCO}_3(s)$$
- 87.** 11.8 g AgI
- 89.** 5.5% by mass

- 91.** **a.** Add 4 particles of solute.
b. Add 1 L solvent.
c. Add 0.3 L solvent.
- 93.** b.
- 98.** **a.** 10.3 ppb; 3.81 ppb, 1.69 ppb
c. If the water provider used first-draw samples, they would have been required to take action. If they used 2 min flush samples, they would not have been required to take action. Residents probably don't flush their pipes before taking water, so the first-draw technique is probably closer to actual practice.

Chapter 6

- 25.** **a.** 0.832 atm **b.** 632 mmHg
c. 12.2 psi **d.** 8.43×10^4 Pa
- 27.** **a.** 809.0 mmHg **b.** 1.064 atm
c. 809.0 torr **d.** 107.9 kPa
- 29.** **a.** 832 mmHg **b.** 718 mmHg
- 31.** 4.4×10^2 mmHg
- 33.** 58.9 mL
- 35.** 4.22 L
- 37.** 3.0 L. The volume would not be different if the gas was argon.
- 39.** 1.16 atm
- 41.** 2.1 mol
- 43.** Yes, the final gauge pressure is 43.5 psi, which exceeds the maximum rating.
- 45.** 16.2 L
- 47.** 286 atm, 17.5 bottles purged
- 49.** **b**
- 51.** 4.76 atm
- 53.** 37.3 L
- 55.** 9.43 g/L
- 57.** 44.0 g/mol
- 59.** 4.00 g/mol
- 61.** $P_{\text{tot}} = 434$ torr, $\text{mass}_{\text{N}_2} = 0.437$ g,
 $\text{mass}_{\text{O}_2} = 0.237$ g, $\text{mass}_{\text{He}} = 0.0340$ g
- 63.** 1.84 atm
- 65.** $\chi_{\text{N}_2} = 0.627$, $\chi_{\text{O}_2} = 0.373$,
 $P_{\text{N}_2} = 0.687$ atm, $P_{\text{O}_2} = 0.409$ atm
- 67.** $P_{\text{H}_2} = 0.921$ atm, $\text{mass}_{\text{H}_2} = 0.0539$ g
- 69.** 7.47×10^{-2} g
- 71.** 38 L
- 73.** $V_{\text{H}_2} = 48.2$ L, $V_{\text{CO}} = 24.1$ L
- 75.** 22.8 g NaN_3
- 77.** 60.4%
- 79.** F_2 , 2.84 g ClF_3
- 81.** **a.** yes
b. no
c. No. Even though the argon atoms are more massive than the helium atoms, both have the same kinetic energy at a given temperature. The argon atoms therefore move more slowly and so exert the same pressure as the helium atoms.
d. He
- 83.** $\text{F}_2 : u_{\text{rms}} = 442$ m/s, $\text{KE}_{\text{avg}} = 3.72 \times 10^3$ J;
 $\text{Cl}_2 : u_{\text{rms}} = 324$ m/s, $\text{KE}_{\text{avg}} = 3.72 \times 10^3$ J;
 $\text{Br}_2 : u_{\text{rms}} = 216$ m/s, $\text{KE}_{\text{avg}} = 3.72 \times 10^3$ J;
rankings: u_{rms} : $\text{Br}_2 < \text{Cl}_2 < \text{F}_2$, KE_{avg} : $\text{Br}_2 = \text{Cl}_2 = \text{F}_2$,
rate of effusion: $\text{Br}_2 < \text{Cl}_2 < \text{F}_2$
- 85.** rate $^{238}\text{UF}_6$ /rate $^{235}\text{UF}_6 = 0.99574$
- 87.** krypton
- 89.** A has the higher molar mass, B has the higher rate of effusion.
- 91.** That the volume of gas particles is small compared to the space between them breaks down under conditions of high pressure. At high pressure, the particles themselves occupy a significant portion of the total gas volume.
- 93.** 0.05826 L (ideal); 0.0708 L (V.D.W.); difference because of high pressure, at which Ne no longer acts ideally
- 95.** 97.8%
- 97.** 27.8 g/mol
- 99.** C_4H_{10}
- 101.** 4.70 L
- 103.** $2 \text{ HCl}(aq) + \text{K}_2\text{S}(s) \longrightarrow \text{H}_2\text{S}(g) + 2 \text{ KCl}(aq)$, 0.191 g $\text{K}_2\text{S}(s)$
- 105.** 11.7 L
- 107.** $\text{mass}_{\text{air}} = 8.56$ g, $\text{mass}_{\text{He}} = 1.20$ g,
mass difference = 7.36 g
- 109.** 4.76 L/s
- 111.** total force = 6.15×10^3 pounds; no, the can cannot withstand this force.
- 113.** 5.8×10^3 balloons
- 115.** 4.0 cm
- 117.** 77.7%
- 119.** 0.32 gram
- 121.** 311 K
- 123.** 5.0 g
- 125.** C_3H_8
- 127.** 0.39 g Ar
- 129.** 74.0 mmHg
- 131.** 25% N_2H_4
- 133.** 25%
- 135.** $P_{\text{CH}_4} = 7.30 \times 10^{-2}$ atm, $P_{\text{O}_2} = 4.20 \times 10^{-1}$ atm,
 $P_{\text{NO}} = 2.79 \times 10^{-3}$ atm, $P_{\text{CO}_2} = 5.03 \times 10^{-3}$ atm,
 $P_{\text{H}_2\text{O}} = 5.03 \times 10^{-3}$ atm, $P_{\text{NO}_2} = 2.51 \times 10^{-2}$ atm,
 $P_{\text{OH}} = 1.01 \times 10^{-2}$ atm, $P_{\text{tot}} = 0.542$ atm
- 137.** 0.42
- 139.** Because helium is less dense than air, the balloon moves in a direction opposite the direction in which the air inside the car is moving due to the acceleration and deceleration of the car.
- 141.** -29%
- 143.** **a.** false **b.** false **c.** false **d.** true
- 145.** four times the initial pressure
- 147.** Although the velocity "tails" have different lengths, the average length of the tails on the helium atoms is longer than the average length of the tails on the neon atoms, which is in turn longer than the average length of the tails on the krypton atoms. The lighter the

atom, the faster the tails must move on average to have the same kinetic energy.



- 153.** **a.** inverse relationship
b. 1.3×10^{-6} mol
c. Yes, because in these equations, 1 mole of O_3 reacts to form 1 mole of NO_2 .

Chapter 7

- 33.** **a.** 1.92×10^9 J **b.** 5.14×10^4 cal
c. 2.37×10^6 J **d.** 0.681 Cal
- 35.** **a.** 9.987×10^6 J **b.** 9.987×10^3 kJ
c. 2.78 kWh
- 37. d**
- 39.** **a.** heat, + **b.** work, - **c.** heat, +
- 41.** -7.27×10^2 kJ
- 43.** 311 kJ
- 45.** The drinks that went into cooler B had more thermal energy than the refrigerated drinks that went into cooler A. The temperature difference between the drinks in cooler B and the ice was greater than the difference between the drinks and the ice in cooler A. More thermal energy was exchanged between the drinks and the ice in cooler B, which resulted in more melting.
- 47.** 4.7×10^5 J
- 49.** **a.** 7.6×10^2 °C
b. 4.3×10^2 °C
c. 1.3×10^2 °C
d. 49 °C
- 51.** -2.8×10^2 J
- 53.** 489 J
- 55.** $\Delta E = -3463$ kJ, $\Delta H = -3452$ kJ
- 57.** **a.** exothermic, -
b. endothermic, +
c. exothermic, -
- 59.** -4.30×10^3 kJ
- 61.** 6.46×10^4 kJ
- 63.** 1.0 kg CO_2
- 65.** mass of silver 77.1 grams
- 67.** final temperature 28.4 °C
- 69.** specific heat capacity of substance A $1.10 \text{ J/g} \cdot ^\circ\text{C}$
- 71.** Measurement B corresponds to conditions of constant pressure. Measurement A corresponds to conditions of constant volume. When a fuel is burned under constant pressure, some of the energy released does work on the atmosphere by expanding against it. Less energy is manifest as heat due to this work. When a fuel is burned under constant volume, all of the energy released by the combustion reaction is evolved as heat.
- 73.** -6.3×10^3 kJ/mol
- 75.** -1.6×10^5 J
- 77.** **a.** $-\Delta H_1$
b. $2 \Delta H_1$
c. $-\frac{1}{2} \Delta H_1$
- 79.** -23.9 kJ
- 81.** -173.2 kJ
- 83.** **a.** $\text{N}_2(g) + 3 \text{H}_2(g) \longrightarrow 2 \text{NH}_3(g)$, $\Delta H_f^\circ = -45.9$ kJ/mol
b. $\text{C(s, graphite)} + \text{O}_2(g) \longrightarrow \text{CO}_2(g)$, $\Delta H_f^\circ = -393.5$ kJ/mol
c. $2 \text{Fe(s)} + 3/2 \text{O}_2(g) \longrightarrow \text{Fe}_2\text{O}_3(s)$, $\Delta H_f^\circ = -824.2$ kJ/mol
d. $\text{C(s, graphite)} + 2 \text{H}_2(g) \longrightarrow \text{CH}_4(g)$, $\Delta H_f^\circ = -74.6$ kJ/mol
- 85.** -380.2 kJ/mol
- 87.** **a.** -137.1 kJ **b.** -41.2 kJ
c. -137 kJ **d.** 290.7 kJ
- 89.** $6 \text{CO}_2(g) + 6 \text{H}_2\text{O}(l) \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6(s) + 6 \text{O}_2(g)$, $\Delta H_{rxn}^\circ = 2803$ kJ
- 91.** -113.0 kJ/mol
- 93.** **a.** 5.49 g CO_2 **b.** 6.46 g CO_2
c. 6.94 g CO_2
Natural gas, $\text{CH}_4(g)$, contributes the least to global warming by producing the least $\text{CO}_2(g)$ per kJ of heat produced.
- 95.** 2×10^{13} kg CO_2 produced per year, 150 years
- 97.** $\Delta E = -1.7$ J, $q = -0.5$ J, $w = -1.2$ J
- 99.** 78 g
- 101.** $\Delta H = 6.0$ kJ/mol, 1.1×10^2 g
- 103.** 26.1 °C
- 105.** palmitic acid: 9.9378 Cal/g; sucrose: 3.938 Cal/g; fat contains more Cal/g than sugar.
- 107.** $\Delta H = \Delta E + nR\Delta T$
- 109.** 5.7 Cal/g
- 111.** $\Delta E = 0$, $\Delta H = 0$, $q = -w = 3.0 \times 10^3$ J
- 113.** -294 kJ/mol
- 115.** 94.0 kJ
- 117.** 23.9 °C
- 119.** 7.3×10^3 g H_2SO_4
- 121.** 7.2×10^2 g
- 123.** 78.2 °C
- 125.** $C_v = \frac{3}{2}R$, $C_p = \frac{5}{2}R$
- 127.** $q = 1030$ kJ, $\Delta H = 1030$ kJ, $\Delta E = 952$ kJ, $w = -78$ kJ
- 129.** -1292 kJ
- 131. d**
- 133.** **a.** At constant pressure, heat can be added and work can be done on the system. $\Delta E = q + w$; therefore, $q = \Delta E - w$.
- 135.** The aluminum is cooler because it has a lower heat capacity (specific heat).
- 137.** $q = -2418$ J, $w = -5$ kJ,
 $\Delta H = -2418$ J/mol, $\Delta E = -2423$ J/mol
- 139. b.** $\Delta H > \Delta E$
- 144.** **a.** $\text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \longrightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(l)$
 $\text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \longrightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(g)$
c. LLV because the water formed is the gaseous state;
 46.3×10^3 kJ

Chapter 8

- 35.** 499 s
37. i. d, c, b, a
ii. a, b, c, d
39. a. 4.74×10^{14} Hz
b. 5.96×10^{14} Hz
c. 5.8×10^{18} Hz
41. a. 3.14×10^{-19} J
b. 3.95×10^{-19} J
c. 3.8×10^{-15} J
43. 1.03×10^{16} photons
45. a. 79.8 kJ/mol
b. 239 kJ/mol
c. 798 kJ/mol

47.

- 49.** 3.6×10^6 m/s
51. 5.39 nm
53. 1.1×10^{-34} m. The wavelength of a baseball is negligible with respect to its size.
55. $\Delta v = 1.04 \times 10^5$ m/s

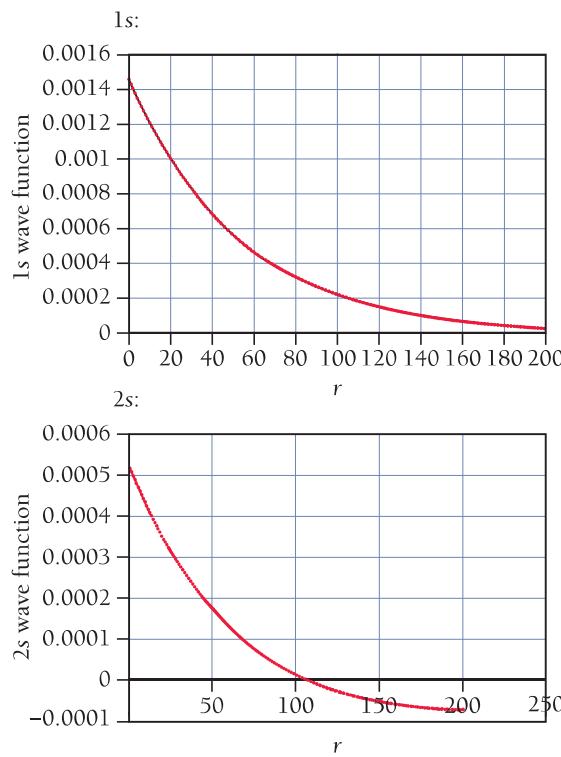
- 57.** 2s
59. a. $l = 0$
b. $l = 0, 1$
c. $l = 0, 1, 2$
d. $l = 0, 1, 2, 3$

- 61. c**
63. See **Figures 7.25** and **7.26**. The 2s and 3p orbitals would, on average, be farther from the nucleus and have more nodes than the 1s and 2p orbitals.

- 65.** $n = 1$
67. 2p \longrightarrow 1s
69. a. 122 nm, UV
b. 103 nm, UV
c. 486 nm, visible
d. 434 nm, visible

- 71.** $n = 2$
73. 344 nm
75. 6.4×10^{17} photons/s
77. 0.0547 nm
79. 91.2 nm

- 81. a.** 4
b. 9
c. 16
83. $n=4 \longrightarrow n=3, n=5 \longrightarrow n=3, n=6 \longrightarrow n=3$, respectively
85. 4.84×10^{14} s⁻¹
87. 11 m
89. 6.78×10^{-3} J
91. 632 nm
93. 2.98×10^{-4} mol
95. a. $E_1 = 2.51 \times 10^{-18}$ J, $E_2 = 1.00 \times 10^{-17}$ J,
 $E_3 = 2.26 \times 10^{-17}$ J
b. 26.5 nm, UV; 15.8 nm, UV

97.

The plot for the 2s wave function extends below the x-axis. The x-intercept represents the radial node of the orbital.

- 99.** 7.39×10^5 m/s
101. $\Delta E = 1.1 \times 10^{-20}$ J, 7.0×10^2 nm
103. 11 m
105. In the Bohr model, electrons exist in specific orbits encircling the atom. In the quantum-mechanical model, electrons exist in orbitals that are really probability density maps of where the electron is likely to be found. The Bohr model is inconsistent with Heisenberg's uncertainty principle.
107. a. yes b. no c. yes d. no
**114. a. 5.93×10^{-19} J c. 2-EHMC
e. 1.4×10^7 J**

Chapter 9

- 39. a.** $1s^2 2s^2 2p^6 3s^2 3p^2$
c. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
d. $1s^2 2s^2 2p^6$
- 41. a.**

↑↓	↑↓	↑↓ ↑↓ ↑		
1s	2s	2p		

b.

↑↓	↑↓	↑↓ ↑↓ ↑		
1s	2s	2p		

c.

↑↓	↑↓	↑↓ ↑↓ ↑			↑↓
1s	2s	2p			3s

d.

↑↓	↑↓	↑↓ ↑↓ ↑			↑↓	↑	
1s	2s	2p			3s	3p	

- 43.** **a.** [Ne]3s²3p³
c. [Kr]5s²4d²
- 45.** **a.** 1 **b.** 10
- 47.** **a.** V, As **b.** Se
- 49.** **a.** 2 **b.** 1 **c.** 10 **d.** 6

51. reactive metal: **a**, reactive nonmetal: **c**

53. c

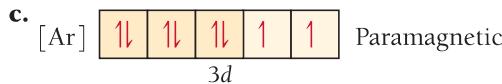
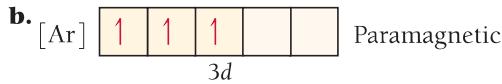
55. The valence electrons of nitrogen will experience a greater effective nuclear charge. The valence electrons of both atoms are screened by two core electrons, but N has a greater number of protons and therefore a greater net nuclear charge.

- 57.** **a.** 1+ **b.** 2+ **c.** 6+ **d.** 4+
- 59.** **a.** In **b.** Si **c.** Pb **d.** C

61. F, S, Si, Ge, Ca, Rb

- 63.** **a.** [Ne] **b.** [Kr] **c.** [Kr]
d. [Ar]3d⁶ **e.** [Ar]3d⁹

65. **a.** [Ar] Diamagnetic



- 67.** **a.** Li **b.** I⁻ **c.** Cr **d.** O²⁻
- 69.** O²⁻, F⁻, Na⁺, Mg²⁺

- 71.** **a.** Br
b. Na
c. cannot tell based on periodic trends
d. P

73. In, Si, N, F

- 75.** **a.** second and third
c. sixth and seventh
- b.** fifth and sixth
d. first and second
- 77.** **a.** Na **b.** S **c.** C **d.** F

- 79.** **a.** Sr **b.** Bi
c. cannot tell based on periodic trends
d. As

81. S, Se, Sb, In, Ba, Fr

Br:1s²2s²2p⁶3s²3p⁶4s²3d¹⁰4p⁵

Kr:1s²2s²2p⁶3s²3p⁶4s²3d¹⁰4p⁶

Krypton's outer electron shell is filled, giving it chemical stability. Bromine is missing an electron from its outer shell and subsequently has a high electron affinity. Bromine tends to be easily reduced by gaining an electron, giving the bromide ion stability due to the filled p subshell that corresponds to krypton's chemically stable electron configuration.

85. V:[Ar] 4s²3d³

V³⁺:[Ar] 3d²

Both V and V³⁺ contain unpaired electrons in their 3d orbitals.

87. A substitute for K⁺ would need to exhibit a 1+ electric charge and have similar mass and atomic radius. Na⁺ and Rb⁺ would not be good substitutes because their radii are significantly smaller and larger, respectively. Based on mass, Ca⁺ and Ar⁺ are the closest to K⁺.

Because the first ionization energy of Ca⁺ is closest to that of K⁺, Ca⁺ is the best choice for a substitute. The difficulty lies in Ca's low second ionization energy, making it easily oxidized.

89. Si, Ge

- 91.** **a.** N:[He] 2s²2p³, Mg:[Ne]3s², O:[He]2s²2p⁴, %
F:[He] 2s²2p⁵, Al:[Ne] 3s²3p¹%

b. Mg, Al, O, F, N

c. Al, Mg, O, N, F

d. Aluminum's first ionization energy is lower than Mg because its 3p electron is shielded by the 3s orbital. Oxygen's first ionization energy is lower than that of N because its fourth 2p electron experiences electron-electron repulsion by the other electron in its orbital.

93. For main-group elements, atomic radii decrease across a period because the addition of a proton in the nucleus and an electron in the outermost energy level increases Z_{eff} . This does not happen in the transition metals because the electrons are added to the $n_{\text{highest}-1}$ orbital and the Z_{eff} stays roughly the same.

95. Noble gases are exceptionally unreactive due to the stability of their completely filled outer quantum levels and their high ionization energies. The ionization energies of Kr, Xe, and Rn are low enough to form some compounds.

97. 6A: ns²np⁴, 7A: ns²np⁵, group 7A elements require only one electron to achieve a noble gas configuration. Since group 6A elements require two electrons, their affinity for one electron is less negative because one electron will merely give them an np⁵ configuration.

99. 85

- 101.** **a.** One If By Land (O, Ne, I, F, B, Y, La, Nd)
b. Atoms Are Fun (N, U, Fe, Ra, S, Mo, Ta backward)

103. 1.390 × 10³ kJ/mol, 86.14 nm

- 105.** **a.** F **b.** B **c.** B **d.** O

107. **a.** $d_{\text{Ar}} \approx 2 \text{ g/L}$, $d_{\text{Xe}} \approx 6.5 \text{ g/L}$

b. $d_{\text{I}_{18}} \approx 13 \text{ g/L}$

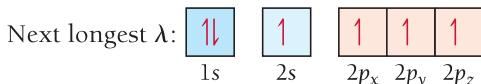
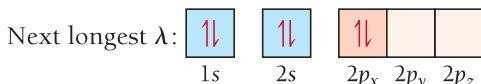
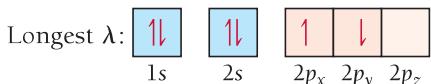
c. mass = $3.35 \times 10^{-23} \text{ g/Ne atom}$, density of Ne atom = $2.3 \times 10^4 \text{ g/L}$. The separation of Ne atoms relative to their size is immense.

d. Kr: $2.69 \times 10^{22} \text{ atoms/L}$, Ne: $2.69 \times 10^{22} \text{ atoms/L}$.

It seems Ar will also have $2.69 \times 10^{22} \text{ atoms/L}$.

$d_{\text{Ar}} = 1.78 \text{ g/L}$. This corresponds to accepted values.

109. Density increases to the right because, though electrons are added successively across the period, they are added to the 3d subshell, which is not a part of the outermost principal energy level. As a result, the atomic radius does not increase significantly across the period, while mass does.

111.**113.** 168, noble gas

115. A relatively high effective nuclear charge is found in gallium with its completed $3d$ subshell and in thallium with its completed $4f$ subshell, accounting for the relatively high first ionization energies of these elements.

117. The second electron affinity requires the addition of an electron to something that is already negatively charged. The monoanions of both of these elements have relatively high electron density in a relatively small volume.

119. 120, 170**121.** Fr, [Rn] $7s^1$, >265, <376, >1.879, <29

- a. $\text{Fr}^+(aq)$, $\text{OH}^-(aq)$, $\text{H}_2(g)$
- b. $\text{Fr}_2\text{O}(s)$
- c. $\text{FrCl}(s)$

123. a. any group 6A element b. any group 5A element
c. any group 1A element

125. a. true b. true c. false d. true

127. Since Ca has valence electrons of $4s^2$, it has a relatively low ionization energy to lose two electrons. F has a highly exothermic electron affinity when gaining one electron but not a second electron because of its $2s^22p^5$ valence electrons. Therefore, calcium and fluoride combine in a 2:1 ratio.

133. a. First ionization energy generally increases as you move from left to right across period 3 because effective nuclear charge increases from left to right.
c. Electron affinity generally decreases (becomes more exothermic) from left to right across period 3 because effective nuclear charge increases from left to right.
e. The overall energy change is approximately 150 kJ/mol. The exchange is endothermic.

Chapter 10

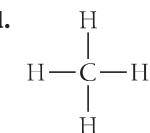
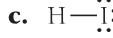
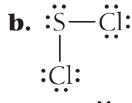
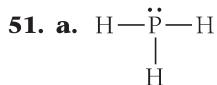
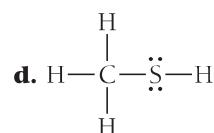
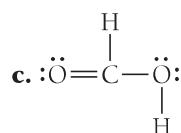
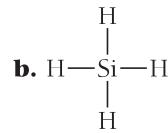
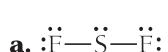
35. $1s^22s^22p^3 \cdot \ddot{\text{N}}:$ **37.** a. Al b. Na^+ c. Cl d. $[\text{Cl}]^-$ **39.** a. $\text{Na}^+[\text{F}]^-$ b. $\text{Ca}^{2+}[\text{O}]^{2-}$
c. $\text{Sr}^{2+}2[\text{Br}]^-$ d. $2\text{K}^+[\text{O}]^{2-}$ **41.** a. SrSe b. BaCl_2 c. Na_2S d. Al_2O_3

43. As the size of the alkaline earth metal ions increases, so does the distance between the metal cations and oxygen anions. Therefore, the magnitude of the lattice energy decreases accordingly because the potential energy decreases as the distance increases.

45. One factor of lattice energy is the product of the charges of the two ions. The product of the ion charges for CsF is -1 , while that for BaO is -4 . Because this product is four times greater, the lattice energy is also four times greater.

