

2002 Edition • Reference Tables for Physical Setting/Chemistry

Table A
Standard Temperature and Pressure

Name	Value	Unit
Standard Pressure	101.3 kPa	kilopascal
	1 atm	atmosphere
Standard Temperature	273 K	kelvin
	0°C	degree Celsius

Table B
Physical Constants for Water

Heat of Fusion	333.6 J/g
Heat of Vaporization	2259 J/g
Specific Heat Capacity of H ₂ O (ℓ)	4.2 J/g•K

Table C
Selected Prefixes

Factor	Prefix	Symbol
10 ³	kilo-	k
10 ⁻¹	deci-	d
10 ⁻²	centi-	c
10 ⁻³	milli-	m
10 ⁻⁶	micro-	μ
10 ⁻⁹	nano-	n
10 ⁻¹²	pico-	p

Table D
Selected Units

Symbol	Name	Quantity
m	meter	length
kg	kilogram	mass
Pa	pascal	pressure
K	kelvin	temperature
mol	mole	amount of substance
J	joule	energy, work, quantity of heat
s	second	time
L	liter	volume
ppm	part per million	concentration
M	molarity	solution concentration

Table E
Selected Polyatomic Ions

H ₃ O ⁺	hydronium	CrO ₄ ²⁻	chromate
Hg ₂ ²⁺	dimercury (I)	Cr ₂ O ₇ ²⁻	dichromate
NH ₄ ⁺	ammonium	MnO ₄ ⁻	permanganate
C ₂ H ₃ O ₂ ⁻ CH ₃ COO ⁻ }	acetate	NO ₂ ⁻	nitrite
CN ⁻	cyanide	NO ₃ ⁻	nitrate
CO ₃ ²⁻	carbonate	O ₂ ²⁻	peroxide
HCO ₃ ⁻	hydrogen carbonate	OH ⁻	hydroxide
C ₂ O ₄ ²⁻	oxalate	PO ₄ ³⁻	phosphate
ClO ⁻	hypochlorite	SCN ⁻	thiocyanate
ClO ₂ ⁻	chlorite	SO ₃ ²⁻	sulfite
ClO ₃ ⁻	chlorate	SO ₄ ²⁻	sulfate
ClO ₄ ⁻	perchlorate	HSO ₄ ⁻	hydrogen sulfate
		S ₂ O ₃ ²⁻	thiosulfate

**Table F
Solubility Guidelines**

Ions That Form Soluble Compounds	Exceptions	Ions That Form Insoluble Compounds	Exceptions
Group 1 ions (Li ⁺ , Na ⁺ , etc.)		carbonate (CO ₃ ²⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
ammonium (NH ₄ ⁺)		chromate (CrO ₄ ²⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
nitrate (NO ₃ ⁻)		phosphate (PO ₄ ³⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
acetate (C ₂ H ₃ O ₂ ⁻ or CH ₃ COO ⁻)		sulfide (S ²⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
hydrogen carbonate (HCO ₃ ⁻)		hydroxide (OH ⁻)	when combined with Group 1 ions, Ca ²⁺ , Ba ²⁺ , or Sr ²⁺
chlorate (ClO ₃ ⁻)			
perchlorate (ClO ₄ ⁻)			
halides (Cl ⁻ , Br ⁻ , I ⁻)	when combined with Ag ⁺ , Pb ²⁺ , and Hg ₂ ²⁺		
sulfates (SO ₄ ²⁻)	when combined with Ag ⁺ , Ca ²⁺ , Sr ²⁺ , Ba ²⁺ , and Pb ²⁺		