47. -708 kJ/mol

- a. H:H, filled duets, 0 formal charge on both atoms
- b. Cl—Cl, filled octets, 0 formal charge on both atoms
- c. O=O, filled octets, 0 formal charge on both atoms
- d. N≡N, filled octets, 0 formal charge on both atoms

**53.**

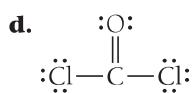
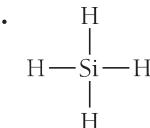
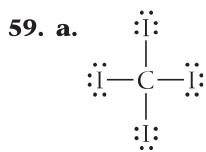
55. a. pure covalent

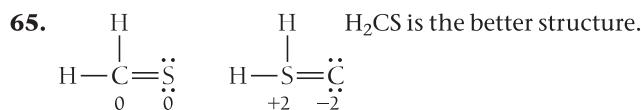
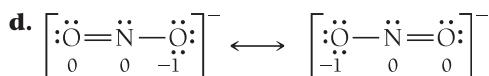
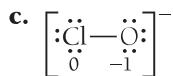
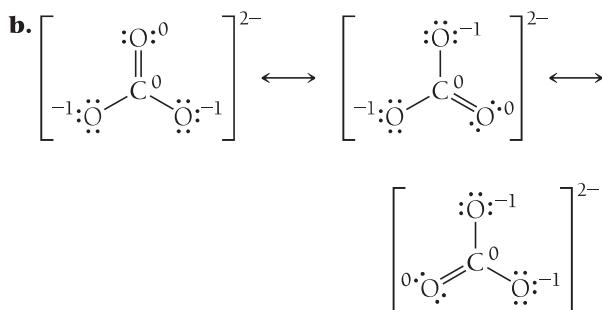
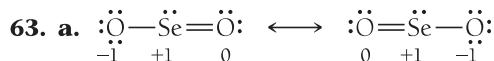
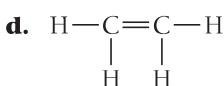
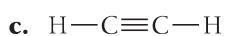
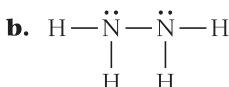
b. polar covalent

c. pure covalent

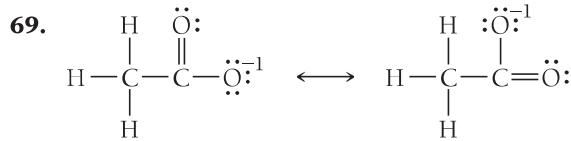
d. ionic bond

57. $\begin{array}{c} \text{C} \equiv \text{O} \\ || \end{array}$; 25%

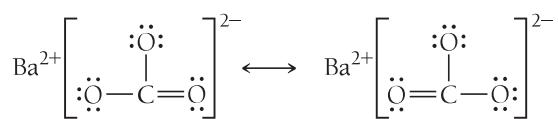
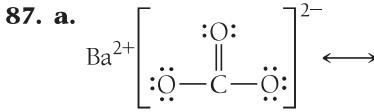
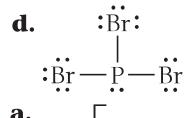
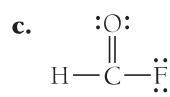
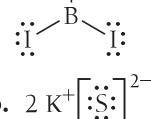
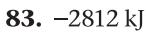
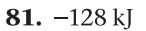
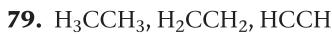
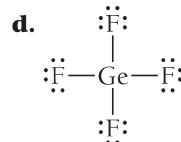
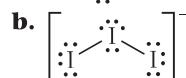
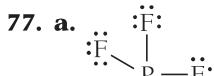
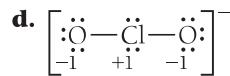
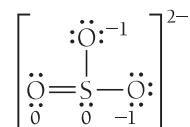
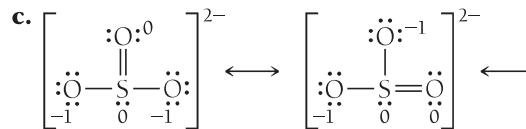
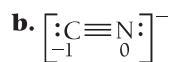
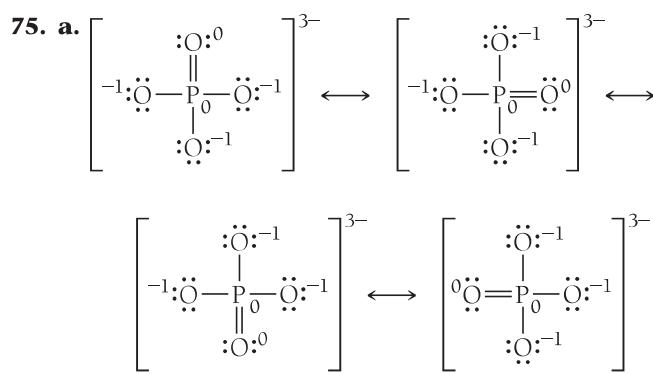
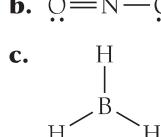
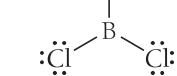


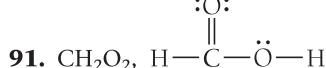
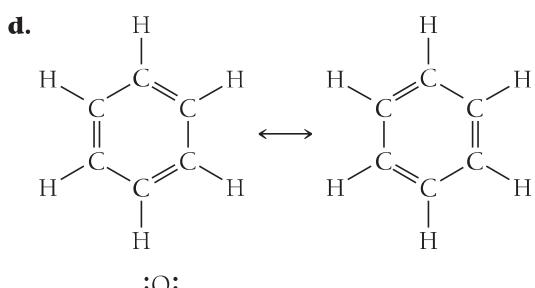
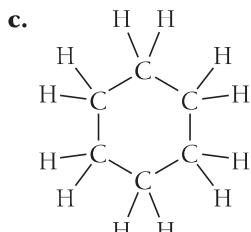
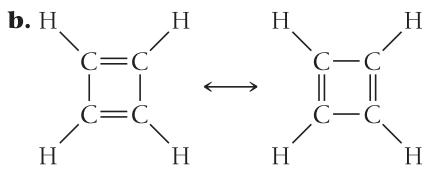
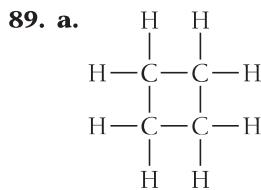
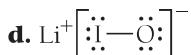
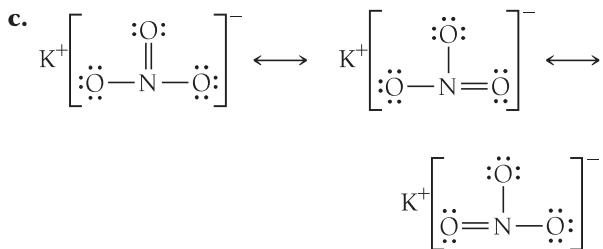
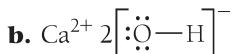


67. $\text{:O}\equiv\text{C}-\ddot{\text{O}}:$ does not provide a significant contribution to the resonance hybrid as it has a +1 formal charge on a very electronegative atom (oxygen).

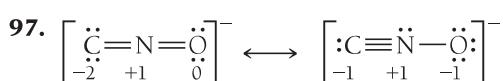
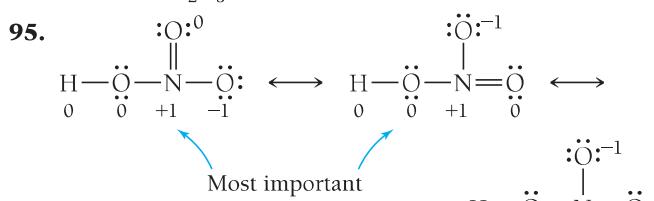


71. N has a formal charge of +1; O has a formal charge of -1.

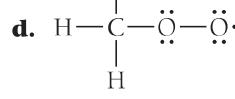
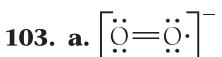
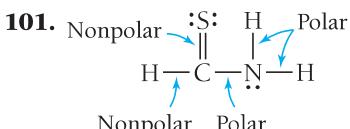
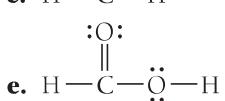
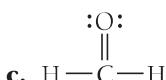
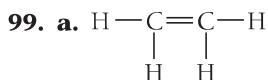




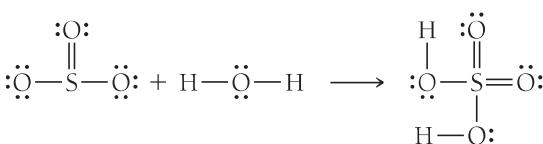
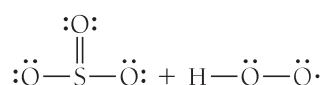
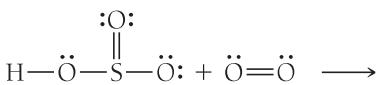
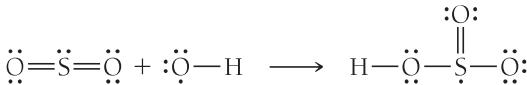
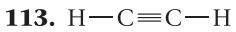
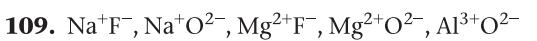
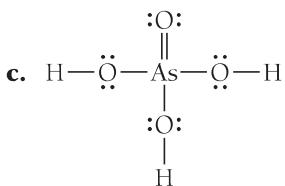
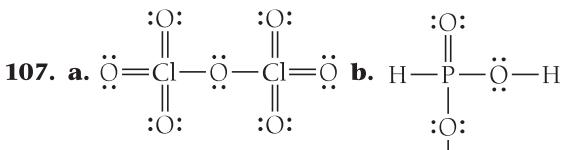
93. The reaction is exothermic due to the energy released when the Al_2O_3 lattice forms.



The fulminate ion is less stable because nitrogen is more electronegative than carbon and should therefore be terminal to accommodate the negative formal charge.



105. $\Delta H_{\text{rxn}(\text{H}_2)} = -243 \text{ kJ/mol} = -121 \text{ kJ/g}$
 $\Delta H_{\text{rxn}(\text{CH}_4)} = -802 \text{ kJ/mol} = -50.0 \text{ kJ/g}$
 CH_4 yields more energy per mole, while H_2 yields more energy per gram.



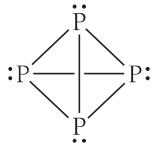
$$\Delta H_{\text{rxn}} = -172 \text{ kJ}$$

117. $r_{\text{HCl}} = 113 \text{ pm}$

$r_{\text{HF}} = 84 \text{ pm}$

These values are close to the accepted values.

119.



121. 126 kJ/mol

123. The oxidation number of the S atoms bonded directly to hydrogen atoms is -1 . The oxidation number of interior S atoms is 0 .

125. 536 kJ

127. The compounds are energy rich because a great deal of energy is released when these compounds undergo a reaction that breaks weak bonds and forms strong ones.

129. The theory is successful because it allows us to predict and account for many chemical observations. The theory is limited because electrons cannot be treated as localized “dots.”

135. a. The lattice energy generally increases as you move across the period.

c. The increase in ionic radius between Cr^{2+} and Mn^{2+} results in a decrease in lattice energy.

Chapter 11

31. 4

33. a. $4 e^-$ groups, 4 bonding groups, 0 lone pair

b. $5 e^-$ groups, 3 bonding groups, 2 lone pairs

c. $6 e^-$ groups, 5 bonding groups, 1 lone pair

35. a. e^- geometry: tetrahedral molecular geometry; trigonal pyramidal idealized bond angle: 109.5° , deviation

b. e^- geometry: tetrahedral molecular geometry: bent idealized bond angle: 109.5° , deviation

c. e^- geometry: tetrahedral molecular geometry: tetrahedral idealized bond angle: 109.5° , deviation (due to large size of Cl compared to H)

d. e^- geometry: linear molecular geometry: linear idealized bond angle: 180°

37. H_2O has a smaller bond angle due to lone pair-lone pair repulsions, the strongest electron group repulsion.

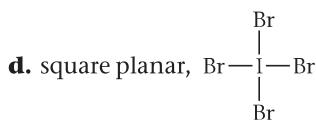


39. a. seesaw, $\text{F}-\text{S}-\text{F}-\text{F}$

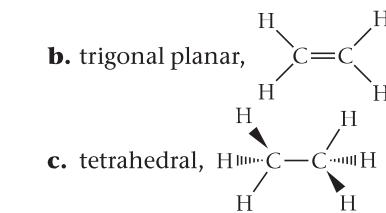


b. T-shape, $\text{F}-\text{Cl}-\text{F}-\text{F}$

c. linear, $\text{F}-\text{I}-\text{F}$



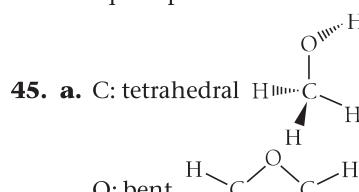
41. a. linear, $\text{H}-\text{C}\equiv\text{C}-\text{H}$



43. a. The lone pair will cause lone pair-bonding pair repulsions, pushing the three bonding pairs out of the same plane. The correct molecular geometry is trigonal pyramidal.

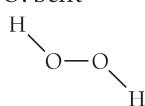
b. The lone pair should take an equatorial position to minimize 90° bonding pair interactions. The correct molecular geometry is seesaw.

c. The lone pairs should take positions on opposite sides of the central atom to reduce lone pair-lone pair interactions. The correct molecular geometry is square planar.



b. C's: tetrahedral

O: bent



c. O's: bent

47. The vectors of the polar bonds in both CO_2 and CCl_4 oppose each other with equal magnitude and sum to 0.

49. PF_3 , polar%

SBr_2 , nonpolar%

CHCl_3 , polar%

CS_2 , nonpolar%

51. a. polar

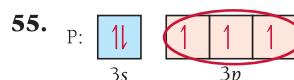
b. polar

c. nonpolar

53. a. 0

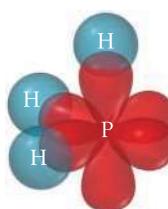
b. 3

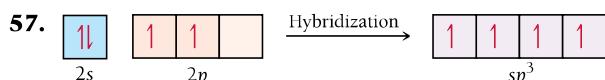
c. 1



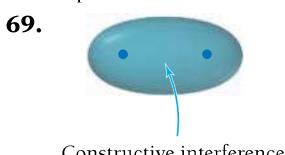
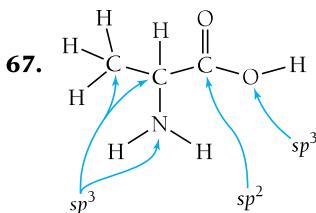
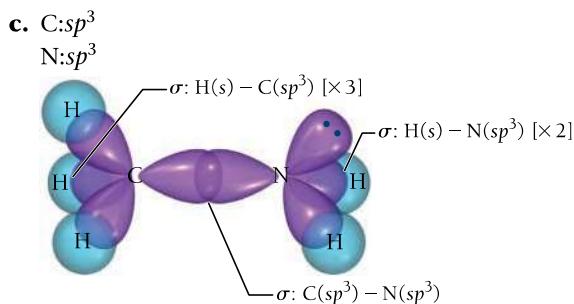
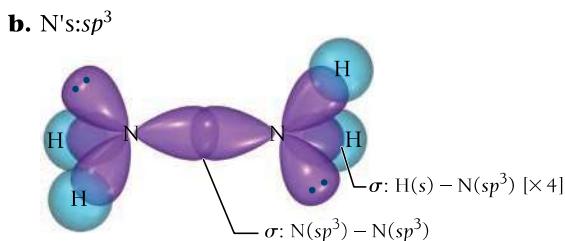
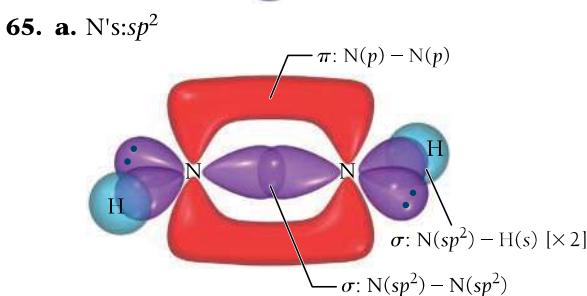
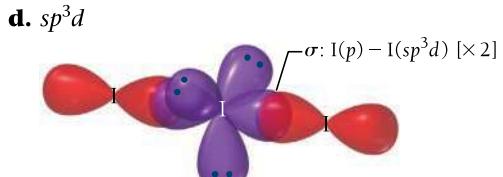
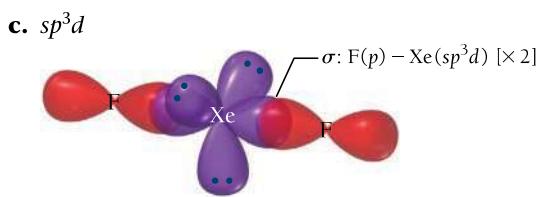
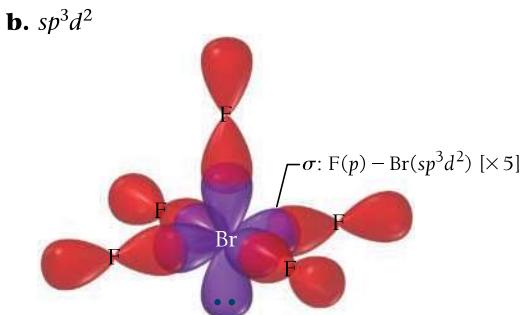
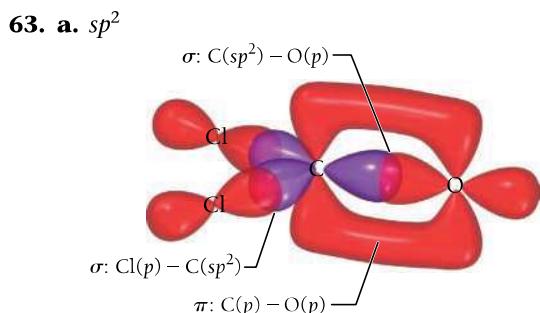
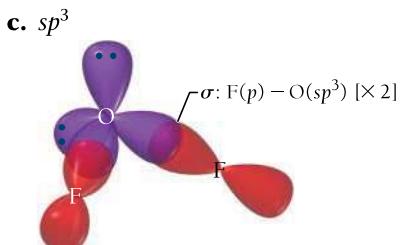
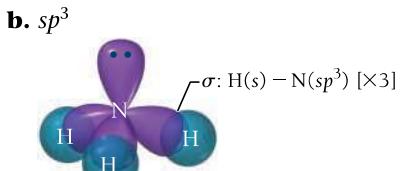
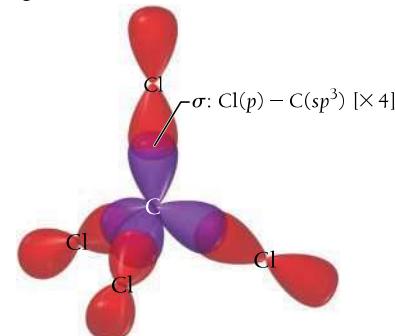
Expected bond angle = 90°

Valence bond theory is compatible with experimentally determined bond angle of 93.3° without hybrid orbitals.





59. sp^2
61. a. sp^3



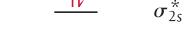
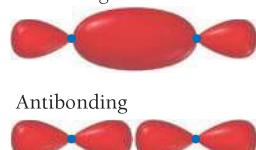


bond order $\text{Be}_2^+ = 1/2$

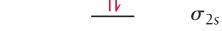
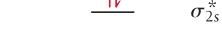
bond order $\text{Be}_2^- = 1/2$

Both will exist in gas phase.

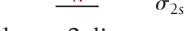
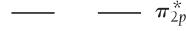
73. Bonding



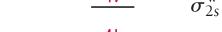
bond order = 0 diamagnetic



bond order = 1 paramagnetic



bond order = 2 diamagnetic



bond order = 2.5 paramagnetic

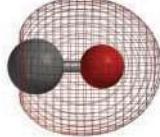
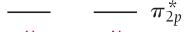
77. a. not stable

c. stable

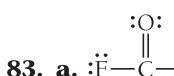
b. not stable

d. not stable

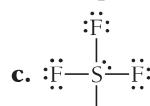
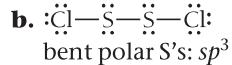
79. C_2^- has the highest bond order, the highest bond energy, and the shortest bond length.



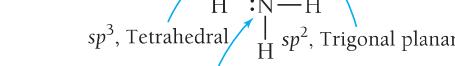
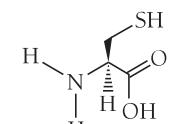
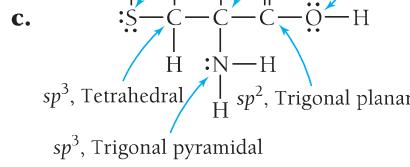
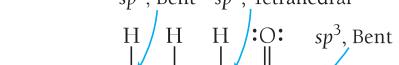
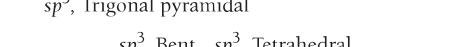
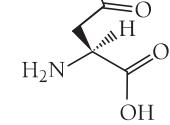
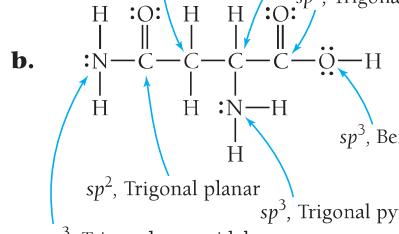
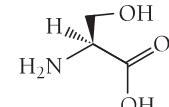
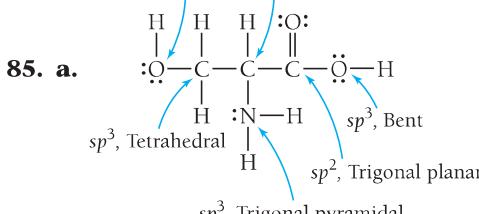
bond order = 3



trigonal planar polar C: sp^2



seesaw polar S: sp^3d



87. σ bonds: 25

π bonds: 4

lone pairs: on O's and N (without methyl group):

sp^2 orbitals

on N's (with methyl group): sp^3 orbitals

89. a. water soluble

b. fat soluble

c. water soluble

d. fat soluble

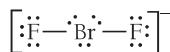


bond order = 1

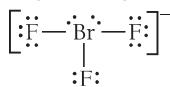
- 93.** BrF, unhybridized, linear



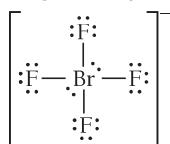
BrF₂⁻ has two bonds and three lone pairs on the central atom. The hybridization is sp³d. The electron geometry is trigonal bipyramidal, with the three lone pairs equatorial. The molecular geometry is linear.



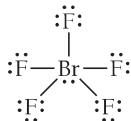
BrF₃ has three bonds and two lone pairs on the central atom. The hybridization is sp³d. The electron geometry is trigonal bipyramidal, with the two lone pairs equatorial. The molecular geometry is T-shaped.



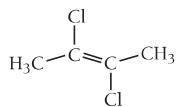
BrF₄⁻ has four bonds and two lone pairs on the central atom. The hybridization is sp³d². The electron geometry is octahedral, with the two lone pairs on the same axis. The molecular geometry is square planar.



BrF₅ has five bonds and one lone pair on the central atom. The hybridization is sp³d². The electron geometry is octahedral. The molecular geometry is square pyramidal.



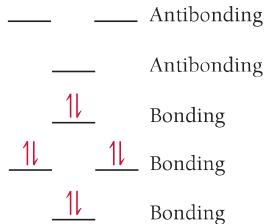
- 95.** The moments of the two Cl's cancel.



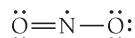
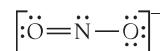
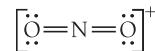
- 97. a. 10 b. 14 c. 2**

- 99.** According to valence bond theory, CH₄, NH₃, and H₂O are all sp³ hybridized. This hybridization results in a tetrahedral electron group configuration with a 109.5° bond angle. NH₃ and H₂O deviate from this idealized bond angle because their lone electron pairs exist in their own sp³ orbitals. The presence of lone pairs lowers the tendency for the central atom's orbitals to hybridize. As a result, as lone pairs are added, the bond angle moves further from the 109.5° hybrid angle and closer to the 90° unhybridized angle.

- 101.** NH₃ is stable due to its bond order of 3.

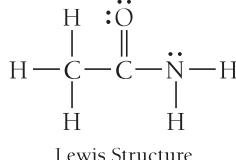


- 103.** In NO₂⁺, the central N has two electron groups, so the hybridization is sp and the ONO angle is 180°. In NO₂⁻ the central N has three electron groups, two bonds and one lone pair. The ideal hybridization is sp², but the ONO bond angle should close down a bit because of the lone pair. A bond angle around 115° is a good guess. In NO₂ there are three electron groups, but one group is a single electron. Again, the ideal hybridization would be sp², but since one unpaired electron must be much smaller than a lone pair or even a bonding pair, we predict that the ONO bond angle will spread and be greater than 120°. As a guess, the angle is probably significantly greater than 120°.

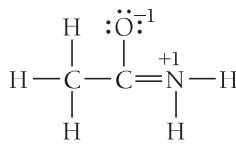


- 105.** In addition to the 2s and the three 2p orbitals, one more orbital is required to make five hybrid orbitals. The closest in energy is the 3s orbital. So the hybridization is s²p³. VSEPR predicts trigonal bipyramidal geometry for five identical substituents.

- 107.**



Lewis Structure



Resonance Structure

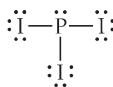
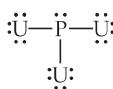
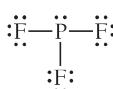
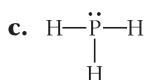
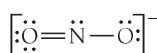
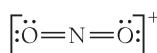
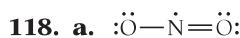
Terminal carbon is tetrahedral, central carbon is trigonal planar, and nitrogen is trigonal pyramidal (but resonance structure is trigonal planar).

- 109. a. This is the best.**

b. This statement is similar to **a** but leaves out non-bonding lone-pair electron groups.

c. Molecular geometries are not determined by overlapping orbitals but rather by the number and type of electron groups around each central atom.

- 111.** Lewis theory defines a single bond, double bond, and triple bond as a sharing of two electrons, four electrons, and six electrons, respectively, between two atoms. Valence bond theory defines a single bond as a sigma overlap of two orbitals, a double bond as a single sigma bond combined with a pi bond, and a triple bond as a double bond with an additional pi bond. Molecular orbital theory defines a single bond, double bond, and triple bond as a bond order of 1, 2, or 3, respectively, between two atoms.



e. The Lewis structures all have four electron groups, one lone pair, and three bonding groups. Based on VESPR, each of these molecules should have a bond angle of slightly less than 109.5° . However, the atomic radius increases in the following order: H < Cl < I. The increasing radius from H to I can explain the increasing bond angle in these compounds.

Chapter 12

35. a. dispersion

b. dispersion, dipole-dipole, hydrogen bonding

c. dispersion, dipole-dipole

d. dispersion

37. a. dispersion, dipole-dipole

b. dispersion, dipole-dipole, hydrogen bonding

c. dispersion

d. dispersion

39. a, b, c, d. Boiling point increases with increasing intermolecular forces. The molecules increase in their intermolecular forces as follows: **a**, dispersion forces; **b**, stronger dispersion forces (broader electron cloud); **c**, dispersion forces and dipole-dipole interactions; **d**, dispersion forces, dipole-dipole interactions, and hydrogen bonding.

41. a. CH_3OH , hydrogen bonding

b. $\text{CH}_3\text{CH}_2\text{OH}$, hydrogen bonding

c. CH_3CH_3 , greater mass, broader electron cloud causes greater dispersion forces.

43. a. Br_2 , smaller mass results in weaker dispersion forces.

b. H_2S , lacks hydrogen bonding

c. PH_3 , lacks hydrogen bonding

45. a. not homogeneous

b. homogeneous, dispersion, dipole-dipole, hydrogen bonding, ion-dipole

c. homogeneous, dispersion

d. homogeneous, dispersion, dipole-dipole, hydrogen bonding

47. Water. Surface tension increases with increasing intermolecular forces, and water can hydrogen-bond while acetone cannot.

49. compound A

51. When the tube is clean, water experiences adhesive forces with glass that are stronger than its cohesive forces, causing it to climb the surface of a glass tube. Water does not experience strong intermolecular forces with oil, so if the tube is coated in oil, the water's cohesive forces will be greater and it will not be attracted to the surface of the tube.

53. The water in the 12-cm dish will evaporate more quickly. The vapor pressure does not change, but the surface area does. The water in the dish evaporates more quickly because the greater surface area allows for more molecules to obtain enough energy at the surface and break free.

55. Water is more volatile than vegetable oil. When the water evaporates, the endothermic process results in cooling.

57. 0.405 L

59. 91 °C

61. $\Delta H_{\text{vap}} = 24.7 \text{ kJ/mol}$, bp = 239 K

63. 41 torr

65. 27.5 kJ/mol

67. 22.0 kJ

69. 2.7 °C

71. 30.5 kJ

73. a. solid

b. liquid

c. gas

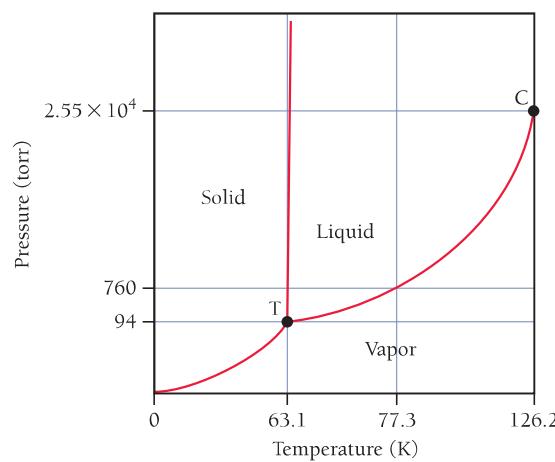
d. supercritical fluid

e. solid/liquid

f. liquid/gas

g. solid/liquid/gas

75. N_2 has a stable liquid phase at 1 atm.



77. a. 0.027 mmHg

b. rhombic

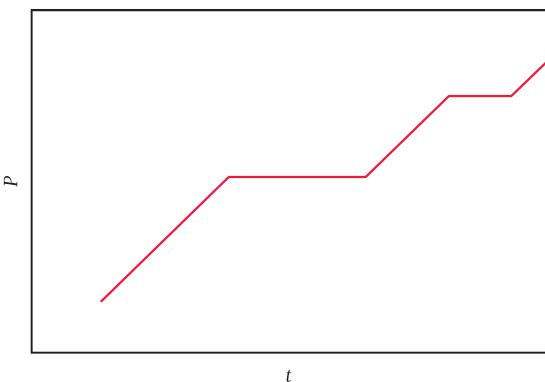
79. Water has strong intermolecular forces. It is polar and experiences hydrogen bonding.

81. Water's exceptionally high specific heat capacity has a moderating effect on Earth's climate. Also, its high ΔH_{vap} causes water evaporation and condensation to have a strong effect on temperature.

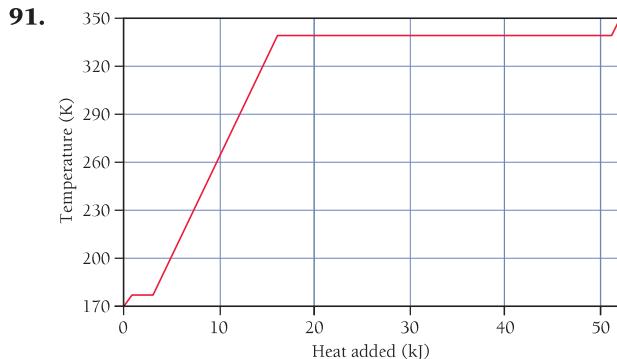
83. The general trend is that melting point increases with increasing mass. This is because the electrons of the larger molecules are held more loosely and a stronger dipole moment can be induced more easily. HF is the exception to the rule. It has a relatively high melting point due to hydrogen bonding.

85. yes, 1.22 g

87. gas \longrightarrow liquid \longrightarrow solid



89. 26 °C



93. 3.4×10^3 g H₂O

95. a. CO₂(s) \longrightarrow CO₂(g) at 195 K

b. CO₂(s) \longrightarrow triple point at 216 K \longrightarrow CO₂(g) just above 216 K

c. CO₂(s) \longrightarrow CO₂(l) at somewhat above 216 K \longrightarrow CO₂(g) at around 250 K

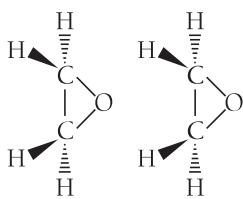
d. CO₂(s) \longrightarrow CO₂(g) \longrightarrow supercritical fluid

97. Decreasing the pressure will decrease the temperature of liquid nitrogen. Because the nitrogen is boiling, its temperature must be constant at a given pressure. As the pressure decreases, the boiling point decreases, and therefore so does the temperature. If the pressure drops below the pressure of the triple point, the phase change will shift from vaporization to sublimation and the liquid nitrogen will become solid.

99. 70.7 L

101. 0.48 atm

103.



105. The water within a container with a larger surface area will evaporate more quickly because there is more surface area from which the molecules can evaporate. Vapor pressure is the pressure of the gas when it is in dynamic equilibrium with the liquid. The vapor pressure is dependent only on the substance and the temperature. The larger the surface area, the more quickly it will reach the dynamic state.

107. The triple point will be at a lower temperature since the fusion equilibrium line has a positive slope. This means that we will be increasing both temperature and pressure as we travel from the triple point to the normal melting point.

109. The liquid segment will have the least steep slope because it takes the most kJ/mol to raise the temperature of the phase.

111. There are substantial intermolecular attractions in the liquid but virtually none in the gas.

117. a. No. Although it does correlate for H₂S, H₂Se, and H₂Te, it does not correlate for H₂O.

c. Water has the highest dipole moment, that together with the small size of the hydrogen atom accounts for the anomalously high boiling point.

Chapter 13

27. 162 pm

b. 2

c. 4

31. 68%

33. $l = 393$ pm, $d = 21.3$ g/cm³

35. 134.5 pm

37. 6.0×10^{23} atoms/mol

39. a. atomic **b.** molecular
c. ionic **d.** atomic

41. LiCl(s). The other three solids are held together by intermolecular forces, while LiCl is held together by stronger coulombic interactions between the cations and anions of the crystal lattice.

43. a. TiO₂(s), ionic solid

b. SiCl₄(s), larger, stronger dispersion forces

c. Xe(s), larger, stronger dispersion forces

d. CaO, ions have greater charge and therefore stronger coulombic forces

45. TiO₂

47. Cs:1(1) = 1

Cl:8(1/8) = 1

1:1

CsCl

Ba:8(1/8) + 6(1/2) = 4

Cl:8(1) = 8

4:8 = 1:2

BaCl₂

49. cesium chloride: none of these; barium(II) chloride: fluorite structure

51. face-centered cubic

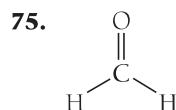
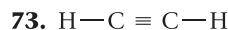
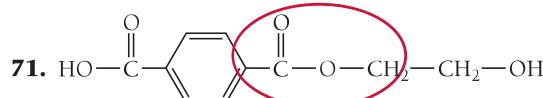
53. a. nonoxide **b.** silicate
c. nonoxide

55. boron oxide, B₂O₃

57. Ca: +2; Si: +2; O: -2

- 59.** a. Zn(s)
61. 0.807 mol orbitals
63. insulator

- 65.** a. p-type
 b. n-type
67. Yes, it has sufficient energy.



77. CsCl has a higher melting point than AgI because of its higher coordination number. In CsCl, one anion bonds to eight cations (and vice versa), while in AgI, one anion bonds to only four cations.

- 79.** a. $4r$
 $c^2 = a^2 + b^2$ $c = 4r$, $a = l$, $b = l$
 $(4r)^2 = l^2 + l^2$
 $16r^2 = 2l^2$
 b. $8r^2 = l^2$
 $l = \sqrt[3]{8r^2}$
 $l = 2\sqrt{2}r$

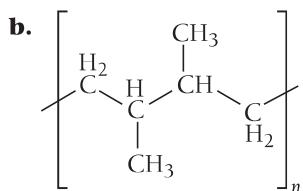
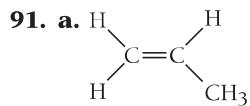
81. 8 atoms/unit

83. 55.843 g/mol

85. 2.00 g/cm³

87. body diagonal = $\sqrt{6r}$,
 radius = $(\sqrt{3} - \sqrt{2})r/\sqrt{2} = 0.2247r$

89. The higher-level electron transitions with their smaller energy gaps would not give off enough energy to create X-rays.



To obtain this structure, the monomer from part a would react in a head-to-head (or tail-to-tail) addition as opposed to the head-to-tail addition that leads to the structure shown in Table 12.3.

- 93.** Because the structure is a face-centered cubic, there are therefore four C_{60} molecules per unit cell. Thus, there must be $3 \times 4 = 12$ Rb atoms per unit cell, and all sites (tetrahedral and octahedral) are occupied.
95. The liquid must be cooled quickly in order to prevent the formation of an organized crystal structure and instead achieve an amorphous product.

97. Both structures may be viewed as having essentially a face-centered cubic unit cell with half of the tetrahedral holes filled. Diamond, however, consists of only one type of atom (C) and is covalently bound, whereas zinc blende has S^{2-} ions at the face-centered cubic sites and Zn^{2+} ions in the tetrahedral holes, and is held together by ionic forces.

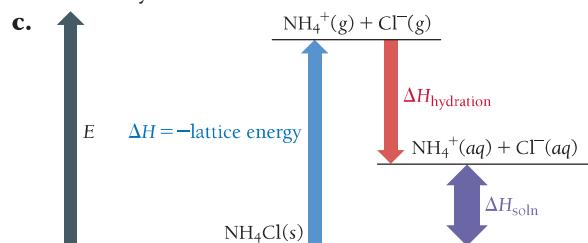
99. d. All of the above would likely lead to an increase in electrical conductivity.

105. a. 20% Cr and 80% Ni; 1405°

a. 97% Cr and 3% Ni; body-centered cubic

Chapter 14

- 29.** a. hexane, toluene, or CCl_4 ; dispersion forces
 b. water, methanol; dispersion, dipole-dipole, hydrogen bonding
 c. hexane, toluene, or CCl_4 ; dispersion forces
 d. water, acetone, methanol, ethanol; dispersion, ion-dipole
31. $HOCH_2CH_2CH_2OH$
33. a. water; dispersion, dipole-dipole, hydrogen bonding
 b. hexane; dispersion
 c. water; dispersion, dipole-dipole
35. a. endothermic
 b. The lattice energy is greater in magnitude than the heat of hydration.



d. The solution forms because chemical systems tend toward greater entropy.

- 37.** -797 kJ/mol
39. $\Delta H_{soln} = -6 \times 10^1$ kJ/mol, -7 kJ of energy evolved
41. unsaturated
43. About 31 g will precipitate.
45. Boiling water releases any O_2 dissolved in it. The solubility of gases decreases with increasing temperature.
47. As pressure increases, nitrogen will more easily dissolve in blood. To reverse this process, divers should ascend to lower pressures.
49. 1.1 g
51. 1.92 M, 2.0 m, 10.4%
53. 0.340 L
55. 1.6×10^2 g
57. 1.4×10^4 g
59. Add water to 7.31 mL of concentrated solution until a total volume of 1.15 L is acquired.
61. a. Add water to 3.73 g KCl to a volume of 100 mL.
 b. Add 3.59 g KCl to 96.41 g H_2O .
 c. Add 5.0 g KCl to 95 g H_2O .
63. a. 0.417 M b. 0.444 m
 c. 7.41% by mass d. 0.00794
 e. 0.794% by mole

- 65.** 0.89 M
67. 15 m, 0.22
69. The level has decreased more in the beaker filled with pure water. The dissolved salt in the seawater decreases the vapor pressure and subsequently lowers the rate of vaporization.
71. 30.7 torr
73. **a.** $P_{\text{hept}} = 24.4 \text{ torr}$, $P_{\text{oct}} = 5.09 \text{ torr}$
b. 29.5 torr
c. 80.8% heptane by mass, 19.2% octane by mass
d. The vapor is richer in the more volatile component.
75. $P_{\text{chl}} = 51.9 \text{ torr}$, $P_{\text{ace}} = 274 \text{ torr}$, $P_{\text{tot}} = 326 \text{ torr}$. The solution is not ideal. The chloroform-acetone interactions are stronger than the chloroform-chloroform and acetone-acetone interactions.
77. freezing point (fp) = -1.27°C , bp = 100.349°C
79. freezing point (fp) = 1.0°C , boiling point (bp) = 82.4°C
81. $1.8 \times 10^2 \text{ g/mol}$
83. 26.1 atm
85. $6.36 \times 10^3 \text{ g/mol}$
87. **a.** fp = -0.558°C , bp = 100.154°C
b. fp = -1.98°C , bp = 100.546°C
c. fp = -2.5°C , bp = 100.70°C
89. 157 g
91. **a.** -0.632°C **b.** 5.4 atm **c.** 100.18°C
93. 2.3
95. 3.4
97. 23.0 torr
99. Chloroform is polar and has stronger solute-solvent interactions than nonpolar carbon tetrachloride.
101. $\Delta H_{\text{soln}} = 51 \text{ kJ/mol}$, -8.7°C
103. $2.2 \times 10^{-3} \text{ M/atm}$
105. $1.3 \times 10^4 \text{ L}$
107. 0.24 g
109. -24°C
111. **a.** 1.1% by mass/V
c. 5.3% by mass/V
113. 2.484
115. 0.229 atm
117. $\chi_{\text{CHCl}_3}(\text{original}) = 0.657$,
 $P_{\text{CHCl}_3}(\text{condensed}) = 0.346 \text{ atm}$
119. 1.74 M
121. $\text{C}_6\text{H}_{14}\text{O}_2$
123. 12 grams
125. $6.4 \times 10^{-3} \text{ L}$
127. 22.4 glucose by mass, 77.6 sucrose by mass
129. $P_{\text{iso}} = 0.131 \text{ atm}$, $P_{\text{pro}} = 0.068 \text{ atm}$. The major intermolecular attractions are between the OH groups. The OH group at the end of the chain in propyl alcohol is more accessible than the one in the middle of the chain in isopropyl alcohol. In addition, the molecular shape of propyl alcohol is a straight chain of carbon atoms, while that of isopropyl alcohol is a branched chain and is more like a ball. The contact area between two ball-like objects is smaller than that of two chain-like objects. The smaller contact area in isopropyl alcohol means the molecules don't attract each other as strongly as do those of propyl alcohol. As a result of both of these factors, the vapor pressure of isopropyl alcohol is higher.
- 131.** 0.005 m
133. Na_2CO_3 0.050 M, NaHCO_3 0.075 M
135. The water should not be immediately cycled back into the river. As the water was warmed, dissolved oxygen would have been released, since the amount of a gas able to be dissolved into a liquid decreases as the temperature of the liquid increases. As such, the water returned to the river would lack dissolved oxygen if it was still hot. To preserve the dissolved oxygen necessary for the survival of fish and other aquatic life, the water must first be cooled.
137. **b.** NaCl
144. **a.** The salinity of seawater is generally higher near the equator and lower near the poles.
c. -2.3°C

Chapter 15

25. **a.** Rate = $-\frac{1}{2} \frac{\Delta [\text{HBr}]}{\Delta t} = \frac{\Delta [\text{H}_2]}{\Delta t} = \frac{\Delta [\text{Br}_2]}{\Delta t}$

b. $1.8 \times 10^{-3} \text{ M/s}$

c. 0.040 mol Br_2

27. **a.** Rate = $-\frac{1}{2} \frac{\Delta [\text{A}]}{\Delta t} = -\frac{\Delta [\text{B}]}{\Delta t} = \frac{1}{3} \frac{\Delta [\text{C}]}{\Delta t}$

b. $\frac{\Delta [\text{B}]}{\Delta t} = -0.0500 \text{ M/s}$, $\frac{\Delta [\text{C}]}{\Delta t} = 0.150 \text{ M/s}$

29.

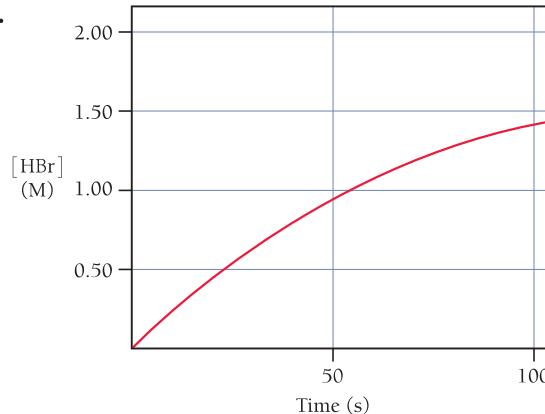
$\Delta[\text{Cl}_2]/\Delta t$	$\Delta[\text{F}_2]/\Delta t$	$\Delta[\text{ClF}_3]/\Delta t$	Rate
-0.012 M/s	-0.036 M/s	0.024 M/s	0.012 M/s

31. **a.** $0 \longrightarrow 10 \text{ s}$: Rate = $8.7 \times 10^{-3} \text{ M/s}$
 $40 \longrightarrow 50 \text{ s}$: Rate = $6.0 \times 10^{-3} \text{ M/s}$

b. $1.4 \times 10^{-2} \text{ M/s}$

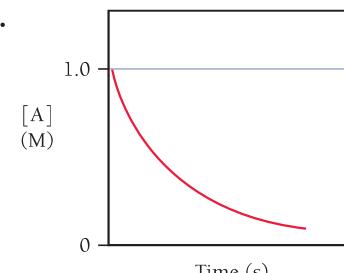
33. **a.** **i.** $1.0 \times 10^{-2} \text{ M/s}$ **ii.** $8.5 \times 10^{-3} \text{ M/s}$
iii. 0.013 M/s

b.



35. **a.** first order

b.



c. Rate = $k[A]^1$, $k = 0.010 \text{ s}^{-1}$

37. **a.** s^{-1} **b.** $M^{-1} s^{-1}$ **c.** $M \cdot s^{-1}$

39. **a.** Rate = $k[A][B]^2$ **b.** third order
c. 2 **d.** 4
e. 1 **f.** 8

41. second order, Rate = $5.25 M^{-1} s^{-1}[A]^2$

43. first order, Rate = $0.065 s^{-1}[A]$

45. Rate = $k[NO_2][F_2]$, $k = 2.57 M^{-1} s^{-1}$, second order

47. **a.** zero order **b.** first order

c. second order

49. second order, $k = 2.25 \times 10^{-2} M^{-1} s^{-1}$, [AB] at 25 s = 0.619 M

51. first order, $k = 1.12 \times 10^{-2} s^{-1}$, Rate = $2.8 \times 10^{-3} M/s$

53. **a.** $4.5 \times 10^{-3} s^{-1}$ **b.** Rate = $4.5 \times 10^{-3} s^{-1}[A]$
c. $1.5 \times 10^2 s$ **d.** $[A] = 0.0908 M$

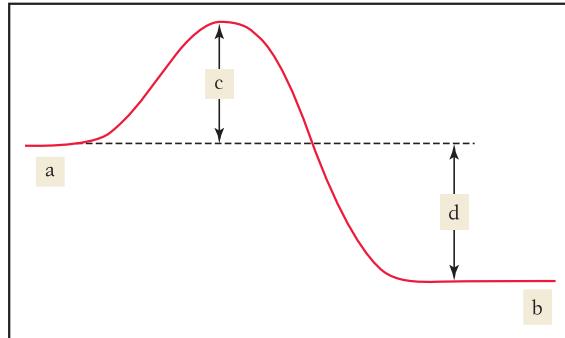
55. **a.** $4.88 \times 10^3 s$ **b.** $9.8 \times 10^3 s$

c. $1.7 \times 10^3 s$

d. 0.146 M at 200 s, 0.140 M at 500 s

57. $6.8 \times 10^8 \text{ yr}$; $1.8 \times 10^{17} \text{ atoms}$

59.



61. $17 s^{-1}$

63. 61.90 kJ/mol

65. $E_a = 251 \text{ kJ/mol}$, $A = 7.93 \times 10^{11} s^{-1}$

67. $E_a = 23.0 \text{ kJ/mol}$, $A = 8.05 \times 10^{10} M^{-1}s^{-1}$

69. **a.** 122 kJ/mol

b. $0.101 s^{-1}$

71. 47.85 kJ/mol

73. **a**

75. The mechanism is valid.

77. **a.** $\text{Cl}_2(g) + \text{CHCl}_3(g) \longrightarrow \text{HCl}(g) + \text{CCl}_4(g)$

b. $\text{Cl}(g), \text{CCl}_3(g)$

c. Rate = $k[\text{Cl}_2]^{1/2}[\text{CHCl}_3]$

79. Heterogeneous catalysts require a large surface area because catalysis can only happen at the surface.

A greater surface area means greater opportunity for the substrate to react, which results in a faster reaction.

81. 10^{12}

83. **a.** first order, $k = 0.0462 \text{ hr}^{-1}$

b. 15 hr

c. $5.0 \times 10^1 \text{ hr}$

85. 0.0531 M/s

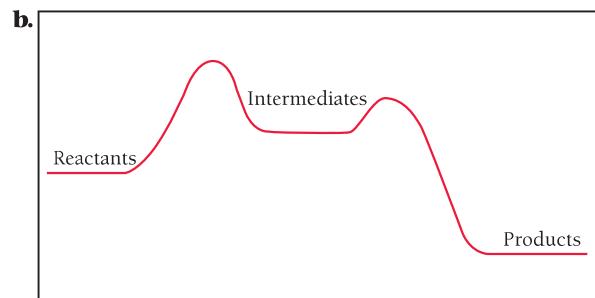
87. rate = $4.5 \times 10^{-4} [\text{CH}_3\text{CHO}]^2$,
 $k = 4.5 \times 10^{-4}, 0.37 \text{ atm}$

89. 219 torr

91. $1 \times 10^{-7} \text{ s}$

93. $1.6 \times 10^2 \text{ seconds}$

95. **a.** 2



c. first step

d. exothermic

97. **a.** 5.41 s

b. 2.2 s for 25%, 5.4 s for 50%

c. 0.28 at 10 s, 0.077 at 20 s

99. **a.** $E_a = 89.5 \text{ kJ/mol}$, $A = 4.22 \times 10^{11} s^{-1}$

b. $2.5 \times 10^{-5} M^{-1} s^{-1}$

c. $6.0 \times 10^{-4} \text{ M/s}$

101. **a.** No

b. No bond is broken, and the two radicals attract each other.

c. Formation of diatomic gases from atomic gases

103. $1.35 \times 10^4 \text{ years}$

105. **a.** Both are valid. For both, all steps sum to overall reaction, and the predicted rate law is consistent with experimental data.

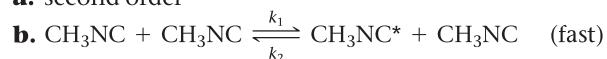
b. Buildup of $I(g)$

107. rate = $k_2[(k_1/k_{-1})[\text{Br}_2]]^{1/2}[\text{H}_2]$ The rate law is 3/2 order overall.

109. **a.** 0% **b.** 25% **c.** 33%

111. 174 kJ

113. **a.** second order



$$k_1[\text{CH}_3\text{NC}]^2 = k_2[\text{CH}_3\text{NC}^*][\text{CH}_3\text{NC}]$$

$$[\text{CH}_3\text{NC}^*] = \frac{k_1}{k_2}[\text{CH}_3\text{NC}]$$

$$\text{Rate} = k_3 \times \frac{k_1}{k_2}[\text{CH}_3\text{NC}]$$

$$\text{Rate} = k[\text{CH}_3\text{NC}]$$

115. Rate = $k[A]^2$

$$\text{Rate} = -\frac{d[A]}{dt}$$

$$\frac{d[A]}{dt} = -k[A]^2$$

$$2\frac{d[A]}{[A]^2} = k dt$$

$$\int_{[A]_0}^{[A]} -\frac{1}{[A]^2} d[A] = \int_0^t k dt$$

$$\left[\frac{1}{[A]} \right]_{[A]_0}^{[A]} = k[t]_0^t$$

$$\frac{1}{[A]} - \frac{1}{[A]_0} = kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

117. $k = 3.20 \times 10^{-4} \text{ s}^{-1}$

119. b)

121. B is first order and A is second order.

B will be linear if you plot $\ln[B]$ versus time; A will be linear if you plot $1/[A]$ versus time.

125. a. The reaction is first order in CH_4 and first order in O_3 .

a. $1.7 \times 10^{-18} \text{ M/s}$

Chapter 16

21. a. $K = \frac{[\text{SbCl}_3][\text{Cl}_2]}{[\text{SbCl}_5]}$

b. $K = \frac{[\text{NO}]^2[\text{Br}_2]}{[\text{BrNO}]^2}$

c. $K = \frac{[\text{CS}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{S}]^2}$

d. $K = \frac{[\text{CO}_2]^2}{[\text{CO}]^2[\text{O}_2]}$

23. The concentration of the reactants will be greater. No, this is not dependent on initial concentrations; it is dependent on the value of K_c .

25. a. figure v

b. The change in the decrease of reactants and increase of products would be faster.

c. No, catalysts affect kinetics, not equilibrium.

27. a. 4.42×10^{-5} , reactants favored

b. 1.50×10^2 , products favored

c. 1.96×10^{-9} , reactants favored

29. 1.3×10^{-29}

31. a. 2.56×10^{-23} b. 1.3×10^{22}

c. 81.9

33. a. $K_c = \frac{[\text{HCO}_3^-][\text{OH}^-]}{[\text{CO}_3^{2-}]}$

b. $K_c = [\text{O}_2]^3$

c. $K_c = \frac{[\text{H}_3\text{O}^+][\text{F}^-]}{[\text{HF}]}$

d. $K_c = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$

35. 136

37.

T(K)	[N ₂]	[H ₂]	[NH ₃]	K _c
500	0.115	0.105	0.439	1.45×10^3
575	0.110	0.249	0.128	9.6
775	0.120	0.140	4.39×10^{-3}	0.0584

39. 234 torr

41. 18

43. 3.3×10^2

45. 764

47. More solid will form.

49. Additional solid will not dissolve.

51. a. [A] = 0.20 M, [B] = 0.80 M

b. [A] = 0.33 M, [B] = 0.67 M

c. [A] = 0.38 M, [B] = 1.2 M

53. [N₂O₄] = 0.0115 M, [NO₂] = 0.0770 M

55. 0.199 M

57. 1.9×10^{-3} M

59. 7.84 torr

61. a. [A] = 0.38 M, [B] = 0.62 M, [C] = 0.62 M

b. [A] = 0.90 M, [B] = 0.095 M, [C] = 0.095 M

c. [A] = 1.0 M, [B] = 3.2×10^{-3} M,

[C] = 3.2×10^{-3} M

63. a. shift left b. shift right

c. shift right

65. a. shift right b. no effect

c. no effect d. shift left

67. a. shift right b. shift left

c. no effect

69. Increase temperature → shift right, decrease temperature → shift left. Increasing the temperature will increase the equilibrium constant.

71. b, d

73. a. 1.7×10^2

b. $\frac{[\text{Hb}-\text{CO}]}{[\text{Hb}-\text{O}_2]} = 0.85 \text{ or } 17/20$

CO is highly toxic, as it blocks O₂ uptake by hemoglobin. CO₂ at a level of 0.1% will replace nearly half of the O₂ in blood.

75. a. 1.68 atm b. 1.41 atm

77. 0.406 g

79. b, c, d

81. 0.0144 atm

83. 3.1×10^2 g, 20% yield

85. 0.12 atm

87. 0.72 atm

89. 0.017 g

91. 0.226

93. a. 29.3 b. 169 torr

95. $P_{\text{NO}} = P_{\text{Cl}_2} = 429$ torr

97. 1.27×10^{-2}

99. $K_p = 5.1 \times 10^{-2}$

101. Yes, because the volume affects Q.

103. a = 1, b = 2

105. K_c = 1

111. a. For system 1, K_p = 0.011; For system 2, K_p = 91.

c. System 1 is more likely.