Table G Solubility Curves

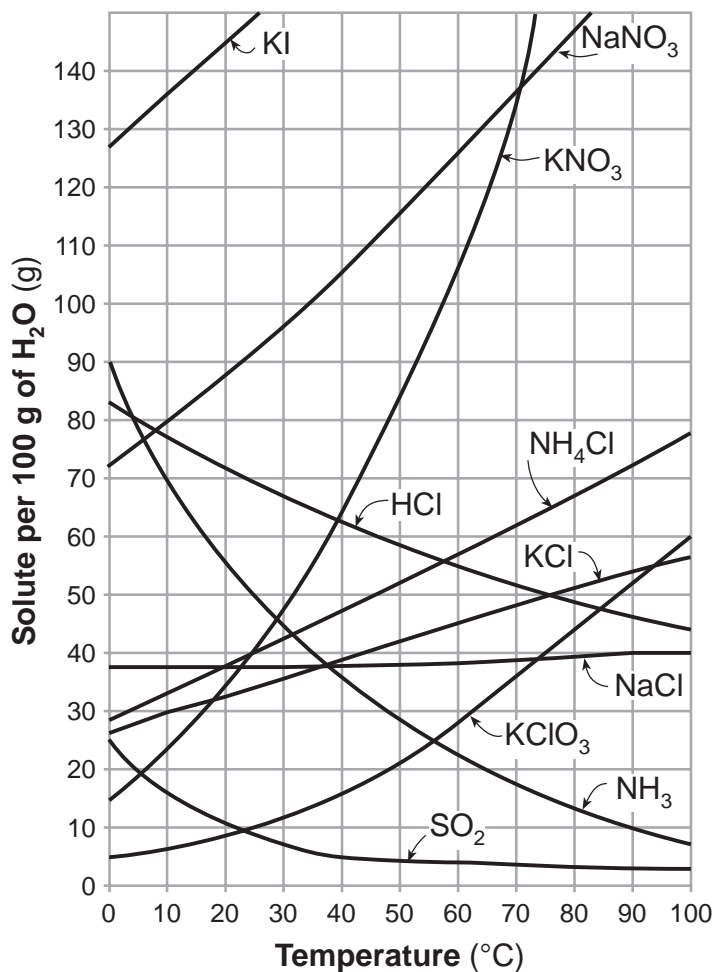


Table H
Vapor Pressure of Four Liquids

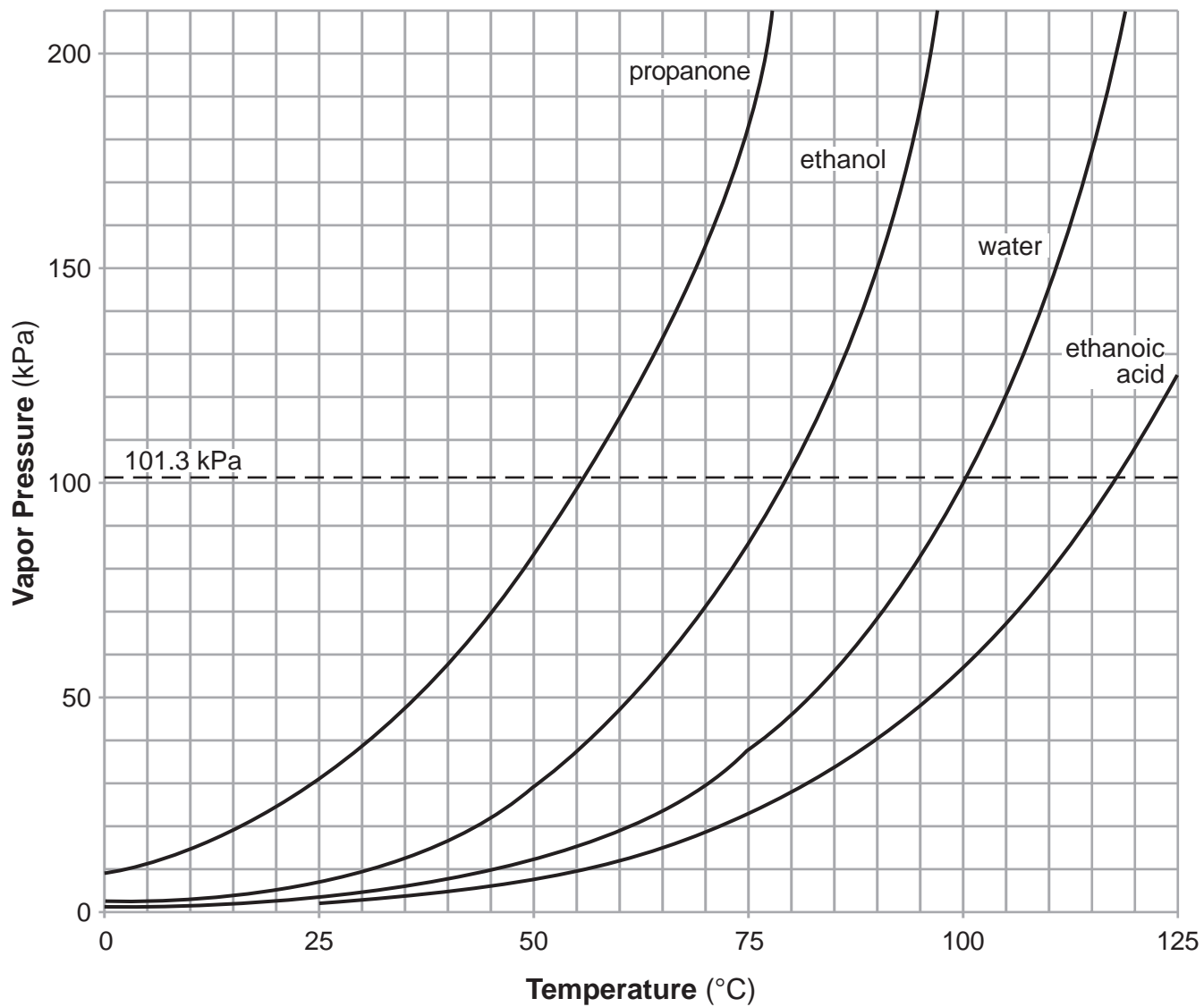


Table I
Heats of Reaction at 101.3 kPa and 298 K

Reaction	ΔH (kJ)*
$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$	-890.4
$\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \longrightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\ell)$	-2219.2
$2\text{C}_8\text{H}_{18}(\ell) + 25\text{O}_2(\text{g}) \longrightarrow 16\text{CO}_2(\text{g}) + 18\text{H}_2\text{O}(\ell)$	-10943
$2\text{CH}_3\text{OH}(\ell) + 3\text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\ell)$	-1452
$\text{C}_2\text{H}_5\text{OH}(\ell) + 3\text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\ell)$	-1367
$\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{O}_2(\text{g}) \longrightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\ell)$	-2804
$2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g})$	-566.0
$\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$	-393.5
$4\text{Al}(\text{s}) + 3\text{O}_2(\text{g}) \longrightarrow 2\text{Al}_2\text{O}_3(\text{s})$	-3351
$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{NO}(\text{g})$	+182.6
$\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow 2\text{NO}_2(\text{g})$	+66.4
$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{g})$	-483.6
$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\ell)$	-571.6
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g})$	-91.8
$2\text{C}(\text{s}) + 3\text{H}_2(\text{g}) \longrightarrow \text{C}_2\text{H}_6(\text{g})$	-84.0
$2\text{C}(\text{s}) + 2\text{H}_2(\text{g}) \longrightarrow \text{C}_2\text{H}_4(\text{g})$	+52.4