Chapter 17

33. a. acid, $\text{HNO}_3(aq) \longrightarrow \text{H}^+(aq) + \text{NO}_3^-(aq)$

b. acid, $\text{NH}_4^+(aq) \rightleftharpoons \text{H}^+(aq) + \text{NH}_3(aq)$

c. base, $\text{KOH}(aq) \longrightarrow \text{K}^+(aq) + \text{OH}^-(aq)$

d. acid, $\text{HC}_2\text{H}_3\text{O}_2(aq) \rightleftharpoons \text{H}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$

35. a. $\text{H}_2\text{CO}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{HCO}_3^-(aq)$

acid base conj. acid conj. base

b. $\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$

base acid conj. acid conj. base

c. $\text{HNO}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{NO}_3^-(aq)$

acid base conj. acid conj. base

d. $\text{C}_5\text{H}_5\text{N}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_5\text{H}_5\text{NH}^+(aq) + \text{OH}^-(aq)$

base acid conj. acid conj. base

37. a. Cl⁻ b. HSO₃⁻ c. CHO₂⁻ d. F⁻

39. $\text{H}_2\text{PO}_4^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HPO}_4^{2-}(aq) + \text{H}_3\text{O}^+(aq)$

$\text{H}_2\text{PO}_4^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{PO}_4(aq) + \text{OH}^-(aq)$

41. a. strong b. strong

c. strong

d. weak, $K_a = \frac{[\text{H}_3\text{O}^+][\text{HSO}_3^-]}{[\text{H}_2\text{SO}_3]}$

43. a, b, c

45. a. F⁻ b. NO₂⁻ c. ClO⁻

47. a. 8.3×10^{-7} , basic b. 1.2×10^{-10} , acidic

c. 2.9×10^{-13} , acidic

- 49.** **a.** pH = 7.77, pOH = 6.23
b. pH = 7.00, pOH = 7.00
c. pH = 5.66, pOH = 8.34

51.

[H ₃ O ⁺]	[OH ⁻]	pH	Acidic or Basic
7.1 × 10 ⁻⁴	1.4 × 10 ⁻¹¹	3.15	Acidic
3.7 × 10 ⁻⁹	2.7 × 10 ⁻⁶	8.43	Basic
7.9 × 10 ⁻¹²	1.3 × 10 ⁻³	11.1	Basic
6.3 × 10 ⁻⁴	1.6 × 10 ⁻¹¹	3.20	Acidic

53. [H₃O⁺] = 1.5 × 10⁻⁷ M, pH = 6.81

55. pH = 1.36, 1.35, 1.34. A difference of 1 in the second significant digit in a concentration value produces a difference of 0.01 in pH. Therefore, the second significant digit in value of the concentration corresponds to the hundredths place in a pH value.

- 57.** **a.** [H₃O⁺] = 0.25 M, [OH⁻] = 4.0 × 10⁻¹⁴ M,
pH = 0.60
b. [H₃O⁺] = 0.015 M, [OH⁻] = 6.7 × 10⁻¹³ M,
pH = 1.82
c. [H₃O⁺] = 0.072 M, [OH⁻] = 1.4 × 10⁻¹³ M,
pH = 1.14
d. [H₃O⁺] = 0.105 M, [OH⁻] = 9.5 × 10⁻¹⁴ M,
pH = 0.979

- 59.** **a.** 1.8 g **b.** 0.57 g **c.** 0.045 g

61. 2.21

63. [H₃O⁺] = 2.5 × 10⁻¹³ M, pH = 2.59

- 65.** **a.** 1.82 (approximation valid)
b. 2.18 (approximation breaks down)
c. 2.72 (approximation breaks down)

67. 2.75**69.** 6.8 × 10⁻⁶**71.** 0.0063%

- 73.** **a.** 0.42% **b.** 0.60%
c. 1.3% **d.** 1.9%

75. 3.61 × 10⁻⁵

77. **a.** pH = 1.88, percent ionization = 5.1%

b. pH = 2.10, percent ionization = 7.9%

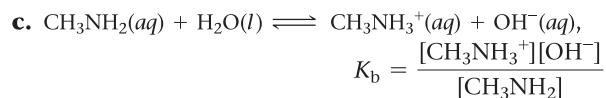
c. pH = 2.26, percent ionization = 11%

- 79.** **a.** 0.939 **b.** 1.07
c. 2.19 **d.** 3.02

- 81.** **a.** [OH⁻] = 0.15 M, [H₃O⁺] = 6.7 × 10⁻¹⁴ M,
pH = 13.17, pOH = 0.83
b. [OH⁻] = 0.003 M, [H₃O⁺] = 3.3 × 10⁻¹² M,
pH = 11.48, pOH = 2.52
c. [OH⁻] = 9.6 × 10⁻⁴ M, [H₃O⁺] = 1.0 × 10⁻¹¹ M,
pH = 10.98, pOH = 3.02
d. [OH⁻] = 8.7 × 10⁻⁵ M, [H₃O⁺] = 1.1 × 10⁻¹⁰ M,
pH = 9.93, pOH = 4.07

83. 13.842**85.** 0.104 L

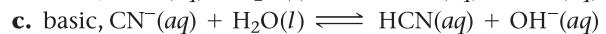
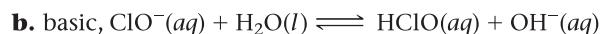
- 87.** **a.** NH₃(aq) + H₂O(l) ⇌ NH₄⁺(aq) + OH⁻(aq),
 $K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$
b. HCO₃⁻(aq) + H₂O(l) ⇌ H₂CO₃(aq) + OH⁻(aq),
 $K_b = \frac{[\text{H}_2\text{CO}_3][\text{OH}^-]}{[\text{HCO}_3^-]}$



89. [OH⁻] = 1.6 × 10⁻³ M, pOH = 2.79, pH = 11.21

91. 7.48

93. 6.7 × 10⁻⁷

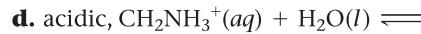
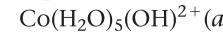
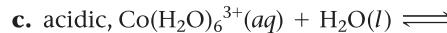
95. **a.** neutral

d. neutral

97. [OH⁻] = 1.4 × 10⁻⁶ M, pH = 8.16

99. **a.** acidic, NH₄⁺(aq) + H₂O(l) ⇌ NH₃(aq) + H₃O⁺(aq)

b. neutral

**101.** **a.** acidic

b. basic

c. neutral

d. acidic

e. acidic

103. NaOH, NaHCO₃, NaCl, NH₄ClO₂, NH₄Cl

105. **a.** 5.13

b. 8.87

c. 7.0

107. [K⁺] = 0.15 M, [F⁻] = 0.15 M, [HF] = 1.5 × 10⁻⁶ M,
[OH⁻] = 1.5 × 10⁻⁶ M; [H₃O⁺] = 6.7 × 10⁻⁹ M

109. H₃PO₄(aq) + H₂O(l) ⇌ H₂PO₄⁻(aq) + H₃O⁺(aq),
 $K_{a_1} = \frac{[\text{H}_3\text{O}^+][\text{H}_2\text{PO}_4^-]}{[\text{H}_3\text{PO}_4]}$

H₂PO₄⁻(aq) + H₂O(l) ⇌ HPO₄²⁻(aq) + H₃O⁺(aq),
 $K_{a_2} = \frac{[\text{H}_3\text{O}^+][\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]}$

HPO₄²⁻(aq) + H₂O(l) ⇌ PO₄³⁻(aq) + H₃O⁺(aq),
 $K_{a_3} = \frac{[\text{H}_3\text{O}^+][\text{PO}_4^{3-}]}{[\text{HPO}_4^{2-}]}$

111. **a.** [H₃O⁺] = 0.048 M, pH = 1.32

b. [H₃O⁺] = 0.12 M, pH = 0.92

113. [H₂SO₃] = 0.418 M

[HSO₃⁻] = 0.082 M

[SO₃²⁻] = 6.4 × 10⁻⁸ M

[H₃O⁺] = 0.082 M

115. **a.** [H₃O⁺] = 0.50 M, pH = 0.30

b. [H₃O⁺] = 0.11 M, pH = 0.96 (*x is small approximation breaks down*)

c. [H₃O⁺] = 0.059 M, pH = 1.23

117. **a.** HCl, weaker bond

b. HF, bond polarity

c. H₂Se, weaker bond

119. **a.** H₂SO₄, more oxygen atoms bonded to S

b. HClO₂ more oxygen atoms bonded to Cl

c. HClO, Cl has higher electronegativity

d. CCl₃COOH, Cl has higher electronegativity

121. S²⁻; its conjugate acid (H₂S), is a weaker acid than H₂S.
123. **a.** Lewis acid **b.** Lewis acid

c. Lewis base **d.** Lewis base

125. **a.** acid: Fe³⁺, base: H₂O

b. acid: Zn²⁺, base: NH₃

c. acid: BF₃, base: (CH₃)₃N

127. **a.** weak **b.** strong

c. weak **d.** strong

129. If blood became acidic, the H^+ concentration would increase. According to Le Châtelier's principle, equilibrium would be shifted to the left and the concentration of oxygenated Hb would decrease.

131. All acid will be neutralized.

133. $[\text{H}_3\text{O}^+](\text{Great Lakes}) = 3 \times 10^{-5} \text{ M}$, $[\text{H}_3\text{O}^+](\text{West Coast}) = 4 \times 10^{-6} \text{ M}$. The rain over the Great Lakes is about eight times more concentrated.

135. 2.7

137. **a.** 2.000 **b.** 1.52 **c.** 12.95

d. 11.12

e. 5.03

139. **a.** 1.260 **b.** 8.22 **c.** 0.824

d. 8.57

e. 1.171

141. **a.** $\text{CN}^-(aq) + \text{H}^+(aq) \rightleftharpoons \text{HCN}(aq)$

b. $\text{NH}_4^+(aq) + \text{OH}^-(aq) \rightleftharpoons \text{NH}_3(aq) + \text{H}_2\text{O}(l)$

c. $\text{CN}^-(aq) + \text{NH}_4^+(aq) \rightleftharpoons \text{HCN}(aq) + \text{NH}_3(aq)$

d. $\text{HSO}_4^-(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq) \rightleftharpoons \text{SO}_4^{2-}(aq) + \text{HC}_2\text{H}_3\text{O}_2(aq)$

e. no reaction between the major species

143. 0.794

145. $K_a = 1.4 \times 10^{-4}$

147. 6.79

149. 2.14

151. $[\text{A}^-] = 4.5 \times 10^{-5} \text{ M}$

$[\text{H}^+] = 2.2 \times 10^{-4} \text{ M}$

$[\text{HA}_2^-] = 1.8 \times 10^{-4} \text{ M}$

153. 9.28

155. 50.1 g NaHCO_3

157. **b**

159. $\text{CH}_3\text{COOH} < \text{CH}_2\text{ClCOOH} < \text{CHCl}_2\text{COOH} < \text{CCl}_3\text{COOH}$

166. **a.** 9.2 g SO_2

c. $\text{S}_2\text{O}_5^{2-}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons 2 \text{HSO}_3^-(aq)$

e. 16 g for (a) and 15 g for (b)

Chapter 18

27. **d**

29. **a.** 3.62 **b.** 9.11

31. pure water: 2.1%, in $\text{NaC}_7\text{H}_5\text{O}_2$: 0.065%. The percent ionization in the sodium benzoate solution is much smaller because the presence of the benzoate ion shifts the equilibrium to the left.

33. **a.** 2.14 **b.** 8.32 **c.** 3.46

35. $\text{HCl} + \text{NaC}_2\text{H}_3\text{O}_2 \longrightarrow \text{HC}_2\text{H}_3\text{O}_2 + \text{NaCl}$
 $\text{NaOH} + \text{HC}_2\text{H}_3\text{O}_2 \longrightarrow \text{NaC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O}$

37. **a.** 3.62 **b.** 9.11

39. **a.** 7.60 **b.** 11.18 **c.** 4.61

41. **a.** 3.86 **b.** 8.95

43. 3.5

45. 3.7 g

47. **a.** 4.74 **b.** 4.68 **c.** 4.81

49. **a.** initial 7.00 after 1.70

b. initial 4.71 after 4.56

c. initial 10.78 after 10.66

51. 1.2 g; 2.7 g

53. **a.** yes **b.** no **c.** yes

d. no

e. no

55. **a.** 7.4 **b.** 0.3 g **c.** 0.14 g

57. $\text{KClO}/\text{HClO} = 0.79$

59. **a.** does not exceed capacity
b. does not exceed capacity
c. does not exceed capacity
d. does not exceed capacity

61. **i.** **a.** $\text{pH} = 8$

b. $\text{pH} = 7$

ii. **a.** weak acid

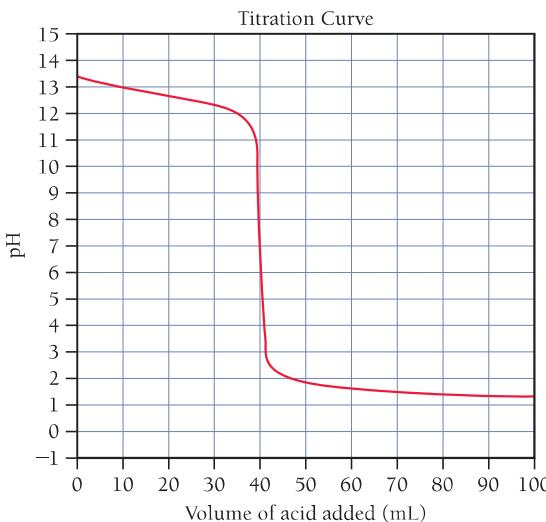
b. strong acid

63. **a.** 40.0 mL HI for both

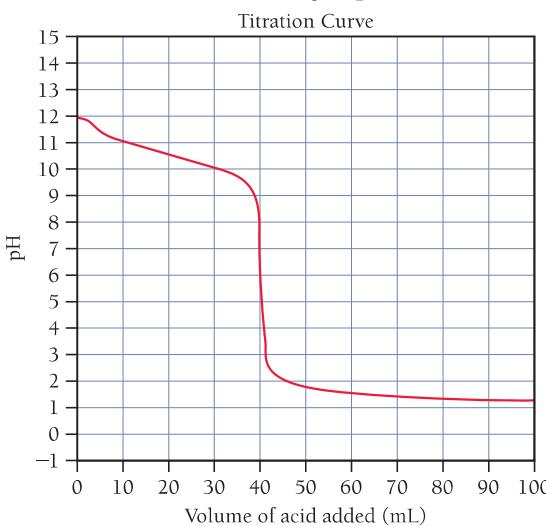
b. KOH: neutral, CH_3NH_2 : acidic

c. CH_3NH_2

d. Titration of KOH with HI:



Titration of CH_3NH_2 with HI:



65. **a.** pH = 9, added base = 30 mL

b. 0 mL **c.** 15 mL

d. 30 mL **e.** 30 mL

67. **a.** 0.757

b. 30.6 mL **c.** 1.038

d. 7 **e.** 12.15

69. **a.** 13.06

b. 28.8 mL **c.** 12.90

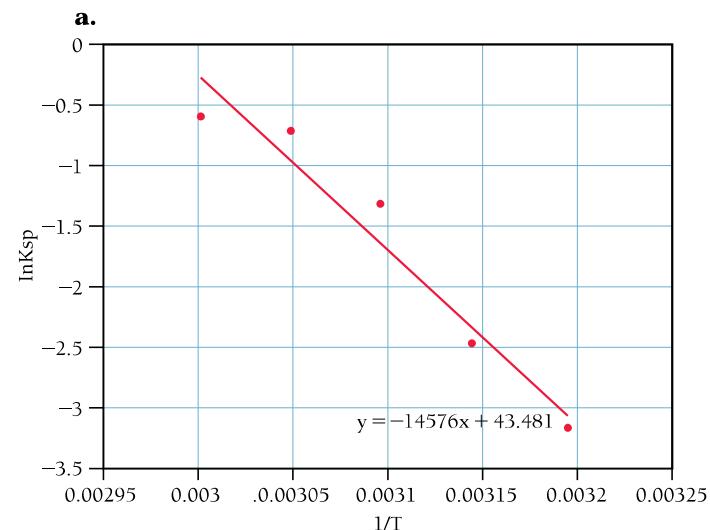
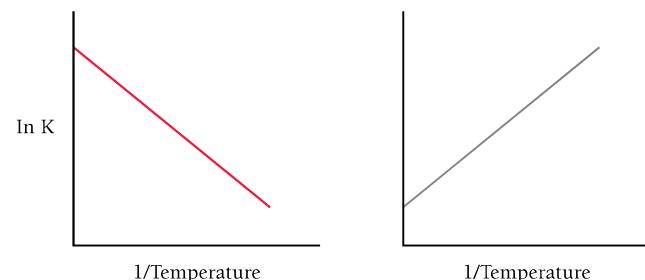
d. 7 **e.** 2.07

- 71.** **a.** 2.86 **b.** 16.8 mL **c.** 4.37
d. 4.74 **e.** 8.75 **f.** 12.17
- 73.** **a.** 11.94 **b.** 29.2 mL **c.** 11.33
d. 10.64 **e.** 5.87 **f.** 1.90
- 75.** **i.** (a)
ii. (b)
- 77.** $pK_a = 3.82$ g/mol
- 79.** First equivalence: 22.7 mL
Second equivalence: 45.4 mL
- 81.** The indicator will appear red. The pH range is 4 to 6.
- 83.** **a.** phenol red, *m*-nitrophenol
b. alizarin, bromothymol blue, phenol red
c. alizarin yellow R
- 85.** **a.** $\text{BaSO}_4(s) \rightleftharpoons \text{Ba}^{2+}(aq) + \text{SO}_4^{2-}(aq)$,
 $K_{\text{sp}} = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$
- b.** $\text{PbBr}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2\text{Br}^-(aq)$,
 $K_{\text{sp}} = [\text{Pb}^{2+}][\text{Br}^-]^2$
- c.** $\text{Ag}_2\text{CrO}_4(s) \rightleftharpoons 2\text{Ag}^+(aq) + \text{CrO}_4^{2-}(aq)$,
 $K_{\text{sp}} = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$
- 87.** **a.** 7.31×10^{-7} M **b.** 3.72×10^{-5} M
c. 3.32×10^{-4} M
- 89.** **a.** 1.07×10^{-21} **b.** 7.14×10^{-7}
c. 7.44×10^{-11}
- 91.** AX_2
- 93.** 2.07×10^{-5} g/100 mL
- 95.** **a.** 0.0183 M **b.** 0.00755 M
c. 0.00109 M
- 97.** **a.** 5×10^{14} M **b.** 5×10^8 M
c. 5×10^4 M
- 99.** **a.** more soluble, CO_3^{2-} is basic
b. more soluble, S^{2-} is basic
c. not, neutral
d. not, neutral
- 101.** precipitate will form, CaF_2
- 103.** precipitate will form, $\text{Mg}(\text{OH})_2$
- 105.** **a.** 0.018 M **b.** 1.4×10^{-7} M
c. 1.1×10^{-5} M
- 107.** **a.** BaSO_4 , 1.1×10^{-8} M
b. 3.0×10^{-8} M
- 109.** 8.7×10^{-10} M
- 111.** 5.6×10^{16}
- 113.** 4.03
- 115.** 3.57
- 117.** HCl, 4.7 g
- 119.** **a.** $\text{NaOH}(aq) + \text{KHC}_8\text{H}_4\text{O}_4(aq) \longrightarrow$
 $\text{Na}^+(aq) + \text{K}^+(aq) + \text{C}_8\text{H}_4\text{O}_4^{2-}(aq) + \text{H}_2\text{O}(l)$
b. 0.1046 M
- 121.** 4.73
- 123.** 176 g/mol; 1.0×10^{-4}
- 125.** 14.2 L
- 127.** 1.6×10^{-7} M
- 129.** 8.0×10^{-8} M
- 131.** 6.29
- 133.** 0.172 M
- 135.** The ratio by mass of dimethyl ammonium chloride to dimethyl amine needed is 3.6.
- 137.** 0.18 M benzoic acid, 0.41 M sodium benzoate
- 139.** 0.78 g NaCO_3
- 141.** 1.8×10^{-11} (based on this data)
- 143.** **a.** 5.5×10^{-25} M **b.** 5.5×10^{-4} M
- 145.** 1.38 L
- 147.** 12.97
- 149.** **a.** $\text{pH} < \text{p}K_a$
b. $\text{pH} > \text{p}K_a$
c. $\text{pH} = \text{p}K_a$
d. $\text{pH} > \text{p}K_a$
- 151.** **b**
- 153.** **a.** no difference
b. less soluble
c. more soluble
- 160.** **a.** 30.0 mL
a. Trimethylamine
- ### Chapter 19
- 27.** **a, c**
- 29.** System B has the greatest entropy. There is only one energetically equivalent arrangement for System A. However, the particles of System B may exchange positions for a second energetically equivalent arrangement.
- 31.** 29.2 J/K
- 33.** -24.7 J/K
- 35.** **a.** $\Delta S > 0$
b. $\Delta S < 0$
c. $\Delta S < 0$
d. $\Delta S < 0$
- 37.** **a.** $\Delta S_{\text{sys}} > 0$, $\Delta S_{\text{surr}} > 0$, spontaneous at all temperatures
b. $\Delta S_{\text{sys}} < 0$, $\Delta S_{\text{surr}} < 0$, nonspontaneous at all temperatures
c. $\Delta S_{\text{sys}} < 0$, $\Delta S_{\text{surr}} < 0$, nonspontaneous at all temperatures
d. $\Delta S_{\text{sys}} > 0$, $\Delta S_{\text{surr}} > 0$, spontaneous at all temperatures
- 39.** **a.** 1.29×10^3 J/K
b. 5.00×10^3 J/K
c. -3.83×10^2 J/K
d. -1.48×10^3 J/K
- 41.** **a.** -649 J/K, nonspontaneous
b. 649 J/K, spontaneous
c. 123 J/K, spontaneous
d. -76 J/K, nonspontaneous
- 43.** **a.** 1.93×10^5 J, nonspontaneous
b. -1.93×10^5 J, spontaneous
c. -3.7×10^4 J, spontaneous
d. 4.7×10^4 J, nonspontaneous
- 45.** -2.247×10^6 J, spontaneous
- 47.**

ΔH	ΔS	ΔG	Low Temperature	High Temperature
-	+	-	Spontaneous	Spontaneous
-	-	Temperature dependent	Spontaneous	Nonspontaneous
+	+	Temperature dependent	Nonspontaneous	Spontaneous
+	-	+	Nonspontaneous	Nonspontaneous
- 49.** It increases.

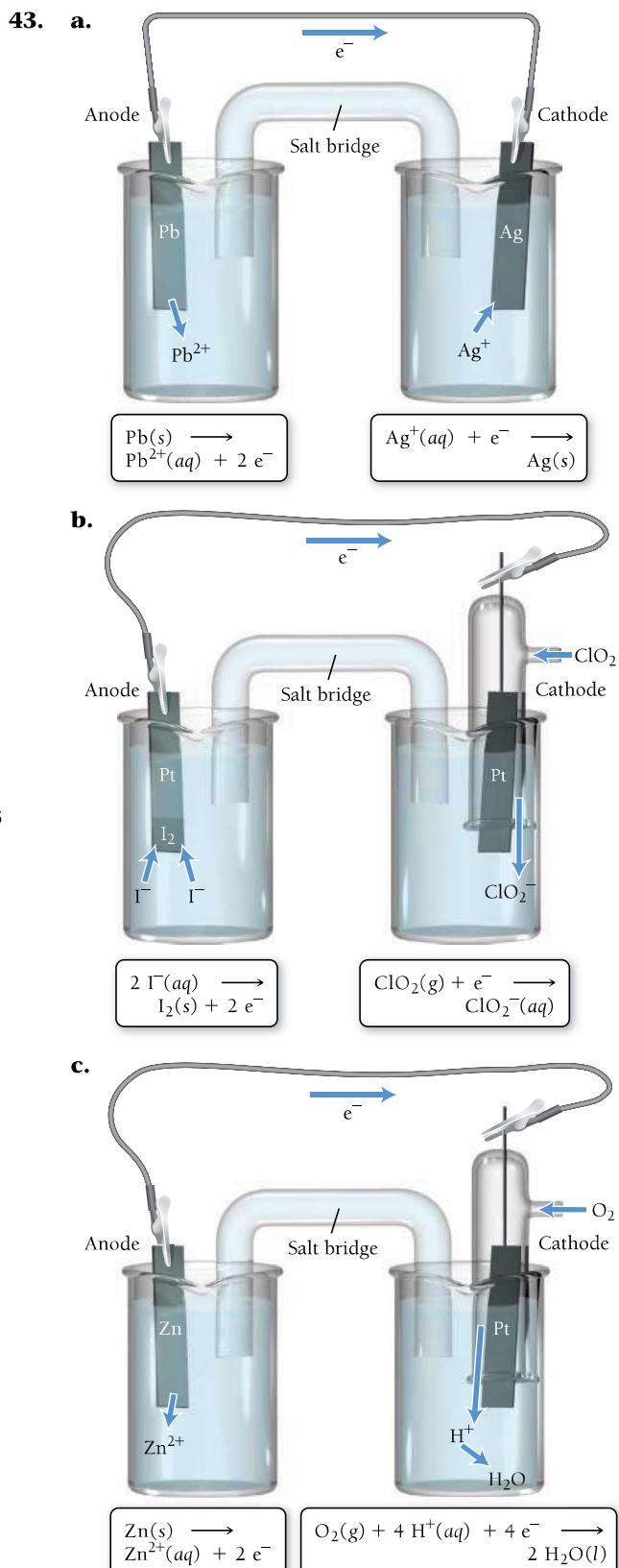
- 51.** **a.** $\text{CO}_2(g)$, greater molar mass and complexity
b. $\text{CH}_3\text{OH}(g)$, gas phase
c. $\text{CO}_2(g)$, greater molar mass and complexity
d. $\text{SiH}_4(g)$, greater molar mass
e. $\text{CH}_3\text{CH}_2\text{CH}_3(g)$, greater complexity
f. $\text{NaBr}(aq)$, aqueous
- 53.** **a.** He, Ne, SO_2 , NH_3 , $\text{CH}_3\text{CH}_2\text{OH}$ From He to Ne there is an increase in molar mass; beyond that, the molecules increase in complexity.
b. $\text{H}_2\text{O}(s)$, $\text{H}_2\text{O}(l)$, $\text{H}_2\text{O}(g)$; increase in entropy in going from solid to liquid to gas phase.
c. CH_4 , CF_4 , CCl_4 ; increasing entropy with increasing molar mass.
- 55.** **a.** -120.8 J/K , decrease in moles of gas
b. 133.9 J/K , increase in moles of gas
c. -42.0 J/K , small change because moles of gas stay constant
d. -390.8 J/K , decrease in moles of gas
- 57.** -89.3 J/K , decrease in moles of gas
- 59.** $\Delta H_{\text{rxn}}^\circ = -1277 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = 313.6 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = -1.370 \times 10^3 \text{ kJ}$; yes
- 61.** **a.** $\Delta H_{\text{rxn}}^\circ = 57.2 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = 175.8 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = 4.8 \times 10^3 \text{ J/mol}$; nonspontaneous, becomes spontaneous at high temperatures
b. $\Delta H_{\text{rxn}}^\circ = 176.2 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = 285.1 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = 91.2 \text{ kJ}$; nonspontaneous, becomes spontaneous at high temperatures
c. $\Delta H_{\text{rxn}}^\circ = 98.8 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = 141.5 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = 56.6 \text{ kJ}$; nonspontaneous, becomes spontaneous at high temperatures
d. $\Delta H_{\text{rxn}}^\circ = -91.8 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = -198.1 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = -32.8 \text{ kJ}$; spontaneous
- 63.** **a.** 2.8 kJ **b.** 91.2 kJ **c.** 56.4 kJ **d.** -32.8 kJ
Values are comparable. The method using ΔH° and ΔS° can be used to determine how ΔG° changes with temperature.
- 65.** **a.** -72.5 kJ , spontaneous
b. -11.4 kJ , spontaneous
c. 9.1 kJ , nonspontaneous
- 67.** -29.4 kJ
- 69.** **a.** 19.3 kJ **b. (i)** 2.9 kJ **(ii)** -2.9 kJ
c. The partial pressure of iodine is very low.
- 71.** 11.9 kJ
- 73.** **a.** $1.48 \times 10^{90} \text{ J}$ **b.** $2.09 \times 10^{-26} \text{ J}$ **c.** 9.4 kJ
- 75.** **a.** -24.8 kJ **b.** 0 kJ **c.** 9.4 kJ
- 77.** **a.** $1.90 \times 10^{47} \text{ J}$ **b.** $1.51 \times 10^{-13} \text{ J}$
- 79.** $\Delta H^\circ = 50.6 \text{ kJ}$ $\Delta S^\circ = 226 \text{ J/K}$
- 81.** 4.8 kJ
- 83.** **a.** + **b.** - **c.** -
- 85.** **a.** $\Delta G^\circ = 175.2 \text{ kJ}$, $K = 1.95 \times 10^{-31}$, nonspontaneous
b. 133 kJ , yes
- 87.** Cl_2 : $\Delta H_{\text{rxn}}^\circ = -182.1 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = -134.4 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = -142.0 \text{ kJ}$ $K = 7.94 \times 10^{24}$
 Br_2 : $\Delta H_{\text{rxn}}^\circ = -121.6 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = -134.2 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = -81.6 \text{ kJ}$ $K = 2.02 \times 10^{14}$
 I_2 : $\Delta H_{\text{rxn}}^\circ = -48.3 \text{ kJ}$, $\Delta S_{\text{rxn}}^\circ = -132.2 \text{ J/K}$,
 $\Delta G_{\text{rxn}}^\circ = -8.9 \text{ kJ}$ $K = 37$
- Cl₂** is the most spontaneous, and **I₂** is the least. Spontaneity is determined by the standard enthalpy of formation of the dihalogenated ethane. Higher temperatures make the reactions less spontaneous.
- 89.** **a.** 107.8 kJ **b.** $5.0 \times 10^{-7} \text{ atm}$
c. spontaneous at higher temperatures, $T = 923.4 \text{ K}$
- 91.** **a.** $2.22 \times 10^5 \text{ J}$ **b.** 94.4 mol
- 93.** **a.** $\Delta G^\circ = -689.6 \text{ kJ}$, ΔG° becomes less negative.
b. $\Delta G^\circ = -665.2 \text{ kJ}$, ΔG° becomes less negative.
c. $\Delta G^\circ = -632.4 \text{ kJ}$, ΔG° becomes less negative.
d. $\Delta G^\circ = -549.3 \text{ kJ}$, ΔG° becomes less negative.
- 95.** With one exception, the formation of any oxide of nitrogen at 298 K requires more moles of gas as reactants than are formed as products. For example, 1 mol of N_2O requires 0.5 mol of O_2 and 1 mol of N_2 , 1 mol of N_2O_3 requires 1 mol of N_2 and 1.5 mol of O_2 , and so on. The exception is NO, where 1 mol of NO requires 0.5 mol of O_2 and 0.5 mol of N_2 :
- $$\frac{1}{2}\text{N}_2(g) + \frac{1}{2}\text{O}_2(g) \longrightarrow \text{NO}(g)$$
- This reaction has a positive ΔS because what is essentially mixing of the N and O has taken place in the product.
- 97.** 15.0 kJ
- 99.** **a.** Positive, the process is spontaneous. It is slow unless a spark is applied.
b. Positive, although the change in the system is not spontaneous; the overall change, which includes such processes as combustion or water flow to generate electricity, is spontaneous.
c. Positive, the acorn-oak tree system is becoming more ordered, so the processes associated with growth are not spontaneous. But they are driven by spontaneous processes such as the generation of heat by the sun and the reactions that produce energy in the cell.
- 101.** At 18.3 mmHg $\Delta G = 0$, at 760 mmHg
 $\Delta G^\circ = 55.4 \text{ kJ}$
- 103.** **a.** $3.24 \times 10^{-3} \text{ M}$
b. $\text{NH}_3 + \text{ATP} + \text{H}_2\text{O} \longrightarrow \text{NH}_3-\text{P}_i + \text{ADP}$
 $\text{NH}_3-\text{P}_i + \text{C}_5\text{H}_8\text{O}_4\text{N}^- \longrightarrow \text{C}_5\text{H}_9\text{O}_3\text{N}_2 + \text{P}_i + \text{H}_2\text{O}$
 $\text{NH}_3 + \text{C}_5\text{H}_8\text{O}_4\text{N}^- + \text{ATP} \longrightarrow \text{C}_5\text{H}_9\text{O}_3\text{N}_2 + \text{ADP} + \text{P}_i$
 $\Delta G^\circ = -16.3 \text{ kJ}$, $K = 7.20 \times 10^2$
- 105.** **a.** -95.3 kJ/mol Since the number of moles of reactants and products is the same, the decrease in volume affects the entropy of both equally, so there is no change in ΔG .
b. 102.8 kJ/mol The entropy of the reactants (1.5 mol) is decreased more than the entropy of the product (1 mol). Since the product is relatively more favored at lower volume, ΔG is less positive.
c. 204.2 kJ/mol The entropy of the product (1 mol) is decreased more than the entropy of the reactant (0.5 mol). Since the product is relatively less favored, ΔG is more positive.
- 107.** $\Delta H^\circ = -93 \text{ kJ}$, $\Delta S^\circ = -2.0 \times 10^2 \text{ J/K}$
- 109.** ΔS_{vap} diethyl ether = 86.1 J/mol K ,
 ΔS_{vap} acetone = 88.4 J/mol K ,

$\Delta S_{\text{vap}} \text{ benzene} = 87.3 \text{ J/mol K}$,
 $\Delta S_{\text{vap}} \text{ chloroform} = 88.0 \text{ J/mol K}$. Because water and ethanol hydrogen bond, they are more ordered in the liquid and we expect ΔS_{vap} to be more positive.
Ethanol $38600/351.0 = 38600/351.0 = 110 \text{ J/mol K}$,
 $\text{H}_2\text{O} = 40700/373.2 = 109 \text{ J/mol K}$

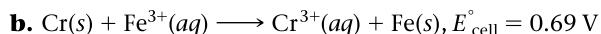
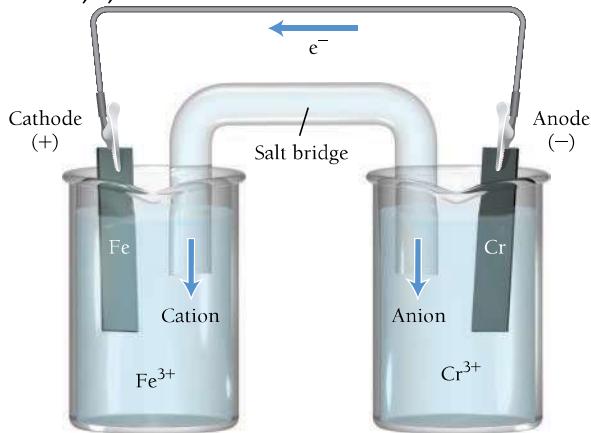
111. c**113. b****115. c****117.** $\Delta G^\circ_{\text{rxn}}$ is negative and ΔG_{rxn} is positive.**123.****c. 362 J/K****e. endothermic**

Chapter 20

- 37.** **a.** $3 \text{K}(s) + \text{Cr}^{3+}(aq) \longrightarrow \text{Cr}(s) + 3 \text{K}^+(aq)$
b. $2 \text{Al}(s) + 3 \text{Fe}^{2+}(aq) \longrightarrow 2 \text{Al}^{3+}(aq) + 3 \text{Fe}(s)$
c. $2 \text{BrO}_3^-(aq) + 3 \text{N}_2\text{H}_4(g) \longrightarrow 2 \text{Br}^-(aq) + 3 \text{N}_2(g) + 6 \text{H}_2\text{O}(l)$
- 39.** **a.** $\text{PbO}_2(s) + 2 \text{I}^-(aq) + 4 \text{H}^+(aq) \longrightarrow \text{Pb}^{2+}(aq) + \text{I}_2(s) + 2 \text{H}_2\text{O}(l)$
b. $5 \text{SO}_3^{2-}(aq) + 2 \text{MnO}_4^-(aq) + 6 \text{H}^+(aq) \longrightarrow 5 \text{SO}_4^{2-}(aq) + 2 \text{Mn}^{2+}(aq) + 3 \text{H}_2\text{O}(l)$
c. $\text{S}_2\text{O}_3^{2-}(aq) + 4 \text{Cl}_2(g) + 5 \text{H}_2\text{O}(l) \longrightarrow 2 \text{SO}_4^{2-}(aq) + 8 \text{Cl}^-(aq) + 10 \text{H}^+(aq)$
- 41.** **a.** $\text{H}_2\text{O}_2(aq) + 2 \text{ClO}_2(aq) + 2 \text{OH}^-(aq) \longrightarrow \text{O}_2(g) + 2 \text{ClO}_2^-(aq) + 2 \text{H}_2\text{O}(l)$
b. $\text{Al}(s) + \text{MnO}_4^-(aq) + 2 \text{H}_2\text{O}(l) \longrightarrow \text{Al}(\text{OH})_4^-(aq) + \text{MnO}_2(s)$
c. $\text{Cl}_2(g) + 2 \text{OH}^-(aq) \longrightarrow \text{Cl}^-(aq) + \text{ClO}^-(aq) + \text{H}_2\text{O}(l)$

**45. a. 0.93 V****b. 0.41 V****c. 1.99 V**

47. a, c, d

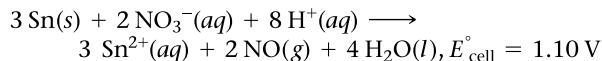
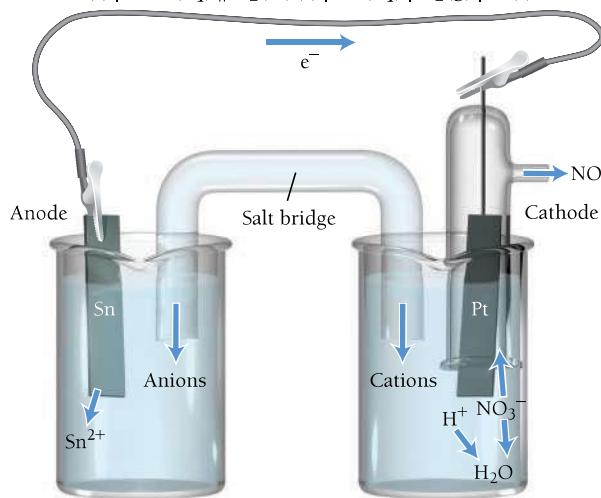


49. a. Pb(s)|Pb²⁺(aq)||Ag⁺(aq)|Ag(s)

b. Pt(s), I₂(s)|I⁻(aq)||ClO₂⁻(aq)|ClO₂(g)|Pt(s)

c. Zn(s)|Zn²⁺(aq)||H₂O(l)|H⁺(aq)|O₂(g)|Pt(s)

51.



53. b, c occur spontaneously in the forward direction.

55. aluminum

57. a. yes, $2 \text{Al}(s) + 6 \text{H}^+(aq) \rightarrow 2 \text{Al}^{3+}(aq) + 3 \text{H}_2(g)$

b. no

c. yes, $\text{Pb}(s) + 2 \text{H}^+(aq) \rightarrow \text{Pb}^{2+}(aq) + \text{H}_2(g)$

59. a. yes, $3 \text{Cu}(s) + 2 \text{NO}_3^-(aq) + 8 \text{H}^+(aq) \rightarrow 3 \text{Cu}^{2+}(aq) + 2 \text{NO}(g) + 4 \text{H}_2\text{O}(l)$

b. no

61. a. -1.70 V, nonspontaneous

b. 1.97 V, spontaneous

c. -1.51 V, nonspontaneous

63. a

65. a. -432 kJ b. 52 kJ

c. $-1.7 \times 10^2 \text{ kJ}$

67. a. 5.31×10^{75} b. 7.7×10^{-10}

c. 6.3×10^{29}

69. 5.6×10^5

71. $\Delta G^\circ = -7.97 \text{ kJ}, E^\circ_{\text{cell}} = 0.041 \text{ V}$

73. a. 1.04 V b. 0.97 V c. 1.11 V

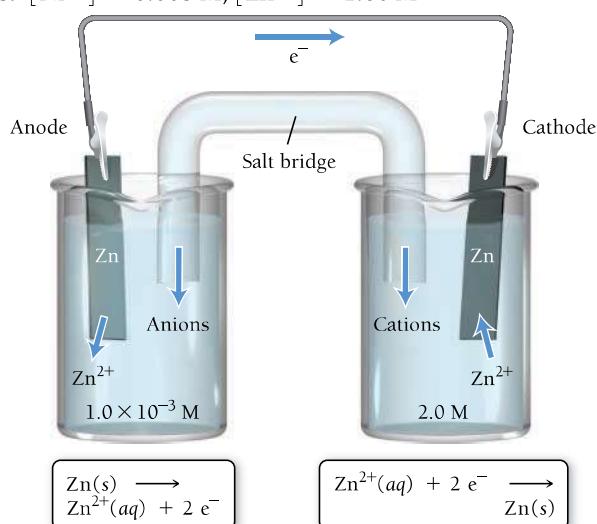
75. 1.87 V

77. a. 0.56 V

b. 0.52 V

c. $[\text{Ni}^{2+}] = 0.003 \text{ M}, [\text{Zn}^{2+}] = 1.60 \text{ M}$

79.



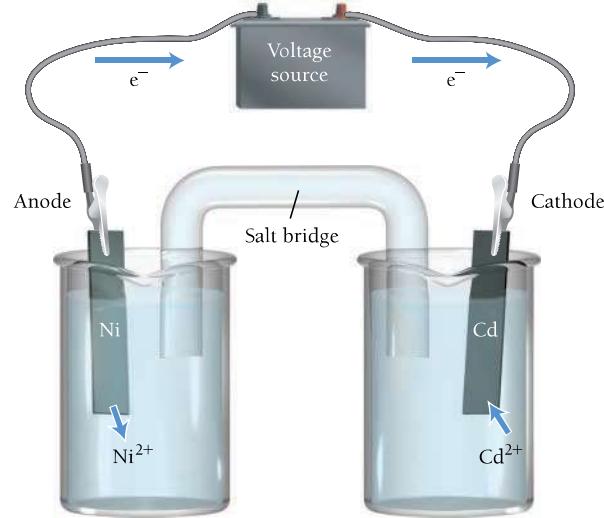
81. $\frac{[\text{Sn}^{2+}](\text{o}\chi)}{[\text{Sn}^{2+}](\text{red})} = 4.2 \times 10^{-4}$

83. 0.3762

85. 1.038 V

87. a, c would prevent the corrosion of iron.

89.



minimum voltage = 0.17 V

91. oxidation: $2 \text{Br}^-(l) \rightarrow \text{Br}_2(g) + 2 \text{e}^-$

reduction: $\text{K}^+(l) + \text{e}^- \rightarrow \text{K}(l)$

93. oxidation: $2 \text{Br}^-(l) \rightarrow \text{Br}_2(g) + 2 \text{e}^-$

reduction: $\text{K}^+(l) + \text{e}^- \rightarrow \text{K}(l)$

95. a. anode: $2 \text{Br}^- \rightarrow \text{Br}_2(l) + 2 \text{e}^-$

cathode: $2 \text{H}_2\text{O}(l) + 2 \text{e}^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-(aq)$

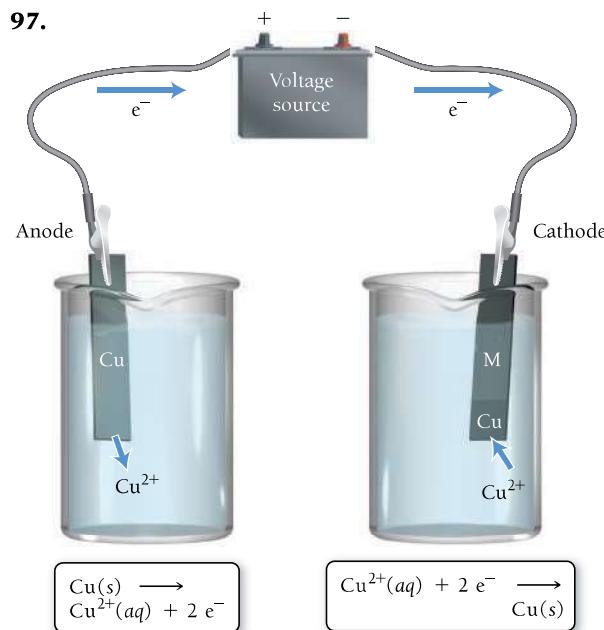
b. anode: $2 \text{I}^-(aq) \rightarrow \text{I}_2(s) + 2 \text{e}^-$

cathode: $\text{Pb}^{2+}(aq) + 2 \text{e}^- \rightarrow \text{Pb}(s)$

c. anode: $2 \text{H}_2\text{O}(l) \rightarrow \text{O}_2(g) + 4 \text{H}^+(aq) + 4 \text{e}^-$

cathode: $2 \text{H}_2\text{O}(l) + 2 \text{e}^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-(aq)$

97.

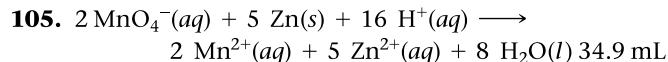


99. $1.8 \times 10^2 \text{ s}$

101. $1.2 \times 10^3 \text{ A}$ $E_{\text{cell}} = 0.0725 \text{ V}$, $K = 282$

103.

$[\text{B}^{2+}]$	$[\text{A}^{2+}]$	Q	E_{cell}	ΔG_{rxn}
1.00	1.0	1.0	0.0725 V	-14.0 kJ
1.00	1.00×10^{-4}	1.00×10^{-4}	0.191	-36.8 kJ
1.00×10^{-4}	1.0	1.00×10^4	-0.0458	8.82 kJ
3.52×10^{-3}	1.0	284	0	0

107. The drawing should show that several Al atoms dissolve into solution as Al^{3+} ions and that several Cu^{2+} ions are deposited on the Al surface as solid Cu.

109. a. 68.3 mL

- b. cannot be dissolved
c. cannot be dissolved

111. 0.25

113. There are no paired reactions that produce more than about 5 or 6 V.

115. a. 2.83 V b. 2.71 V c. 16 hr

117. 176 hr

119. 0.71 V

121. a. $\Delta G^\circ = 461 \text{ kJ}$, $K = 1.4 \times 10^{-81}$ b. $\Delta G^\circ = 2.7 \times 10^2 \text{ kJ}$, $K = 2.0 \times 10^{-48}$ 123. MCl_4

125. 51.3%

127. $\text{pH} = 0.85$

129. 0.83 M

131. $4.1 \times 10^5 \text{ L}$

133. 435 s

135. 8.39% U

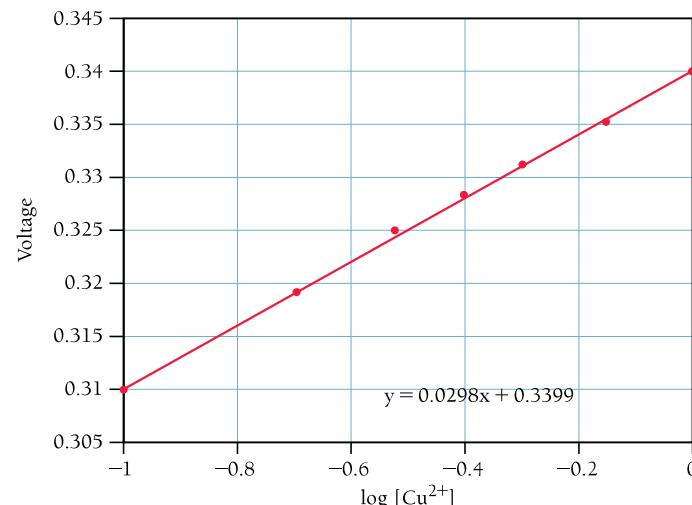
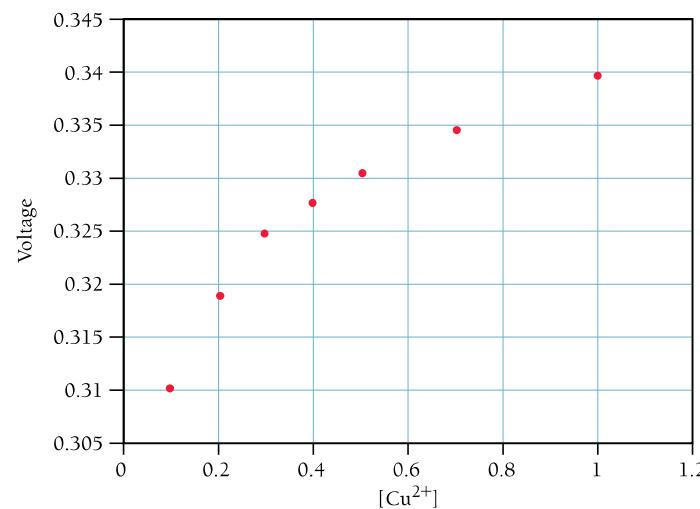
137. The overall cell reaction for both cells is

 $2 \text{Cu}^+(aq) \longrightarrow \text{Cu}^{2+}(aq) + \text{Cu}(s)$. The difference in E° is because $n = 1$ for the first cell and $n = 2$ for the second cell. For both cells, $\Delta G^\circ = -35.1 \text{ kJ}$.

139. a

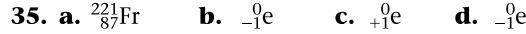
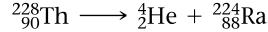
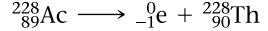
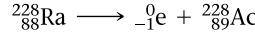
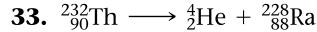
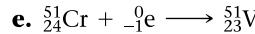
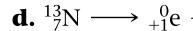
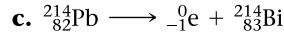
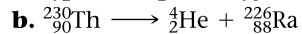
141. $\Delta G_{\text{rxn}}^\circ$ is positive and E_{cell}° is negative.

147. a.



e. Slope = 0.0298; intercept = 0.340; yes, the slope should be $0.0592/n$ and the intercept should be E_{cell}° .

Chapter 21



37. a. stable; N/Z ratio is close to 1, acceptable for low Z atoms.

b. not stable; N/Z ratio is much too high for low Z atom.

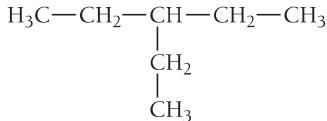
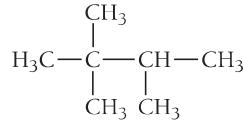
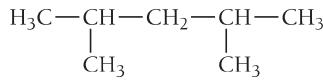
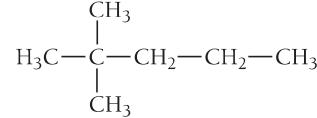
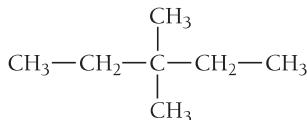
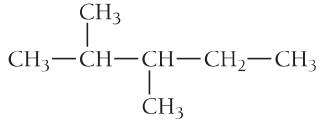
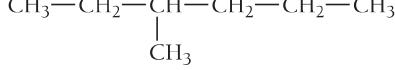
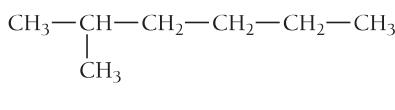
c. not stable; N/Z ratio is less than 1, much too low.

d. stable; N/Z ratio is acceptable for this Z.