$2\text{C}(\text{s}) + \text{H}_2(\text{g}) \longrightarrow \text{C}_2\text{H}_2(\text{g})$	+227.4
$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \longrightarrow 2\text{HI}(\text{g})$	+53.0
$\text{KNO}_3(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{K}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$	+34.89
$\text{NaOH}(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$	-44.51
$\text{NH}_4\text{Cl}(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$	+14.78
$\text{NH}_4\text{NO}_3(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{NH}_4^+(\text{aq}) + \text{NO}_3^-(\text{aq})$	+25.69
$\text{NaCl}(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$	+3.88
$\text{LiBr}(\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{Li}^+(\text{aq}) + \text{Br}^-(\text{aq})$	-48.83
$\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \longrightarrow \text{H}_2\text{O}(\ell)$	-55.8

*Minus sign indicates an exothermic reaction.

Table J
Activity Series**

Most	Metals	Nonmetals	Most
↓	Li	F ₂	↓
	Rb	Cl ₂	
	K	Br ₂	
	Cs	I ₂	
	Ba		
	Sr		
	Ca		
	Na		
	Mg		
	Al		
	Ti		
	Mn		
	Zn		
	Cr		
	Fe		
	Co		
	Ni		
	Sn		
	Pb		
**H ₂			
Cu			
Ag			
Au			
Least			Least

**Activity Series based on hydrogen standard

Table K
Common Acids

Formula	Name
HCl(aq)	hydrochloric acid
HNO ₃ (aq)	nitric acid
H ₂ SO ₄ (aq)	sulfuric acid
H ₃ PO ₄ (aq)	phosphoric acid
H ₂ CO ₃ (aq) or CO ₂ (aq)	carbonic acid
CH ₃ COOH(aq) or HC ₂ H ₃ O ₂ (aq)	ethanoic acid (acetic acid)

Table L
Common Bases

Formula	Name
NaOH(aq)	sodium hydroxide
KOH(aq)	potassium hydroxide
Ca(OH) ₂ (aq)	calcium hydroxide
NH ₃ (aq)	aqueous ammonia

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromocresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