- 39.** Sc, V, and Mn; each have odd numbers of protons. Atoms with an odd number of protons typically have less stable isotopes than those with an even number of protons.
- 41.** **a.** beta decay
b. positron emission
c. positron emission
d. positron emission
- 43.** **a.** Cs-125 **b.** Fe-62
- 45.** 2.34×10^9 years
- 47.** 0.57 g
- 49.** 10.8 hr
- 51.** 2.66×10^3 yr
- 53.** 2.4×10^4 yr
- 55.** 2.7×10^9 yr
- 57.** $^{235}_{92}\text{U} + {}_0^1\text{n} \longrightarrow {}^{144}_{54}\text{Xe} + {}^{90}_{38}\text{Sr} + 2 {}_0^1\text{n}$
- 59.** ${}^1_1\text{H} + {}^2_1\text{H} \longrightarrow {}^3_2\text{He} + {}_0^1\text{n}$
- 61.** ${}^{238}_{92}\text{U} + {}_0^1\text{n} \longrightarrow {}^{239}_{92}\text{U}$
 ${}^{239}_{92}\text{U} \longrightarrow {}^{239}_{93}\text{Np} + {}_{-1}^0\text{e}$
 ${}^{239}_{93}\text{Np} \longrightarrow {}^{239}_{94}\text{Pu} + {}_{-1}^0\text{e}$
- 63.** ${}^{249}_{98}\text{Cf} + {}^{12}_6\text{C} \longrightarrow {}^{257}_{104}\text{Rf} + 4 {}_0^1\text{n}$
- 65.** 9.0×10^{13} J
- 67.** **a.** mass defect = 0.13701 amu binding energy
= 7.976 MeV/nucleon
b. mass defect = 0.54369 amu binding energy
= 8.732 MeV/nucleon
c. mass defect = 1.16754 amu binding energy
= 8.431 MeV/nucleon
- 69.** 7.228×10^{10} J/g U-235
- 71.** 7.84×10^{10} J/g H-2
- 73.** radiation: 25 J, fall: 370 J
- 75.** 68 mi
- 77.** **a.** ${}^1_1\text{p} + {}^4_2\text{Be} \longrightarrow {}^6_3\text{Li} + {}^2_2\text{He}$ 1.03×10^{11} J/mol
b. ${}^{209}_{83}\text{Bi} + {}^{64}_{28}\text{Ni} \longrightarrow {}^{272}_{111}\text{Rg} + {}_0^1\text{n}$ 1.141×10^{13} J/mol
c. ${}^{179}_{74}\text{W} + {}_{-1}^0\text{e} \longrightarrow {}^{179}_{73}\text{Ta}$ 7.59×10^{10} J/mol
- 79.** **a.** ${}^{114}_{44}\text{Ru} \longrightarrow {}_{-1}^0\text{e} + {}^{114}_{45}\text{Rh}$
b. ${}^{216}_{88}\text{Ra} \longrightarrow {}_{+1}^0\text{e} + {}^{216}_{87}\text{Fr}$
c. ${}^{58}_{30}\text{Zn} \longrightarrow {}_{-1}^0\text{e} + {}^{58}_{29}\text{Cu}$
d. ${}^{31}_{10}\text{Ne} \longrightarrow {}_{-1}^0\text{e} + {}^{31}_{11}\text{Na}$
- 81.** 2.9×10^{21} beta emissions, 3700 Ci
- 83.** 1.6×10^{-5} L
- 85.** 4.94×10^7 kJ/mol
- 87.** 7.72 MeV
- 89.** ${}^{14}\text{N}$
- 91.** 0.15%
- 93.** 1.24×10^{21} atoms
- 95.** 2.42×10^{-12} m
- 97.** -0.7 MeV; there is no coulombic barrier for collision with a neutron.
- 99.** **a.** 1.164×10^{10} kJ
b. 0.1299 g
- 101.** U-235 forms Pb-207 in seven α -decays and four β -decays, and Th-232 forms Pb-208 in six α -decays and four β -decays.
- 103.** 3.0×10^2 K
- 105.** ${}^{21}_9\text{F} \longrightarrow {}^{21}_{10}\text{Ne} + {}_{-1}^0\text{e}$
- 107.** Nuclide A is more dangerous because the half-life is shorter (18.5 days) and so it decays faster.
- 109.** Iodine is used by the thyroid gland to make hormones. Normally, we ingest iodine in foods, especially iodized salt. The thyroid gland cannot tell the difference between stable and radioactive iodine and will absorb both. KI tablets work by blocking radioactive iodine from entering the thyroid. When a person takes KI, the stable iodine in the tablet gets absorbed by the thyroid. Because KI contains so much stable iodine, the thyroid gland becomes "full" and cannot absorb any more iodine—either stable or radioactive—for the next 24 hours.
- 115.** **a.** 0.34 g at 200 minutes; 0.23 g at 400 minutes
c. $0.63 \mu\text{g}$

Chapter 22

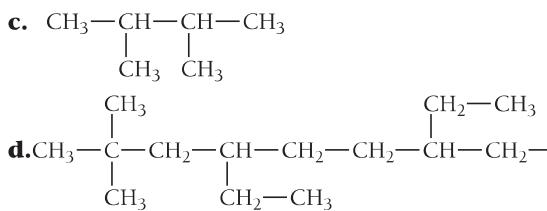
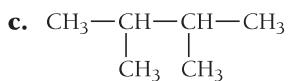
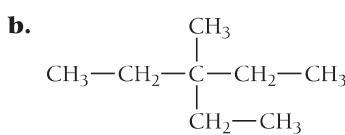
- 33.** **a.** alkane
b. alkene
c. alkyne
d. alkene
- 35.** $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$



- 37.** **a.** no **b.** yes **c.** yes **d.** no
- 39.** **a.** enantiomers **b.** same **c.** enantiomers

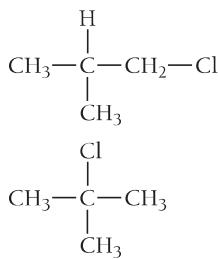
- 41.** a. pentane
b. 2-methylbutane
c. 4-isopropyl-2-methylheptane
d. 4-ethyl-2-methylhexane

43. a. $\text{CH}_3-\text{CH}_2-\underset{\text{C}}{\text{CH}}-\text{CH}_2-\text{CH}_2-\text{CH}_3$



- 45.** a. $\text{CH}_3\text{CH}_2\text{CH}_3 + 5 \text{ O}_2 \longrightarrow 3 \text{ CO}_2 + 4 \text{ H}_2\text{O}$
 b. $\text{CH}_3\text{CH}_2\text{CH} = \text{CH}_2 + 6 \text{ O}_2 \longrightarrow 4 \text{ CO}_2 + 4 \text{ H}_2\text{O}$
 c. $2 \text{ CH}\equiv\text{CH} + 5 \text{ O}_2 \longrightarrow 4 \text{ CO}_2 + 2 \text{ H}_2\text{O}$

- 47.** a. $\text{CH}_3\text{CH}_2\text{Br}$
 b. $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$, $\text{CH}_3\text{CHClCH}_3$

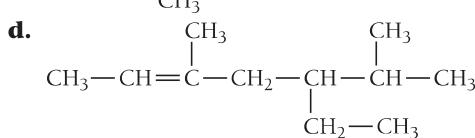
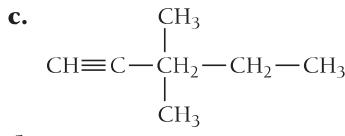
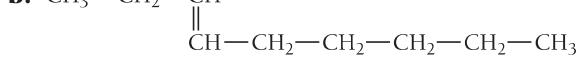


- 49.** $\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$
 $\text{CH}_3-\text{CH}-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3$
 $\text{CH}_3-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}_3$

- 51.** a. 1-butene
b. 3,4-dimethyl-2-pentene
c. 3-isopropyl-1-hexene
d. 2,4-dimethyl-3-hexene

- 53.** a. 2-butyne
b. 4,4-dimethyl-2-hexyne
c. 3-isopropyl-1-hexyne
d. 3,6-dimethyl-4-nonyne

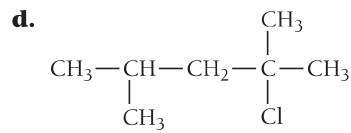
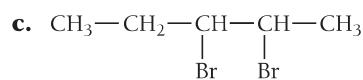
- 55.** a. $\text{CH}_3-\text{CH}_2-\text{CH}-\text{C}\equiv\text{C}-\text{CH}_2-\text{CH}_2-\text{CH}_3$
 b. $\text{CH}_3-\text{CH}_2-\text{CH}_3$



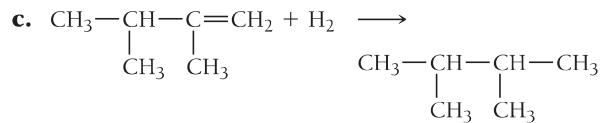
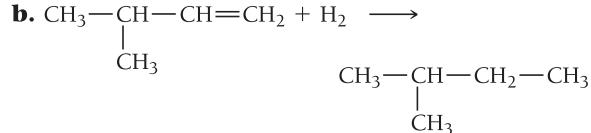
- 57.** a. $\text{CH}_3-\underset{\text{Cl}}{\overset{|}{\text{CH}}}-\underset{\text{Cl}}{\overset{|}{\text{CH}}}-\text{CH}_3$

- b.** $\text{CH}_3-\underset{\text{CH}_3}{\overset{|}{\text{CH}}}-\text{CH}_2-\underset{\text{Br}}{\overset{|}{\text{CH}}}-\text{CH}_3 +$

$$\text{CH}_3-\underset{\text{CH}_3}{\overset{|}{\text{CH}}}-\underset{\text{Br}}{\overset{|}{\text{CH}}}-\text{CH}_2-\text{CH}_3$$



- 59. a.** $\text{CH}_2=\text{CH}-\text{CH}_3 + \text{H}_2 \longrightarrow \text{CH}_3-\text{CH}_2-\text{CH}_3$



- 61.** a. methylbenzene or toluene

- b.** bromobenzene

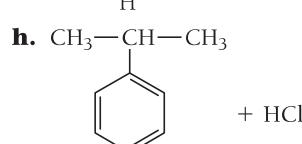
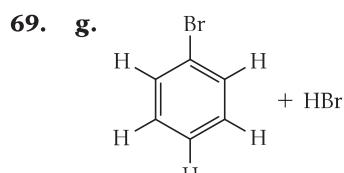
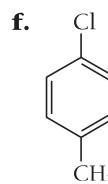
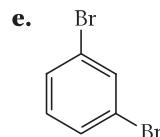
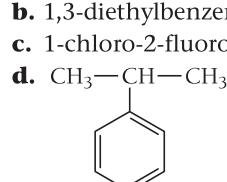
- c. chlorobenzene

- 63. a.** 3,5-dimethyl-7-phenylnonane

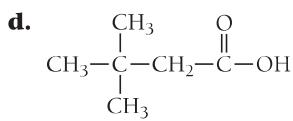
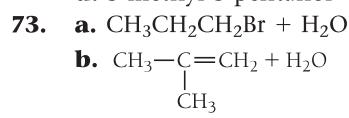
- b.** 2-phenyl-3-octene

- c. 4,5-dimethyl-6-phenyl-2-octyne

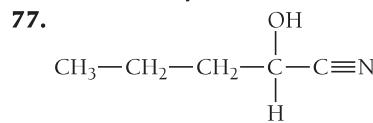
- 65. a.** 1,4-dibromobenzene or *p*-dibromobenzene



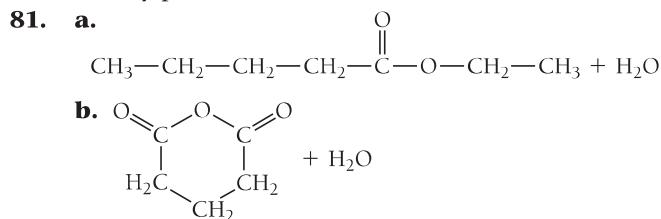
- 71.** **a.** 1-propanol
b. 4-methyl-2-hexanol
c. 2,6-dimethyl-4-heptanol
d. 3-methyl-3-pentanol



- 75.** **a.** butanone
b. pentanal
c. 3,5,5-trimethylhexanal
d. 4-methyl-2-hexanone



- 79.** **a.** methylbutanoate
b. propanoic acid
c. 5-methylhexanoic acid
d. ethylpentanoate



- 83.** **a.** ethyl propyl ether
b. ethyl pentyl ether
c. dipropyl ether
d. butyl ethyl ether

- 85.** **a.** diethylamine
b. methylpropylamine
c. butylmethylpropylamine

- 87.** **a.** acid-base, $(\text{CH}_3)_2\text{NH}_2^+(\text{aq}) + \text{Cl}^-(\text{aq})$
b. condensation, $\text{CH}_3\text{CH}_2\text{CONHCH}_2\text{CH}_3(\text{aq}) + \text{H}_2\text{O}$
c. acid-base, $\text{CH}_3\text{NH}_3^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$

- 89.** **a.** ester, methyl 3-methylbutanoate
b. ether, ethyl 2-methylbutyl ether
c. aromatic, 1-ethyl-3-methylbenzene or *m*-ethylmethylbenzene
d. alkyne, 5-ethyl-4-methyl-2-heptyne
e. aldehyde, butanal
f. alcohol, 2-methyl-1-propanol

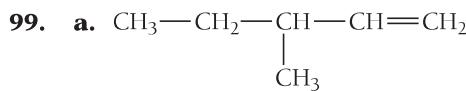
- 91.** **a.** 5-isobutyl-3-methylnonane
b. 5-methyl-3-hexanone
c. 3-methyl-2-butanol
d. 4-ethyl-3,5-dimethyl-1-hexyne

- 93.** **a.** isomers **b.** isomers

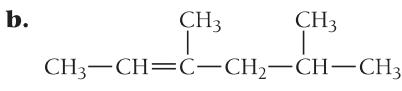
- c.** same

95. 558 g

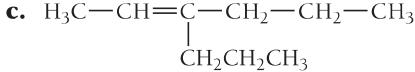
- 97.** **a.** combustion
b. alkane substitution
c. alcohol elimination
d. aromatic substitution



Can exist as a stereoisomer

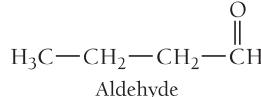


Can exist as a stereoisomer

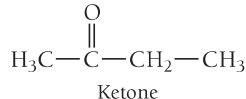


Can exist as a stereoisomer

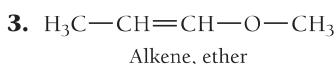
101. 1.



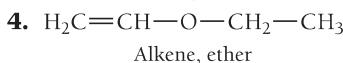
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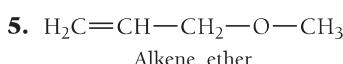
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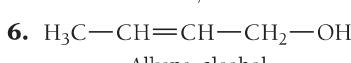
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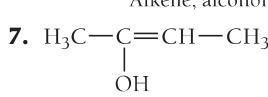
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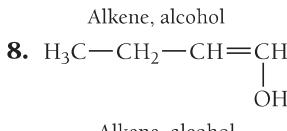
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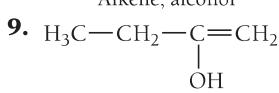
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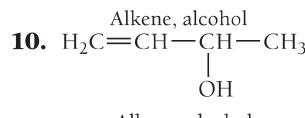
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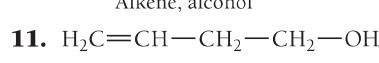
9.



10.

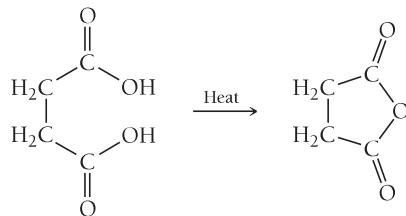


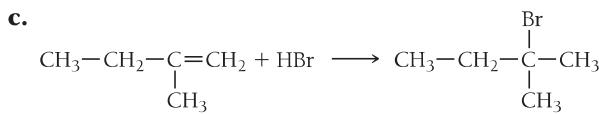
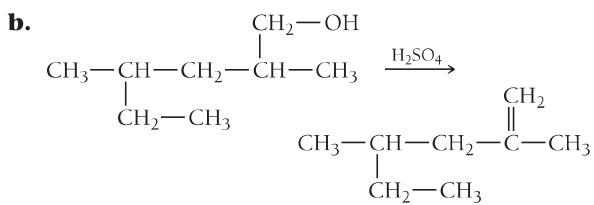
11.



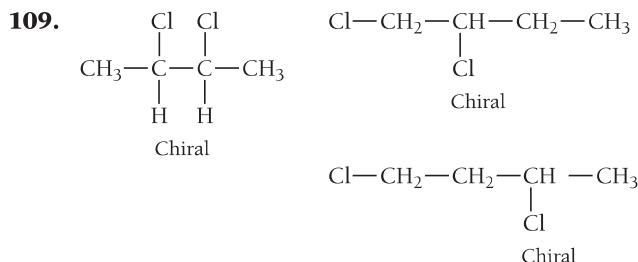
- 103.** In the acid form of the carboxylic acid, electron withdrawal by the $\text{C}=\text{O}$ enhances acidity. The conjugate base, the carboxylate anion, is stabilized by resonance, so the two O atoms are equivalent and bear the negative charge equally.

105. a.

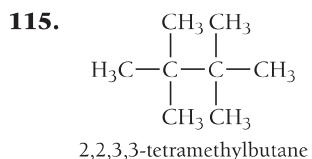
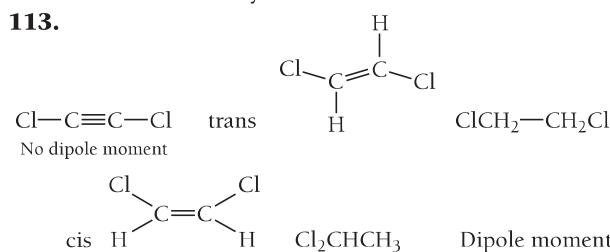




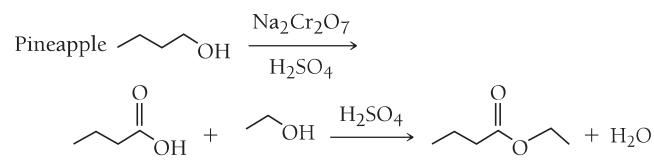
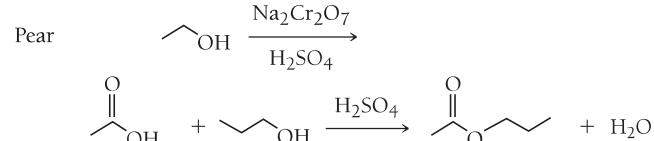
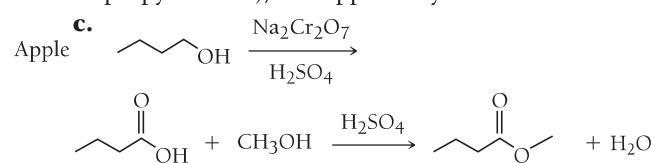
- 107. a.** 3:1
b. 2° hydrogen atoms are more reactive. The reactivity of 2° hydrogens to 1° hydrogens is 11:3.



- 111.** The first propagation step for F is very rapid and exothermic because of the strength of the H—F bond that forms. For I the first propagation step is endothermic and slow because the H—I bond that forms is relatively weak.



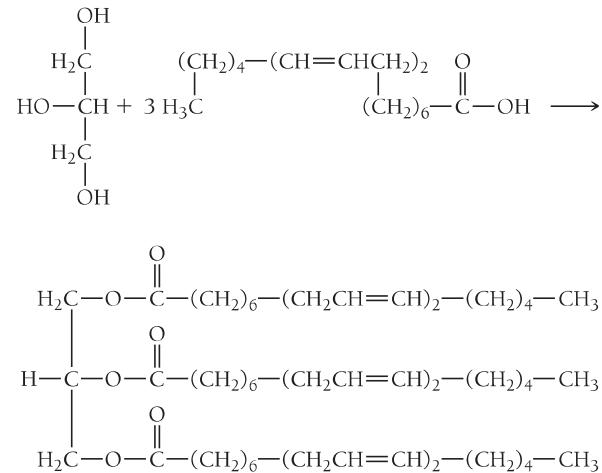
- 121. a.** Apple: methylbutanoate; Pear: propyl ethanoate (or propyl acetate); Pineapple: ethyl butanoate



Chapter 23

- 31.** a. saturated fatty acid
b. steroid

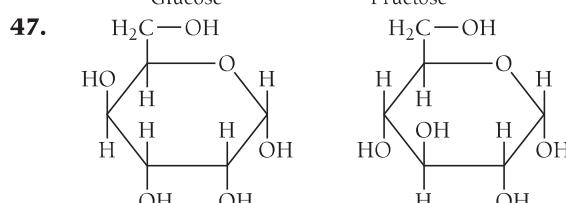
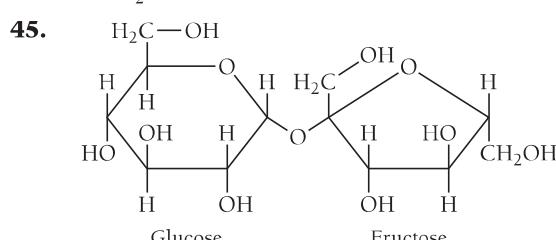
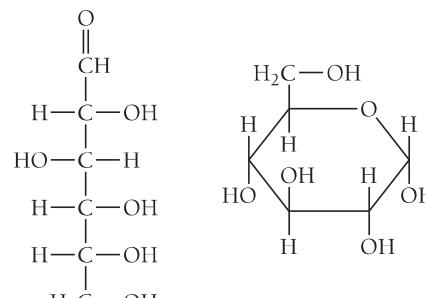
33. a. saturated fatty acid
b. not a fatty acid
c. not a fatty acid
d. monounsaturated fatty acid



Triglyceride is expected to be an oil.

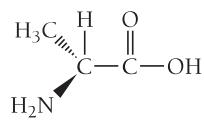
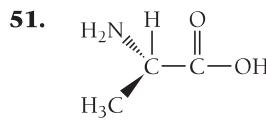
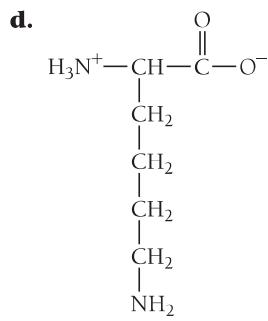
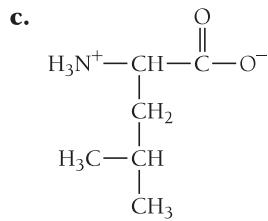
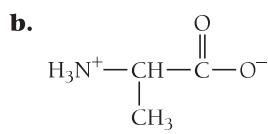
- 37.** a. monosaccharide c. disaccharide
39. a. aldose, hexose b. aldose, pentose
 c. ketose, tetrose d. aldose, tetrose

- 41.** a. 5 b. 3 c. 1 d. 3

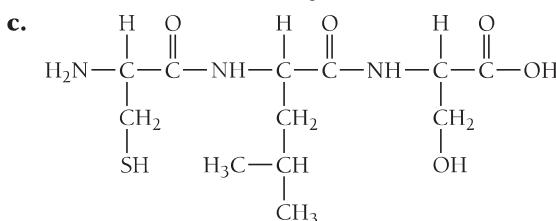
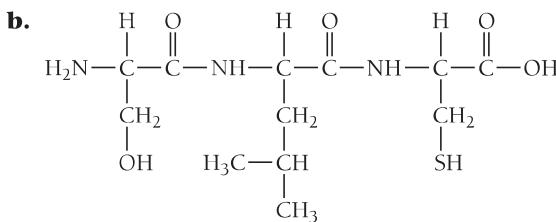
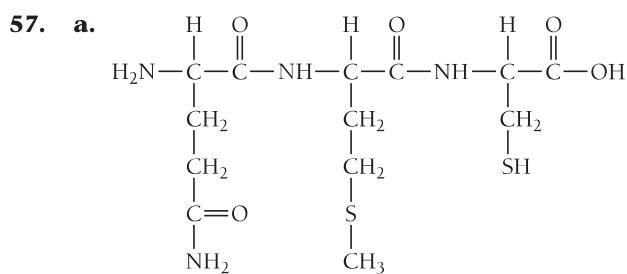
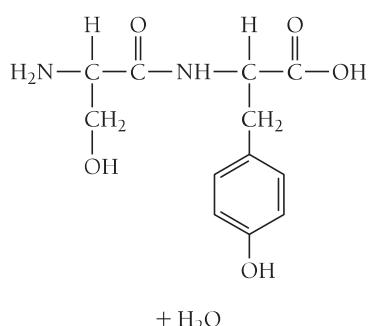
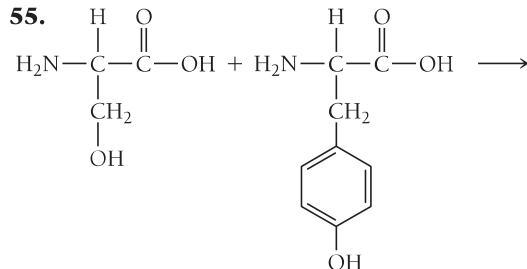


- 49. a.**

$$\begin{array}{c} \text{H}_3\text{N}^+ - \text{CH} - \overset{\text{O}}{\underset{\text{O}^-}{\text{C}}} - \text{O}^- \\ | \\ \text{HO} - \text{CH} \\ | \\ \text{CH}_3 \end{array}$$



53. 6, Ser-Gly-Cys, Ser-Cys-Gly, Gly-Ser-Cys, Gly-Cys-Ser, Cys-Ser-Gly, Cys-Gly-Ser

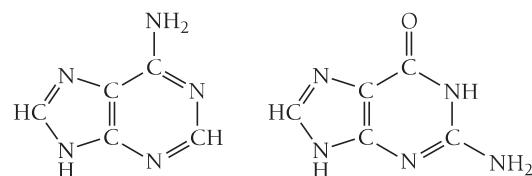


59. tertiary

61. primary

63. a. A

b. T



67. A C A T G C G

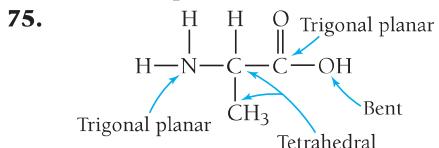
69. 154 codons, 462 nucleotides

71. a. protein

b. carbohydrate

c. lipid

73. A codon is composed of three nucleotides. A codon codes for a specific amino acid, while a gene codes for an entire protein.

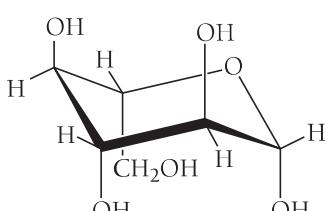


77. valine, leucine, isoleucine, phenylalanine

79. Gly-Arg-Ala-Leu-Phe-Gly-Asn-Lys-Trp-Glu-Cys

81.

a.



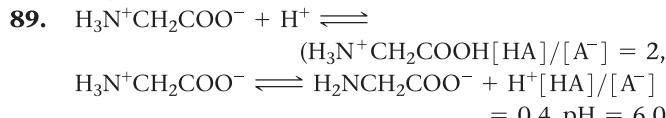
b.



83. As the temperature increases, the favorable entropy for uncoiling a chain becomes dominant. On cooling, the favorable enthalpy of forming hydrogen bonds between paired bases is dominant.

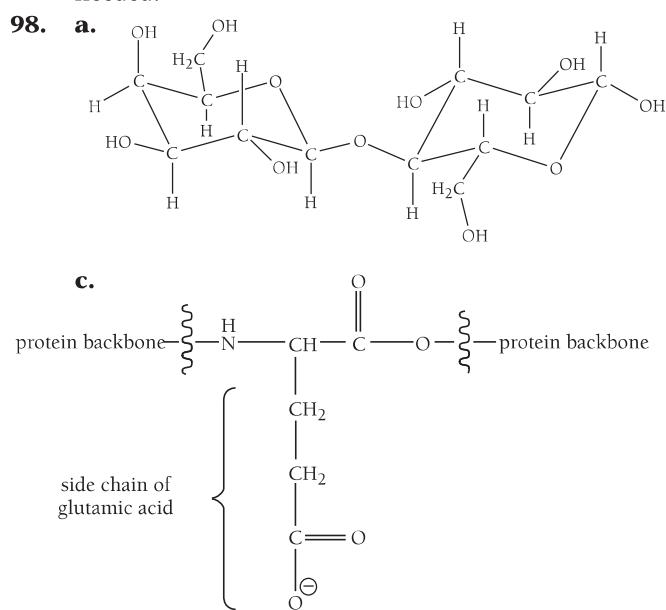
85. When the fake thymine nucleotide is added to the replicating DNA, the chain cannot continue to form because the $-N = N^+ = NH$ group on the sugar prevents future phosphate linkages.

87. $V_{\max} = 47.6$, $K_t = 1.68$



91. A three-base codon codes for a single amino acid. If there are only three bases, there could be 27 different three-base codon arrangements. Therefore, you could theoretically code for the 20 different amino acids needed.

98.



Chapter 24

15. a. +4 b. +4 c. +4



19. 4

21. tetrahedrons stand alone, orthosilicates

23. amphibole or double-chain structure;
 Ca^{2+} , Mg^{2+} , Fe^{2+} , Al^{3+}

25. 950 g

27. NCl_3 has a lone pair that BCl_3 lacks, giving it a trigonal pyramidal shape, as opposed to BCl_3 's trigonal planar shape.

29. a. 6 vertices, 8 faces

b. 12 vertices, 20 faces

31. *creso*-Boranes have the formula $B_nH_n^{2-}$ and form fully closed polyhedra, *nido*-boranes have the formula B_nH_{n+4} and consist of a cage missing a corner, and *arachno*-boranes have the formula B_nH_{n+6} and consist of a cage missing two or three corners.

33. Activated charcoal consists of fine particles, rather than a lump of charcoal, and subsequently has a much higher surface area.

35. Ionic carbides are composed of carbon, generally in the form of the carbide ion, C_2^{2-} , and low-electronegativity metals, such as the alkali and alkaline earth metals. Covalent carbides are composed of carbon and low-electronegativity nonmetals or metalloids, such as silicon.