Table N
Selected Radioisotopes

Nuclide	Half-Life	Decay Mode	Nuclide Name
¹⁹⁸ Au	2.69 d	β ⁻	gold-198
¹⁴ C	5730 y	β ⁻	carbon-14
³⁷ Ca	175 ms	β ⁺	calcium-37
⁶⁰ Co	5.26 y	β ⁻	cobalt-60
¹³⁷ Cs	30.23 y	β ⁻	cesium-137
⁵³ Fe	8.51 min	β ⁺	iron-53
²²⁰ Fr	27.5 s	α	francium-220
³ H	12.26 y	β ⁻	hydrogen-3
¹³¹ I	8.07 d	β ⁻	iodine-131
³⁷ K	1.23 s	β ⁺	potassium-37
⁴² K	12.4 h	β ⁻	potassium-42
⁸⁵ Kr	10.76 y	β ⁻	krypton-85
¹⁶ N	7.2 s	β ⁻	nitrogen-16
¹⁹ Ne	17.2 s	β ⁺	neon-19
³² P	14.3 d	β ⁻	phosphorus-32
²³⁹ Pu	2.44 × 10 ⁴ y	α	plutonium-239
²²⁶ Ra	1600 y	α	radium-226
²²² Rn	3.82 d	α	radon-222
⁹⁰ Sr	28.1 y	β ⁻	strontium-90
⁹⁹ Tc	2.13 × 10 ⁵ y	β ⁻	technetium-99
²³² Th	1.4 × 10 ¹⁰ y	α	thorium-232
²³³ U	1.62 × 10 ⁵ y	α	uranium-233
²³⁵ U	7.1 × 10 ⁸ y	α	uranium-235
²³⁸ U	4.51 × 10 ⁹ y	α	uranium-238

ms = milliseconds; s = seconds; min = minutes;
h = hours; d = days; y = years

Table O
Symbols Used in Nuclear Chemistry

Name	Notation	Symbol
alpha particle	${}^4_2\text{He}$ or ${}^4_2\alpha$	α
beta particle (electron)	${}^0_{-1}\text{e}$ or ${}^0_{-1}\beta$	β^-
gamma radiation	${}^0_0\gamma$	γ
neutron	${}^1_0\text{n}$	n
proton	${}^1_1\text{H}$ or ${}^1_1\text{p}$	p
positron	${}^0_{+1}\text{e}$ or ${}^0_{+1}\beta$	β^+

Table P
Organic Prefixes

Prefix	Number of Carbon Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Table Q
Homologous Series of Hydrocarbons

Name	General Formula	Examples	
		Name	Structural Formula
alkanes	$\text{C}_n\text{H}_{2n+2}$	ethane	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $
alkenes	C_nH_{2n}	ethene	$ \begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{H} \end{array} $
alkynes	$\text{C}_n\text{H}_{2n-2}$	ethyne	$\text{H}-\text{C}\equiv\text{C}-\text{H}$

n = number of carbon atoms

Table R
Organic Functional Groups

Class of Compound	Functional Group	General Formula	Example
halide (halocarbon)	-F (fluoro-) -Cl (chloro-) -Br (bromo-) -I (iodo-)	$R-X$ (X represents any halogen)	$\text{CH}_3\text{CHClCH}_3$ 2-chloropropane
alcohol	-OH	$R-OH$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ 1-propanol
ether	-O-	$R-O-R'$	$\text{CH}_3\text{OCH}_2\text{CH}_3$ methyl ethyl ether
aldehyde	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \\ R-\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2\text{C}-\text{H} \end{array}$ propanal
ketone	$\begin{array}{c} \text{O} \\ \\ -\text{C}- \end{array}$	$\begin{array}{c} \text{O} \\ \\ R-\text{C}-R' \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_3 \end{array}$ 2-pentanone
organic acid	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{OH} \end{array}$	$\begin{array}{c} \text{O} \\ \\ R-\text{C}-\text{OH} \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2\text{C}-\text{OH} \end{array}$ propanoic acid
ester	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}- \end{array}$	$\begin{array}{c} \text{O} \\ \\ R-\text{C}-\text{O}-R' \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2\text{COCH}_3 \end{array}$ methyl propanoate
amine	$\begin{array}{c} \\ -\text{N}- \end{array}$	$\begin{array}{c} R' \\ \\ R-\text{N}-R'' \end{array}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ 1-propanamine
amide	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{NH} \end{array}$	$\begin{array}{c} \text{O} \quad R' \\ \quad \\ R-\text{C}-\text{NH} \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2\text{C}-\text{NH}_2 \end{array}$ propanamide

R represents a bonded atom or group of atoms.