37. a. solid \longrightarrow gas

b. gas \longrightarrow liquid \longrightarrow solid

c. solid \longrightarrow gas

39. a. $CO(g) + CuO(s) \longrightarrow CO_2(g) + Cu(s)$

b. $SiO_2(s) + 3 C(s) \longrightarrow SiC(s) + 2 CO(g)$

c. $S(s) + CO(g) \longrightarrow COS(g)$

41. a. +2 b. +4 c. +4/3

43. Fixing nitrogen refers to converting N_2 to a nitrogen-containing compound.

45. White phosphorus consists of P_4 molecules in a tetrahedral shape with the atoms at the corners of the tetrahedron. This allotrope is unstable because of the strain from the bond angles. Red phosphorus is much more stable because one bond of the tetrahedron is broken, allowing the phosphorus atoms to make chains with bond angles that are less strained.

47. saltpeter: 13.86% N by mass Chile saltpeter: 16.48% N by mass

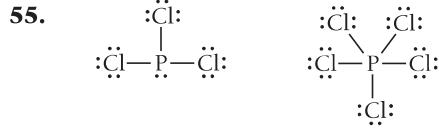
49. HN_3 has a positive ΔG_f° , meaning that it spontaneously decomposes into H_2 and N_2 at room temperature. There are no temperatures at which HN_3 will be stable. ΔH_f is positive and ΔS_f is negative, so ΔG_f will always be negative.

51. a. $NH_4NO_3(aq) + \text{heat} \longrightarrow N_2O(g) + 2 H_2O(l)$

b. $3 NO_2(g) + H_2O(l) \longrightarrow 2 HNO_3(l) + NO(g)$

c. $2 PCl_3(l) + O_2(g) \longrightarrow 2 POCl_3(l)$

53. NO_3^- , NO_2^- , N_3^- , $N_2H_5^+$, NH_4^+



Trigonal pyramidal Trigonal bipyramidal

57. $CO(NH_2)_2 + 2 H_2O \longrightarrow (NH_4)_2CO_3$
 14g

59. P_4O_6 forms if there is only a limited amount of oxygen available, while P_4O_{10} will form with greater amounts of oxygen.

61. The major source of oxygen is the fractionation of air by which air is cooled and liquefied and oxygen is separated from the other components.

63. a. superoxide b. oxide

c. peroxide

65. Initially, liquid sulfur becomes less viscous when heated because the S_8 rings have greater thermal energy, which overcomes intermolecular forces. Above 150 °C the rings break and the broken rings entangle one another, causing greater viscosity.

- 67.** **a.** 4×10^{-22} g
b. 4.0×10^{-19} g
- 69.** $2 \text{FeS}_2(s) \xrightarrow{\text{heat}} 2 \text{FeS}(s) + \text{S}_2(g)$
510 L
- 71.** **a.** +2, linear
b. +6, octahedral
c. +6, square pyramidal
- 73.** $\text{Cl}_2(g) + 2 \text{Br}^-(aq) \longrightarrow 2 \text{Cl}^-(aq) + \text{Br}_2(l)$
Oxidizing agent: Cl_2
Reducing agent: Br^-
- 75.** No, there is not enough HF to dissolve all of the SiO_2 . HF is the limiting reagent. 1.6 g SiO_2 .
- 77.** 8 kg from lignite, 40 kg from bituminous
- 79.** Chlorine is much more electronegative than iodine, allowing it to withdraw an electron and ionize in solution much more easily.
- 81.** **a.** $\text{rate}_{\text{HCl}}/\text{rate}_{\text{Cl}_2} = 1.395$
b. $\text{rate}_{\text{HCl}}/\text{rate}_{\text{HF}} = 0.7407$
c. $\text{rate}_{\text{HCl}}/\text{rate}_{\text{HI}} = 1.873$
- 83.** $4 \text{Na}_2\text{O}_2 + 3 \text{Fe} \longrightarrow 4 \text{Na}_2\text{O} + \text{Fe}_3\text{O}_4$
- 85.** The bond length of the O_2 species increases as electrons are added because they are added to the π^* antibonding orbital. O_2^{2-} is diamagnetic.
- 87.** 2.0 mol of C—C bonds, 715 kJ/mol, 6.9×10^2 kJ/mol. This value calculated from the bond energy is too low because it doesn't include van der Waals attractions between C atoms not directly bonded to each other.
- 89.** −50 kJ/mol
- 91.** **a.** −13.6 kJ/mol **b.** −11.0 kJ/mol
c. −24.8 kJ/mol
- Fe_2O_3 is the most exothermic because it has the highest oxidation state and is therefore able to oxidize the most CO per mol Fe.
- 93.** **a.** $\ddot{\text{O}}=\text{C}=\text{C}=\text{C}=\ddot{\text{O}}$
b. *sp*
c. −92 kJ/mol
- 95.** **a.** 7.6×10^{-22} **b.** 1.2×10^{-8}
c. $[\text{N}_2\text{H}_4] = 0.009 \text{ M}$, $[\text{N}_2\text{H}_5^+] = 0.0025 \text{ M}$,
 $[\text{N}_2\text{H}_6^{2+}] = 7.0 \times 10^{-13} \text{ M}$
- 97.** The acid is
a. $\text{HO}-\overset{\cdot\cdot}{\text{N}}=\text{N}-\text{OH}$
and the base is
b. $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{N}-\overset{\text{+}}{\underset{\text{-}}{\text{N}}}-\text{O}^- \end{array}$
- The acid is weaker than nitrous acid because of electron donation by resonance in contributing structures such as
- c.** $\begin{array}{c} \text{HO}-\overset{\text{-}}{\underset{\text{-}}{\text{N}}}=\text{N}=\overset{\text{+}}{\underset{\text{-}}{\text{O}}} \end{array}$
- The base is weaker than ammonia because of electron withdrawal by the electronegative nitro group.
- 99.** The triple bond in nitrogen is much stronger than the double bond in oxygen, so it is much harder to break. This makes it less likely that the bond in nitrogen will be broken.
- 101.** Sodium dinitrogen phosphate (NaH_2PO_4) can act as a weak base or a weak acid. A buffer can be made by mixing it with either Na_2HPO_4 or with Na_3PO_4 , depending on the desired pH of the buffer solution.
- 103.** F is extremely small, and so there is a huge driving force to fill the octet by adding an electron, giving a −1 oxidation state. Other halogens have access to *d* orbitals, which allows for more hybridization and oxidation state options.
- 105.** SO_3 cannot be a reducing agent because the oxidation state of S is +6, the highest possible oxidation state for S. Reducing agents need to be able to be oxidized. SO_2 can be a reducing agent or an oxidizing agent because the oxidation state of S is +4.
- 112.** **a.** The solubility of H_2S in water decreases as temperature increases.
c. No
e. Copper(II)
f. 4.8 g CuS

Chapter 25

- 15.** Metals are typically opaque, are good conductors of heat and electricity, and are ductile and malleable, meaning they can be drawn into wires and flattened into sheets.
- 17.** aluminum, iron, calcium, magnesium, sodium, potassium
- 19.** Fe: hematite (Fe_2O_3), magnetite (Fe_3O_4)
Hg: cinnabar (HgS)
V: vanadite [$\text{Pb}_5(\text{VO}_4)_3\text{Cl}$], carnotite [$\text{K}_2(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 3 \text{H}_2\text{O}$]
Nb: columbite [$\text{Fe}(\text{NbO}_3)_2$]
- 21.** $\text{MgCO}_3(s) + \text{heat} \longrightarrow \text{MgO}(s) + \text{CO}_2(g)$
 $\text{Mg}(\text{OH})_2(s) + \text{heat} \longrightarrow \text{MgO}(s) + \text{H}_2\text{O}(g)$
- 23.** The flux is a material that will react with the gangue to form a substance with a low melting point. MgO is the flux.
- 25.** Hydrometallurgy is used to separate metals from ores by selectively dissolving the metal in a solution, filtering out impurities, and then reducing the metal to its elemental form.
- 27.** The Bayer process is a hydrometallurgical process by which Al_2O_3 is selectively dissolved, leaving other oxides as solids. The soluble form of aluminum is $\text{Al}(\text{OH})_4^-$.
- 29.** Sponge-powdered iron contains many small holes in the iron particles due to the escaping of the oxygen when the iron is reduced. Water-atomized powdered iron has much smoother and denser particles as the powder is formed from molten iron.
- 31.** **a.** 50% Cr, 50% V by moles; 50.5% Cr, 49.5% V by mass
b. 25% Fe, 75% V by moles; 26.8% Fe, 73.2% V by mass
c. 25% Cr, 25% Fe, 50% V by moles; 24.8% Cr, 26.6% Fe, 48.6% V by mass
- 33.** Cr and Fe are very close to each other in mass, so their respective atomic radii are probably close enough to form an alloy. Also, they both form body-centered cubic structures.

- 35.** A: solid, 20% Cr, 80% Fe
B: liquid, 50% Cr, 50% Fe
- 37.** A: solid (20% Co and 80% Cu overall. Two phases; one is the Cu structure with 4% Co, and the other is the Co structure with 7% Cu. There will be more of the Cu structure).
B: solid (Co structure), 90% Co, 10% Cu
- 39.** C would fill interstitial holes; Mn and Si would substitute for Fe.
- 41.** **a.** Mo₂N **b.** CrH₂
- 43.** **a.** zinc **b.** copper
c. manganese
d. -19.4 kJ/mol
- 47.** When Cr is added to steel, it reacts with oxygen in steel to prevent it from rusting. A Cr steel alloy would be used in any situation where the steel might be easily oxidized, such as when it comes in contact with water.
- 49.** rutile: 33.3% Ti by moles, 59.9% Ti by mass ilmenite: 20.0% Ti by moles, 31.6% Ti by mass
- 51.** Titanium must be arc-melted in an inert atmosphere because the high temperature and flow of electrons would cause the metal to oxidize in a normal atmosphere.
- 53.** TiO₂ is the most important industrial product of titanium, and it is often used as a pigment in white paint.
- 55.** The Bayer process is a hydrometallurgical process used to separate Al₂O₃ from other oxides. The Al₂O₃ is selectively dissolved by hot, concentrated NaOH. The other oxides are removed as solids, and the Al₂O₃ precipitates out of solution when the solution is neutralized.
- 57.** cobalt and tungsten
- 59.** 3.3 kg Fe, 2.0 kg Ti
- 61.** Four atoms surround a tetrahedral hole, and six atoms surround an octahedral hole. The octahedral hole is larger because it is surrounded by a greater number of atoms.
- 63.** Mn has one more electron orbital available for bonding than does chromium.
- 65.** Ferromagnetic atoms, like paramagnetic ones, have unpaired electrons. However, in ferromagnetic atoms, these electrons align with their spin oriented in the same direction, resulting in a permanent magnetic field.
- 67.** The nuclear charge of the last three is relatively high because of the lanthanide series in which the 4f subshell falls between them and the other six metals of the group.
- 69.** **a.** 16.0 cm **b.** 4.95 cm **c.** 14%
- 71.** 92%
- 73.** 5.4 × 10⁷
- 75.** First, roast to form the oxide.

$$4 \text{CoAsS}(s) + 9 \text{O}_2(g) \longrightarrow 4 \text{CoO}(s) + 4 \text{SO}_2(g) + \text{As}_4\text{O}_6(s)$$
 Then reduce the oxide with coke.

$$\text{CoO}(s) + \text{C}(s) \longrightarrow \text{Co}(s) + \text{CO}(g)$$
- The oxides of arsenic are relatively volatile and can be separated, but they are poisonous.
- 77.** Au and Ag are found in elemental form because of their low reactivity. Na and Ca are group 1 and group 2 metals, respectively, and are highly reactive as they readily lose their valence electrons to obtain octets.
- 84.** **a.** Because they are stronger and harder.
b. Tin, 232 °C; Lead 328 °C
c. Because the melting range is neither too sharp nor too broad. It has a pasty range that helps it to set, but it then hardens quickly.

Chapter 26

- 17.** **a.** [Ar] 4s²3d⁸, [Ar] 3d⁸
b. [Ar] 4s²3d⁵, [Ar] 3d³
c. [Kr] 5s²4d¹, [Kr] 5s¹4d¹
d. [Xe] 6s²4f¹⁴5d³, [Xe] 4f¹⁴5d³
- 19.** **a.** +5 **b.** +7 **c.** +4
- 21.** **a.** +3, 6 **b.** +2, 6
c. +2, 4 **d.** +1, 2
- 23.** **a.** hexaaquaquachromium(III)
b. tetracyanocuprate(II)
c. pentaaminebromoiron(III) sulfate
d. aminetetraaquahydroxycobalt(III) chloride
- 25.** **a.** [Cr(NH₃)₆]³⁺
b. K₃[Fe(CN)₆]
c. [Cu(en)(SCN)₂]
d. [Pt(H₂O)₄][PtCl₆]
- 27.** **a.** [Co(NH₃)₃(CN)₃], triaminetricyanocobalt(III)
b. [Cr(en)₃]³⁺, tris(ethylenediamine)chromium(III)
- 29.**
- 31.** [Fe(H₂O)₅Cl]Cl · H₂O pentaaquaquachloroiron(II) chloride monohydrate

$$[\text{Fe}(\text{H}_2\text{O})_4\text{Cl}_2] \cdot 2 \text{H}_2\text{O}$$
, tetraaquadichloroiron(II) dihydrate
- 33.** **b, c, e**
- 35.** **a.** 3
b. No geometric isomers.
- 37.** **a.**
- b.**
- 39.** *cis* isomer is optically active.

41. a.
- b.
- c.
- d.

43. 163 kJ/mol
 45. $[\text{Co}(\text{CN})_6]^{3-}$ \rightarrow 290 nm, colorless
 $[\text{Co}(\text{NH}_3)_6]^{3+}$ \rightarrow 440 nm, yellow
 $[\text{CoF}_6]^{3-}$ \rightarrow 770 nm, green

47. weak
 49. a. 4 b. 3 c. 1
 51. 3

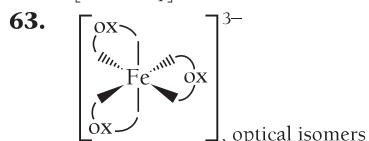
53. porphyrin

55. Water is a weak-field ligand that forms a high-spin complex with hemoglobin. Because deoxyhemoglobin is a weak field, it absorbs large-wavelength light and appears blue. Oxyhemoglobin is a low-spin complex and absorbs small-wavelength light, so O_2 must be a strong-field ligand.

57. a. $[\text{Ar}]4s^13d^5$, $[\text{Ar}]3d^5$, $[\text{Ar}]3d^4$, $[\text{Ar}]3d^3$
 b. $[\text{Ar}]4s^13d^{10}$, $[\text{Ar}]3d^{10}$, $[\text{Ar}]3d^9$

59. a.
 b.
 c.

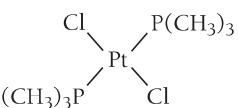
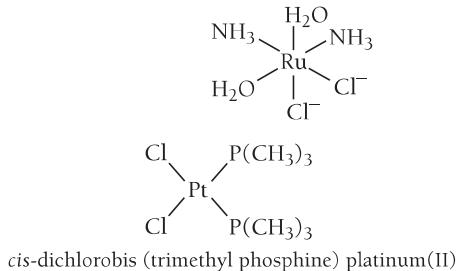
61. $[\text{MA}_2\text{B}_2\text{C}_2]$ all cis; A trans and B and C cis; B trans and A and C cis; C trans and A and B cis; all trans.
 $[\text{MA}_2\text{B}_3\text{C}]$ will have fac-mer isomers.
 $[\text{MAB}_2\text{C}_3]$ will have fac-mer isomers.
 $[\text{MAB}_3\text{C}_2]$ will have fac-mer isomers.
 $[\text{MA}_3\text{B}_2\text{C}]$ will have fac-mer isomers.
 $[\text{MA}_2\text{BC}_3]$ will have fac-mer isomers.
 $[\text{MA}_3\text{BC}_2]$ will have fac-mer isomers.
 $[\text{MABC}_2]$ will have AB cis-trans isomers.
 $[\text{MAB}_4\text{C}]$ will have AC cis-trans isomers.
 $[\text{MA}_4\text{BC}]$ will have BC cis-trans isomers.
 $[\text{MABC}_4]$ will have AB cis-trans isomers.



- 65.

67. 1.
 2.
 3.
 4.
 5.

Only structure 3. is chiral. This is its mirror image.



71. d_{z^2}
 $d_{x^2-y^2}$ and d_{xy}
 d_{xz} and d_{yz}
73. a. $2 \times 10^{-8} \text{ M}$
 b. $6.6 \times 10^{-3} \text{ M}$
 c. NiS will dissolve more easily in the ammonia solution because the formation of the complex ion is favorable, removing Ni^{2+} ions from the solution and allowing more NiS to dissolve.
75. Prepare a solution that contains both $[\text{MCl}_6]^{3-}$ and $[\text{MBr}_6]^{3-}$ and see if any complex ions that contain both Cl and Br form. If they do, it would demonstrate that these complexes are labile.
77. pH = 10.1
 79. Au
 86. a. red
 c. smaller (because it absorbs at longer wavelengths)
 e. The crystal fields splitting energies of the two complexes must be similar (because they have the same color).

Answers to In-Chapter Practice Problems

Chapter 1

- 1.1.** **a.** The composition of the copper is not changing; thus, being hammered flat is a physical change that signifies a physical property.
b. The dissolution and color change of the nickel indicate that it is undergoing a chemical change and exhibiting a chemical property.
c. Sublimation is a physical change indicative of a physical property.
d. When a match ignites, a chemical change begins as the match reacts with oxygen to form carbon dioxide and water. Flammability is a chemical property.
- 1.2.** **a.** $29.8\text{ }^{\circ}\text{C}$
b. 302.9 K
- 1.3.** 21.4 g/cm^3 . This matches the density of platinum.
- 1.3.** *For More Practice* 4.50 g/cm^3 The metal is titanium.
- 1.4.** The thermometer shown has markings every $1\text{ }^{\circ}\text{F}$; thus, the first digit of uncertainty is 0.1. The answer is $103.1\text{ }^{\circ}\text{F}$.
- 1.5.** **a.** Each figure in this number is significant by rule 1: three significant figures.
b. This is a defined quantity that has an unlimited number of significant figures.
c. Both 1's are significant (rule 1), and the interior zero is significant as well (rule 2): three significant figures.
d. Only the two 9's are significant, the leading zeroes are not (rule 3): two significant figures.
e. There are five significant figures because the 1, 4, and 5 are nonzero (rule 1) and the trailing zeroes are after a decimal point so they are significant as well (rule 4).
f. The number of significant figures is ambiguous because the trailing zeroes occur before an implied decimal point (rule 4).
- 1.6.** **a.** 0.381
b. 121.0
c. 1.174
d. 8
- 1.7.** 3.15 yd
- 1.8.** 2.446 gal
- 1.9.** $1.61 \times 10^6\text{ cm}^3$
- 1.9.** *For More Practice* $3.23 \times 10^3\text{ kg}$
- 1.10.** 1.03 kg
- 1.10.** *For More Practice* $2.9 \times 10^{-2}\text{ cm}^3$
- 1.11.** 0.855 cm
- 1.12.** 2.70 g/cm^3
- 1.13.** 0.33 ppm/yr; The rate is lower because less fossil fuel was being burned in that era.

Chapter 2

- 2.1.** For the first sample:

$$\frac{\text{mass of oxygen}}{\text{mass of carbon}} = \frac{17.2\text{ g O}}{12.9\text{ g C}} = 1.33 \text{ or } 1.33 : 1$$

For the second sample:

$$\frac{\text{mass of oxygen}}{\text{mass of carbon}} = \frac{10.5\text{ g O}}{7.88\text{ g C}} = 1.33 \text{ or } 1.33 : 1$$

The ratios of oxygen to carbon are the same in the two samples of carbon monoxide, so these results are consistent with the law of definite proportions.

- 2.2.** Mass of hydrogen to 1 g of oxygen in water/mass of hydrogen to 1 g of oxygen in hydrogen peroxide = $0.125/0.0625 = 2.00$.

The ratio of the mass of hydrogen from one compound to the mass of hydrogen in the other is equal to 2. This is a simple whole number and therefore consistent with the law of multiple proportions.

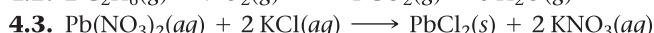
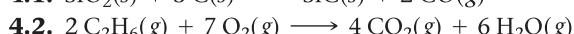
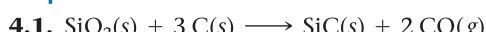
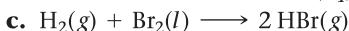
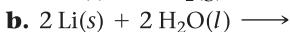
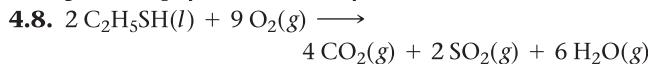
- 2.3.** **a.** $Z = 6, A = 13, {}^{13}_6\text{C}$
b. 19 protons, 20 neutrons
- 2.4.** **a.** N^{3-}
b. Rb^+
- 2.5.** 24.31 amu
- 2.5.** *For More Practice* 70.92 amu
- 2.6.** $4.65 \times 10^{-2}\text{ mol Ag}$
- 2.7.** 0.563 mol Cu
- 2.7.** *For More Practice* 22.6 g Ti
- 2.8.** $1.3 \times 10^{22}\text{ C atoms}$
- 2.8.** *For More Practice* 6.87 g W
- 2.9.** $l = 1.72\text{ cm}$
- 2.9.** *For More Practice* $2.90 \times 10^{24}\text{ Cu atoms}$

Chapter 3

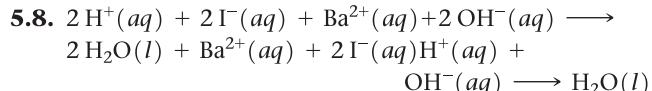
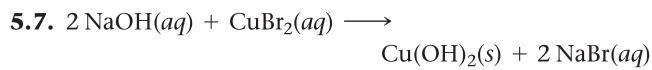
- 3.1.** **a.** C_5H_{12}
b. HgCl
c. CH_2O
- 3.2.** **a.** molecular element
b. molecular compound
c. atomic element
d. ionic compound
e. ionic compound
- 3.3.** K_2S
- 3.4.** AlN
- 3.5.** silver nitride
- 3.5.** *For More Practice* Rb_2S
- 3.6.** iron(II) sulfide
- 3.6.** *For More Practice* RuO_2
- 3.7.** tin(II) chlorate

3.7. For More Practice $\text{Co}_3(\text{PO}_4)_2$ **3.8.** dinitrogen pentoxide**3.8.** For More Practice PBr_3 **3.9.** hydrofluoric acid**3.10.** nitrous acid**3.10.** For More Practice HClO_4 **3.11.** sulfurous acid**3.12.** 164.10 amu**3.13.** $5.839 \times 10^{20} \text{ C}_{13}\text{H}_{18}\text{O}_2$ molecules**3.13.** For More Practice 1.06 g H_2O **3.14.** 53.29%**3.14.** For More Practice 74.19% Na**3.15.** 83.9 g Fe_2O_3 **3.15.** For More Practice 8.6 g Na**3.16.** 4.0 g O**3.16.** For More Practice 3.60 g C**3.17.** CH_2O **3.18.** $\text{C}_{13}\text{H}_{18}\text{O}_2$ **3.19.** C_6H_6 **3.19.** For More Practice $\text{C}_2\text{H}_8\text{N}_2$ **3.20.** C_2H_5 **3.21.** $\text{C}_2\text{H}_4\text{O}$

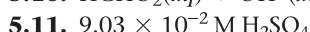
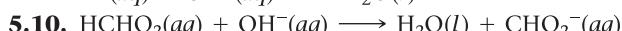
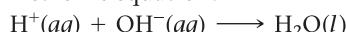
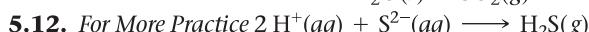
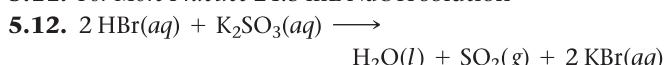
Chapter 4

**4.4.** 4.08 g HCl**4.5.** 22 kg HNO_3 **4.6.** H_2 is the limiting reagent, since it produces the least amount of NH_3 . Therefore, 29.4 kg NH_3 is the theoretical yield.**4.7.** CO is the limiting reagent, since it only produces 114 g Fe. Therefore, 114 g Fe is the theoretical yield: percentage yield = 63.4% yield.

Chapter 5

5.1. 0.214 M NaNO_3 **5.1.** For More Practice 44.6 g KBr**5.2.** 402 g $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ **5.2.** For More Practice 221 mL of KCl solution**5.3.** 667 mL**5.3.** For More Practice 0.105 L**5.4.** 51.4 mL HNO_3 solution**5.4.** For More Practice 0.170 g CO_2 **5.5. a.** insoluble**b.** insoluble**c.** soluble**d.** soluble**5.6.** $\text{NH}_4\text{Cl}(aq) + \text{Fe}(\text{NO}_3)_3(aq) \longrightarrow$ NO REACTION**5.9.** Molecular equation:

Net ionic equation:

**5.11.** For More Practice 24.5 mL NaOH solution**5.13. a.** Cr = 0**b.** $\text{Cr}^{3+} = +3$ **c.** $\text{Cl}^- = -1, \text{C} = +4$ **d.** $\text{Br} = -1, \text{Sr} = +2$ **e.** $\text{O} = -2, \text{S} = +6$ **f.** $\text{O} = -2, \text{N} = +5$ **5.14.** Sn is oxidized and N is reduced.**5.14.** For More Practice **b.** Reaction b is the only redox reaction. Al is oxidized and O is reduced.**5.15. a.** This is a redox reaction in which Li is the reducing agent (it is oxidized) and Cl_2 is the oxidizing reagent (it is reduced).**b.** This is a redox reaction in which Al is the reducing agent and Sn^{2+} is the oxidizing agent.**c.** This is not a redox reaction because no oxidation states change.**d.** This is a redox reaction in which C is the reducing agent and O_2 is the oxidizing agent.**5.16. a.** Yes**b.** No

Chapter 6

6.1. 15.0 psi**6.1.** For More Practice 80.6 kPa**6.2.** 2.1 atm at a depth of approximately 11 m**6.3.** 123 mL**6.4.** 11.3 L**6.5.** 1.63 atm, 23.9 psi**6.6.** 16.1 L**6.6.** For More Practice 976 mmHg**6.7.** $d = 4.91 \text{ g/L}$ **6.7.** For More Practice 44.0 g/mol**6.8.** 70.7 g/mol**6.9.** 0.0610 mol H_2 **6.10.** 4.2 atm**6.11.** 12.0 mg H_2 **6.12.** 82.3 g Ag_2O **6.12.** For More Practice 7.10 g Ag_2O **6.13.** 6.53 L O_2 **6.14.** $u_{\text{rms}} = 238 \text{ m/s}$ **6.15.** $\frac{\text{rate}_{\text{H}_2}}{\text{rate}_{\text{Kr}}} = 6.447$

Chapter 7

7.1. $\Delta E = 71\text{ J}$

7.2. $C_s = 0.38 \frac{\text{J}}{\text{g} \cdot ^\circ\text{C}}$

The specific heat capacity of gold is $0.128\text{ J/g} \cdot ^\circ\text{C}$; therefore, the rock cannot be pure gold.

7.2. For More Practice $T_f = 42.1\text{ }^\circ\text{C}$

7.3. 37.8 grams Cu

7.4. -122 J

7.4. For More Practice $\Delta E = -998\text{ J}$

7.5. $\Delta E_{\text{reaction}} = -3.91 \times 10^3\text{ kJ/mol C}_6\text{H}_{14}$

7.5. For More Practice $C_{\text{cal}} = 4.55 \frac{\text{kJ}}{\text{^\circ C}}$

7.6. a. endothermic, positive ΔH

b. endothermic, positive ΔH

c. exothermic, negative ΔH

7.7. $-2.06 \times 10^3\text{ kJ}$

7.7. For More Practice 33 g C_4H_{10}

99 g CO_2

7.8. $\Delta H_{\text{rxn}} = -68\text{ kJ}$

7.9. $\text{N}_2\text{O}(g) + \text{NO}_2(g) \longrightarrow 3 \text{NO}(g)$, $\Delta H_{\text{rxn}} = +157.6\text{ kJ}$

7.9. For More Practice

3 $\text{H}_2(g) + \text{O}_3(g) \longrightarrow 3 \text{H}_2\text{O}(g)$, $\Delta H_{\text{rxn}} = -868.1\text{ kJ}$

7.10. d. $\text{Na}(s) + \frac{1}{2} \text{Cl}_2(g) \longrightarrow$

$\text{NaCl}(s)$, $\Delta H_f^\circ = -411.2\text{ kJ/mol}$

e. $\text{Pb}(s) + \text{N}_2(g) + 3 \text{O}_2(g) \longrightarrow$

$\text{Pb}(\text{NO}_3)_2(s)$, $\Delta H_f^\circ = -451.9\text{ kJ/mol}$

7.11. $\Delta H_{\text{rxn}}^\circ = -851.5\text{ kJ}$

7.12. $\Delta H_{\text{rxn}}^\circ = -1648.4\text{ kJ}$

111 kJ emitted (-111 kJ)

7.13. $1.2 \times 10^2\text{ kg CO}_2$

Chapter 8

8.1. $5.83 \times 10^{14}\text{ s}^{-1}$

8.2. 2.64×10^{20} photons

8.2. For More Practice 435 nm

8.3. a. blue < green < red

b. red < green < blue

c. red < green < blue

8.4. $6.1 \times 10^6\text{ m/s}$

8.5. For the 5d orbitals:

$n = 5$

$l = 2$

$m_l = -2, -1, 0, 1, 2$

The five integer values for m_l signify that there are five 5d orbitals.

8.6. a. l cannot equal 3 if $n = 3$. $l = 2$

b. m_l cannot equal -2 if $l = -1$. Possible values for $m_l = -1, 0,$ or 1

c. l cannot be 1 if $n = 1$. $l = 0$

8.7. 397 nm

8.7. For More Practice $n = 1$

Chapter 9

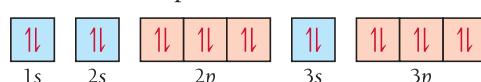
9.1. a. $\text{Cl} 1s^2 2s^2 2p^6 3s^2 3p^5$ or $[\text{Ne}]3s^2 3p^5$

b. $\text{Si} 1s^2 2s^2 2p^6 3s^2 3p^2$ or $[\text{Ne}]3s^2 3p^2$

c. $\text{Sr} 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$ or $[\text{Kr}]5s^2$

d. $\text{O} 1s^2 2s^2 2p^4$ or $[\text{He}]2s^2 2p^4$

9.2. There are no unpaired electrons.



9.3. $1s^2 2s^2 2p^6 3s^2 3p^3$ or $[\text{Ne}]3s^2 3p^3$. The 5 electrons in the $3s^2 3p^3$ orbitals are the valence electrons, while the 10 electrons in the $1s^2 2s^2 2p^6$ orbitals belong to the core.

9.4. $[\text{Xe}]6s^2 4f^{14} 5d^{10} 6p^3$

9.4. For More Practice $[\text{Kr}]5s^2 4d^{10} 5p^5$

9.5. a. Sn

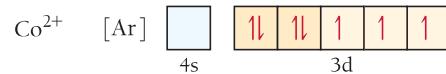
b. cannot predict

c. W

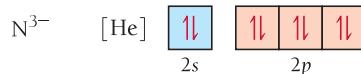
d. Se

9.5. For More Practice Rb > Ca > Si > S > F

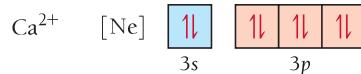
9.6. a. $[\text{Ar}]4s^0 3d^7$. Co^{2+} is paramagnetic.



b. $[\text{He}]2s^2 2p^6$. N^{3-} is diamagnetic.



c. $[\text{Ne}]3s^2 3p^6$. Ca^{2+} is diamagnetic.



9.7. a. K

b. F^-

c. Cl^-

9.8. a. I

b. Ca

c. cannot predict

d. F

9.8. For More Practice F > S > Si > Ca > Rb

9.9. a. Sn

b. cannot predict based on simple trends (Po is larger)

c. Bi

d. B

9.9. For More Practice Cl < Si < Na < Rb

Chapter 10

10.1. Mg_3N_2

10.2. $\text{KI} < \text{LiBr} < \text{CaO}$

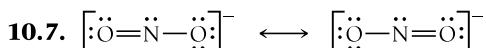
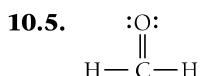
10.2. For More Practice MgCl_2

10.3. a. pure covalent

b. ionic

c. polar covalent

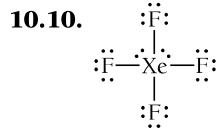
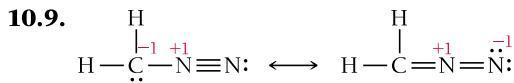
10.4. $:\text{C}\equiv\text{O}:^+$



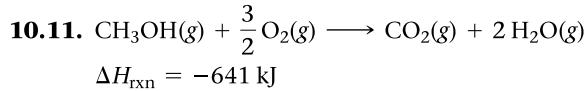
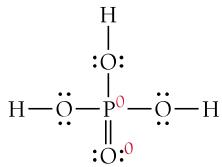
10.8.

Structure	A	B	C
	$:\ddot{\text{N}}=\text{N}=\ddot{\text{O}}:$	$:\ddot{\text{N}}\equiv\text{N}-\ddot{\text{O}}:$	$:\ddot{\text{N}}-\text{N}\equiv\ddot{\text{O}}:$
number of valence e ⁻	5 5 6	5 5 6	5 5 6
number of nonbonding e ⁻	-4 -0 -4 -2 -0 -6 -6 -0 -2		
$\frac{1}{2}$ (number of bonding e ⁻)	-2 -4 -2 -3 -4 -1 -1 -4 -3		
Formal charge	-1 -1 0 0 +1 -1 -2 +1 +1		
Structure B contributes the most to the correct overall structure of N ₂ O			

10.8. For More Practice The nitrogen is +1, the singly bonded oxygen atoms are -1, and the double-bonded oxygen atom has no formal charge.



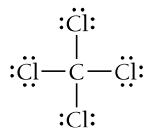
10.10. For More Practice



10.11. For More Practice $\Delta H_{\text{rxn}} = -8.0 \times 10^1 \text{ kJ}$

Chapter 11

11.1. tetrahedral



11.2. bent

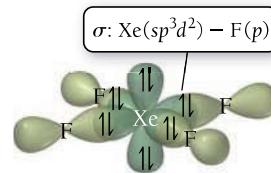
11.3. linear

11.4.

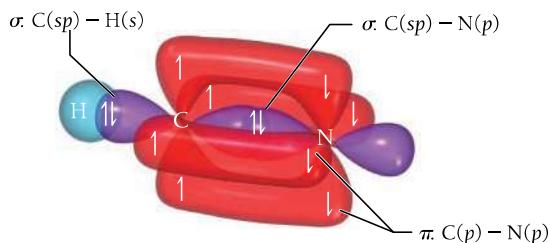
Atom	Number of Electron Groups	Number of Lone Pairs	Molecular Geometry
Carbon (left)	4	0	Tetrahedral
Carbon (right)	3	0	Trigonal planar
Oxygen	4	2	Bent

11.5. The molecule is nonpolar.

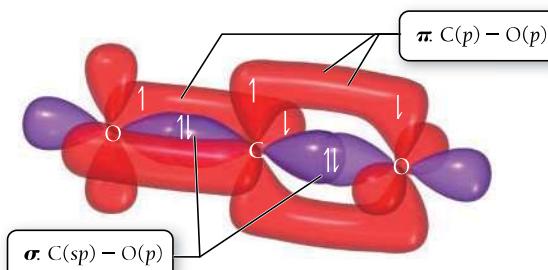
11.6. The xenon atom has six electron groups and therefore has an octahedral electron geometry. An octahedral electron geometry corresponds to sp^3d^2 hybridization (refer to Table 11.3).



11.7. Since there are only two electron groups around the central atom (C), the electron geometry is linear. According to Table 11.3, the corresponding hybridization on the carbon atom is sp .



11.8. Since there are only two electron groups about the central atom (C), the electron geometry is linear. The hybridization on C is sp (refer to Table 11.3).

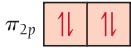
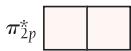


11.8. For More Practice There are five electron groups about the central atom (I); therefore, the electron geometry is trigonal bipyramidal and the corresponding hybridization of I is sp^3d (refer to Table 11.3).

11.9. H_2^+ bond order = $+\frac{1}{2}$

Since the bond order is positive, the H_2^+ ion should be stable; however, the bond order of H_2^+ is lower than the bond order of H_2 (bond order = 1). Therefore, the bond in H_2^+ is weaker than in H_2 .

- 11.10.** The bond order of N_2^+ is 2.5, which is lower than that of the N_2 molecule (bond order = 3); therefore, the bond is weaker. The MO diagram shows that the N_2^+ ion has one unpaired electron and is therefore paramagnetic.



- 11.10. For More Practice** The bond order of Ne_2 is 0, which indicates that dineon does not exist.

- 11.11.** The bond order of NO is +2.5. The MO diagram shows that the ion has one unpaired electron and is therefore paramagnetic.

Chapter 12

- 12.1. b, c**

- 12.2.** HF has a higher boiling point than HCl because, unlike HCl, HF is able to form hydrogen bonds. The hydrogen bond is the strongest of the intermolecular forces and requires more energy to break.

12.3. $5.83 \times 10^3 \text{ kJ}$

- 12.3. For More Practice** 49 °C

12.4. 33.8 KJ/mol

12.5. $7.04 \times 10^3 \text{ torr}$

Chapter 13

13.1. 29.4°

13.2. 78.5%

13.3. $3.24 \times 10^{-23} \text{ cm}^3$

13.4. $7.18 \frac{\text{g}}{\text{cm}^3}$

- 13.5.** Metallic

Chapter 14

- 14.1. a.** not soluble

- b.** soluble

- c.** not soluble

- d.** not soluble

14.2. $2.7 \times 10^{-4} \text{ M}$

14.3. 42.5 g $\text{C}_{12}\text{H}_{22}\text{O}_{11}$

14.3. For More Practice $3.3 \times 10^4 \text{ L}$

14.4. a. $M = 0.415 \text{ M}$

b. $m = 0.443 \text{ g}$

c. % by mass = 13.2%

d. $\chi_{\text{C}_{12}\text{H}_{22}\text{O}_{11}} = 0.00793$

e. mole percent = 0.793%

14.5. 0.600 M

14.5. For More Practice 0.651 m

14.6. 22.5 torr

14.6. For More Practice 0.144

14.7. a. $P_{\text{benzene}} = 26.6 \text{ torr}$

$P_{\text{toluene}} = 20.4 \text{ torr}$

b. 47.0 torr

c. 52.5% benzene; 47.5% toluene The vapor will be richer in the more volatile component, which in this case is benzene.

14.8. $T_f = -4.8 \text{ }^\circ\text{C}$

14.9. 101.84 °C

14.10. 11.8 atm

14.11. −0.60 °C

14.12. 0.014 mol NaCl

Chapter 15

15.1. $\frac{\Delta[\text{H}_2\text{O}_2]}{\Delta t} = -4.40 \times 10^{-3} \text{ M/s}$

$$\frac{\Delta[\text{I}_3^-]}{\Delta t} = 4.40 \times 10^{-3} \text{ M/s}$$

- 15.2. a.** Rate = $k[\text{CHCl}_3][\text{Cl}_2]^{1/2}$. (Fractional-order reactions are not common but are occasionally observed.)

b. $3.5 \text{ M}^{-1/2} \cdot \text{s}^{-1}$

15.3. $5.78 \times 10^{-2} \text{ M}$

15.4. 0.0277 M

15.5. $1.64 \times 10^{-3} \text{ M}$

15.6. 79.2 s

15.7. $2.07 \times 10^{-5} \frac{\text{L}}{\text{mol} \cdot \text{s}}$

15.8. $6.13 \times 10^{-4} \frac{\text{L}}{\text{mol} \cdot \text{s}}$

15.9. $2\text{A} + \text{B} \longrightarrow \text{A}_2\text{B}$

Rate = $k[\text{A}]^2$

Chapter 16

16.1. $K = \frac{[\text{CO}_2]^3[\text{H}_2\text{O}]^4}{[\text{C}_3\text{H}_8][\text{O}_2]^5}$

16.2. 2.1×10^{-13}

16.2. For More Practice 1.4×10^2

16.3. 6.2×10^2

16.4. $K_c = \frac{[\text{Cl}_2]^2}{[\text{HCl}]^4[\text{O}_2]}$

16.5. 9.4

16.6. 1.1×10^{-6}

16.7. $Q_c = 0.0196$
Reaction proceeds to the left.

16.8. 0.033 M

16.9. $[N_2] = 4.5 \times 10^{-3} \text{ M}$
 $[O_2] = 4.5 \times 10^{-3} \text{ M}$
 $[NO] = 1.1 \times 10^{-3} \text{ M}$

16.10. $[N_2O_4] = 0.005 \text{ M}$
 $[NO_2] = 0.041 \text{ M}$

16.11. $P_{I_2} = 0.0027 \text{ atm}$
 $P_{Cl_2} = 0.0027 \text{ atm}$
 $P_{ICl_2} = 0.246 \text{ atm}$

16.12. $1.67 \times 10^{-7} \text{ M}$

16.13. $6.78 \times 10^{-6} \text{ M}$

16.14. Adding Br_2 increases the concentration of Br_2 , causing a shift to the left (away from the Br_2). Adding $BrNO$ increases the concentration of $BrNO$, causing a shift to the right.

16.15. Decreasing the volume causes the reaction to shift right. Increasing the volume causes the reaction to shift left.

16.16. If we increase the temperature, the reaction shifts to the left. If we decrease the temperature, the reaction shifts to the right.

Chapter 17

17.1. a. H_2O donates a proton to C_5H_5N , making it the acid. The conjugate base is therefore OH^- . Since C_5H_5N accepts the proton, it is the base and becomes the conjugate acid $C_5H_5NH^+$.

b. Since HNO_3 donates a proton to H_2O , it is the acid, making NO_3^- the conjugate base. Since H_2O is the proton acceptor, it is the base and becomes the conjugate acid, H_3O^+ .

17.2. a. Since $[H_3O^+] < [OH^-]$, the solution is basic.

b. $[H_3O^+] = 1.0 \times 10^{-7} \text{ M}$
Neutral solution.

c. $[H_3O^+] = 1.2 \times 10^{-5} \text{ M}$
Since $[H_3O^+] > [OH^-]$, the solution is acidic.

17.3. a. 8.02 (basic)
b. 11.85 (basic)

17.4. $4.3 \times 10^{-9} \text{ M}$

17.5. 0.013 M

17.6. 3.28

17.7. 2.72

17.8. 1.8×10^{-6}

17.9. 0.85%

17.10. $2.0 \times 10^{-7} \text{ M}$

17.11. $[OH^-] = 0.020 \text{ M}$ pH = 12.30

17.12. $[OH^-] = 1.2 \times 10^{-2} \text{ M}$ pH = 12.08

17.13. a. weak base
b. pH-neutral

17.14. 9.07

17.15. a. pH-neutral
b. weak acid
c. weak acid

17.16. a. basic

b. acidic

c. pH-neutral

d. acidic

17.17. 3.83

17.18. $[SO_4^{2-}] = 0.00386 \text{ M}$
pH = 1.945

17.19. $5.6 \times 10^{-11} \text{ M}$

Chapter 18

18.1. 4.44

18.1. *For More Practice* 3.44

18.2. 9.14

18.3. 4.87

18.3. *For More Practice* 4.65

18.4. 9.68

18.4. *For More Practice* 9.56

18.5. hypochlorous acid ($HClO$); 2.4 g NaClO

18.6. 1.74

18.7. 8.08

18.8. $2.30 \times 10^{-6} \text{ M}$

18.9. 5.3×10^{-13}

18.10. $1.21 \times 10^{-5} \text{ M}$

18.11. $FeCO_3$ will be more soluble in an acidic solution than $PbBr_2$ because the CO_3^{2-} ion is a basic anion, whereas Br^- is the conjugate base of a strong acid (HBr) and is therefore pH-neutral.

18.12. $Q > K_{sp}$; therefore, a precipitate forms.

18.13. $2.9 \times 10^{-6} \text{ M}$

18.14. a. $AgCl$ precipitates first; $[NaCl] = 7.1 \times 10^{-9} \text{ M}$

b. $[Ag^+] = 1.5 \times 10^{-8} \text{ M}$ when $PbCl_2$ begins to precipitate, and $[Pb^{2+}]$ is 0.085 M.

18.15. $9.6 \times 10^{-6} \text{ M}$

Chapter 19

19.1. a. positive

b. negative

c. positive

19.2. 15.2 J/K

19.3. a. -548 J/K

b. ΔS_{sys} is negative.

c. ΔS_{univ} is negative, and the reaction is not spontaneous.

19.3. *For More Practice* 375 K

19.4. $\Delta G = -101.6 \times 10^3 \text{ J}$

Therefore, the reaction is spontaneous. Since both ΔH and ΔS are negative, as the temperature increases ΔG will become more positive.

19.5. -153.2 J/K

19.6. $\Delta G_{rxn}^\circ = -36.3 \text{ kJ}$

Since ΔG_{rxn}° is negative, the reaction is spontaneous at this temperature.

19.7. $\Delta G_{rxn}^\circ = -42.1 \text{ kJ}$

Since the value of ΔG_{rxn}° at the lowered temperature is more negative (or less positive) (which is -36.3 kJ), the reaction is more spontaneous.

19.8. $\Delta G_{\text{rxn}}^{\circ} = -689.6 \text{ kJ}$

Since $\Delta G_{\text{rxn}}^{\circ}$ is negative, the reaction is spontaneous at this temperature.

19.8. For More Practice $\Delta G_{\text{rxn}}^{\circ} = -689.7 \text{ kJ}$ (at 25°)

The value calculated for $\Delta G_{\text{rxn}}^{\circ}$ from the tabulated values (-689.6 kJ) is the same, to within 1 in the least significant digit, as the value calculated using the equation for $\Delta G_{\text{rxn}}^{\circ}$

$$\Delta G_{\text{rxn}}^{\circ} = -649.7 \text{ kJ}$$
 (at 500.0 K)

You could not calculate $\Delta G_{\text{rxn}}^{\circ}$ at 500.0 K using tabulated ΔG_f° values because the tabulated values of free energy are calculated at a standard temperature of 298 K, much lower than 500 K.

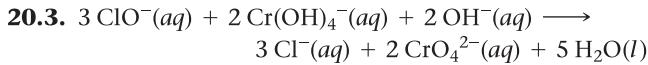
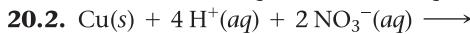
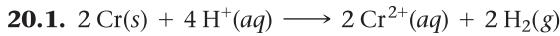
19.9. +107.1 kJ

19.10. $\Delta G_{\text{rxn}} = -129 \text{ kJ}$

The reaction is more spontaneous under these conditions than under standard conditions because ΔG_{rxn} is more negative than $\Delta G_{\text{rxn}}^{\circ}$.

19.11. -10.9 kJ

Chapter 20



20.4. +0.60 V

a. The reaction will be spontaneous as written.

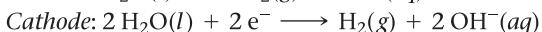
b. The reaction will not be spontaneous as written.

20.6. $\Delta G^{\circ} = -3.63 \times 10^5 \text{ J}$

Since ΔG° is negative, the reaction is spontaneous.

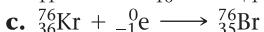
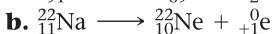
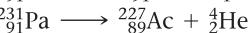
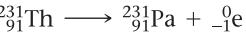
20.7. 4.5×10^3

20.8. 1.08 V

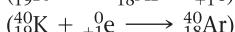
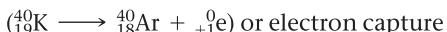


20.10. $6.0 \times 10^1 \text{ min}$

Chapter 21



21.2. For More Practice Positron emission



21.3. a. positron emission

b. beta decay

c. positron emission

21.4. 10.7 yr

21.5. $t = 964 \text{ yr}$

No, the C-14 content suggests that the scroll is from about A.D. 1000, not 500 B.C.

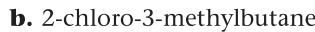
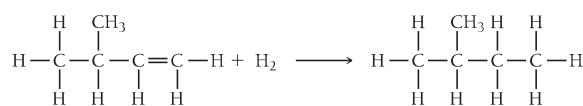
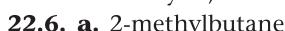
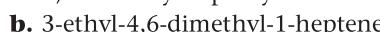
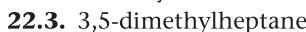
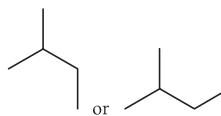
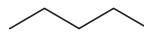
21.6. $1.0 \times 10^9 \text{ yr}$

21.7. Mass defect = 1.934 amu

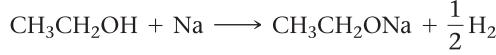
Nuclear binding energy = 7.569 MeV/nucleon

Chapter 22

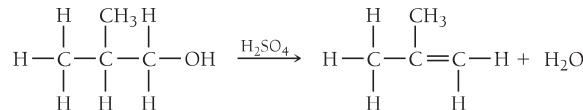
22.1.



22.7. a. Alcohol reacting with an active metal.



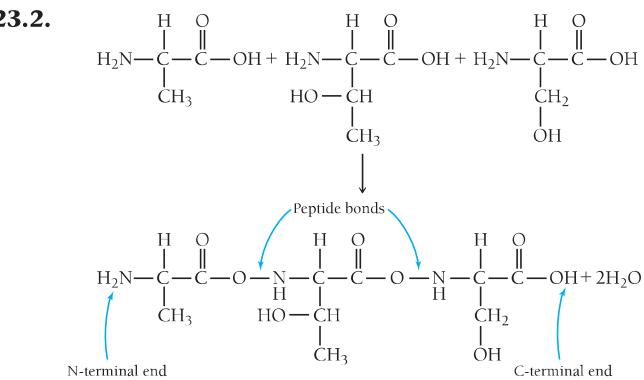
b. dehydration reaction



Chapter 23

23.1. Fructose exhibits optical isomerism. It contains three chiral carbons.

23.2.



Chapter 24

- 24.1.** KAlSi_3O_8

24.2. $x = 2$

24.3. Orthosilicate (or neosilicate): each of the two Be ions has a charge of $2+$ for a total of $4+$, and the SiO_4 unit has a charge of $4-$.

24.4. Inosilicate (or pyroxene): Ca and Mg each have a charge of $2+$ for a total of $4+$, and the Si_2O_6 unit has a charge of $4-$ (two SiO_3^{2-} units).

24.5. $2 \text{H}_2\text{S}(g) + 3 \text{O}_2(g) \longrightarrow 2 \text{H}_2\text{O}(g) + \text{SO}_2(g)$
S changes from the -2 to $+4$ oxidation state.

24.6. The oxidation state for Cl is $+7$ in ClO_4^- and -1 in Cl^- .

24.7. $\text{I}_2(s) + 5 \text{F}_2(g) \longrightarrow 2 \text{IF}_5(g)$

24.8. The electron geometry is tetrahedral, and the shape is bent for ICl_2^+ .

24.9. The electron geometry is octahedral for BrF_5 , and the molecular geometry is square pyramidal.

24.10. The oxidation number changes from -1 to 0 for the oxidation of the Cl in HCl to Cl_2 and from $+5$ to $+4$ for the reduction of the Cl in NaClO_3 to ClO_2 . The oxidizing agent is NaClO_3 , and the reducing agent is HCl .

Chapter 25

- 25.1.** At 50 mol% Ni and 1000 °C, this is a solid phase with half of the atoms each Ni and Cu.

25.2. At 50 mol% Ni and 1400 °C, this is a liquid phase with half of the atoms each Ni and Cu.

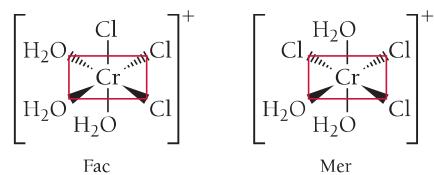
25.3. At 900 °C and 60 mol% Cr, this is a two-phase region with more Ni-rich face-centered cubic crystals than Cr-rich body-centered cubic crystals. The Ni-rich phase is about 42 mol% Cr and 58 mol% Ni. The Cr-rich phase is about 94 mol% Cr and 6 mol% Ni.

25.4. At 900 °C and 98 mol% Cr, this is a single-phase region with 100 mol% of the Cr-rich body-centered cubic crystals that contains 2% Ni.

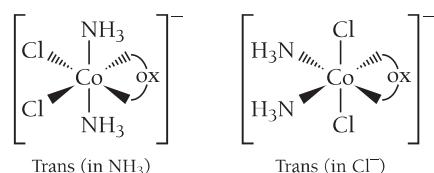
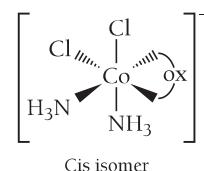
Chapter 26

- 26.1.** [Xe] $6s^24f^{14}5d^6$
26.2. [Kr] $5s^04d^3$ or [Kr] $4d^3$

- 26.3.** pentaamminecarbonylmanganese(II) sulfate
26.4. sodium tetrachloroplatinate(II)
26.5. The complex ion $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3]^+$ fits the general formula MA_3B_3 , which results in fac and mer isomers.



- 26.6.** The oxalate ligand is a small bidentate ligand, so it will have to occupy two adjacent (*cis*) positions of the octahedron. There are three ways to arrange the two NH_3 and two Cl^- ligands in the four remaining positions. One has both NH_3 and both Cl^- in *cis* positions (*cis* isomer). Another has the NH_3 ligands in a *trans* arrangement with both Cl^- in *cis* positions (*trans*-ammine isomer). The third has both NH_3 ligands *cis* and Cl^- ligands *trans* (*trans*-chloro isomer).



- 26.7.** Both the fac and mer isomers are superimposable (by rotating 180°) on their mirror images, so neither one is optically active.

26.8. 288 kJ/mol

26.9. five unpaired electrons

26.10. one unpaired electron