Periodic Table

Period	1						
	1						
1	<table border="1"> <tr> <td>1.00794</td> <td>+1</td> </tr> <tr> <td>H</td> <td>-1</td> </tr> <tr> <td>1</td> <td>1</td> </tr> </table>	1.00794	+1	H	-1	1	1
1.00794	+1						
H	-1						
1	1						

KEY	
Atomic Mass →	12.0111
Symbol →	C
Atomic Number →	6
Electron Configuration →	2-4

Selected C
Relative at
on ¹²C = 1
Note: Mas
are mass r
stable or c

		Group																									
		1		2			3	4	5	6	7	8	9														
2	6.941	+1	Li	9.01218	+2	Be																					
	3	2-1		4	2-2																						
3	22.98977	+1	Na	24.305	+2	Mg																					
	11	2-8-1		12	2-8-2																						
4	39.0983	+1	K	40.08	+2	Ca	44.9559	+3	Sc	47.88	+2	Ti	50.9415	+2	V	51.996	+2	Cr	54.9380	+2	Mn	55.847	+2	Fe	58.9332	+2	Co
	19	2-8-8-1		20	2-8-8-2		21	2-8-9-2		22	2-8-10-2		23	2-8-11-2		24	2-8-13-1		25	2-8-13-2		26	2-8-14-2		27	2-8-15-2	
5	85.4678	+1	Rb	87.62	+2	Sr	88.9059	+3	Y	91.224	+4	Zr	92.9064	+3	Nb	95.94	+3	Mo	(98)	+4	Tc	101.07	+3	Ru	102.906	+3	Rh
	37	2-8-18-8-1		38	2-8-18-8-2		39	2-8-18-9-2		40	2-8-18-10-2		41	2-8-18-12-1		42	2-8-18-13-1		43	2-8-18-14-1		44	2-8-18-15-1		45	2-8-18-16-1	
6	132.905	+1	Cs	137.33	+2	Ba	138.906	+3	La	178.49	+4	Hf	180.948	+5	Ta	183.85	+6	W	186.207	+4	Re	190.2	+3	Os	192.22	+3	Ir
	55	2-8-18-18-8-1		56	2-8-18-18-8-2		57	2-8-18-18-9-2		72	**18-32-10-2		73	-18-32-11-2		74	-18-32-12-2		75	-18-32-13-2		76	-18-32-14-2		77	-18-32-15-2	
7	(223)	+1	Fr	226.025	+2	Ra	227.028	+3	Ac	(261)		Rf	(262)		Db	(263)		Sg	(264)		Bh	(265)		Hs	(268)		Mt
	87	-18-32-18-8-1		88	-18-32-18-8-2		89	-18-32-18-9-2		104		105		106		107		108		109							

**Denotes the presence of (2-8-) for elements 72 and above

140.12	+3	Ce	140.908	+3	Pr	144.24	+3	Nd	(145)	+3	Pm	150.36	+2	Sm
58	+4		59		60		61		62				+3	
232.038	+4	Th	231.036	+4	Pa	238.029	+3	U	237.048	+3	Np	(244)	+3	Pu
90	+5		91	+5	92	+6	93	+6	94			+4	+5	+6

of the Elements

Oxidation States

Atomic masses are based
2.000

Numbers in parentheses
numbers of the most
common isotope.

18

4.00260	0
He	
2	2

			Group					
			13	14	15	16	17	18
			10.81 B 5 2-3	12.0111 C 6 2-4	14.0067 N 7 2-5	15.9994 O 8 2-6	18.998403 F 9 2-7	20.179 Ne 10 2-8
			26.98154 Al 13 2-8-3	28.0855 Si 14 2-8-4	30.97376 P 15 2-8-5	32.06 S 16 2-8-6	35.453 Cl 17 2-8-7	39.948 Ar 18 2-8-8
8.69 Ni 28 -8-16-2	63.546 Cu 29 2-8-18-1	65.39 Zn 30 2-8-18-2	69.72 Ga 31 2-8-18-3	72.59 Ge 32 2-8-18-4	74.9216 As 33 2-8-18-5	78.96 Se 34 2-8-18-6	79.904 Br 35 2-8-18-7	83.80 Kr 36 2-8-18-8
06.42 Pd 46 -8-18-18	107.868 Ag 47 2-8-18-18-1	112.41 Cd 48 2-8-18-18-2	114.82 In 49 2-8-18-18-3	118.71 Sn 50 2-8-18-18-4	121.75 Sb 51 2-8-18-18-5	127.60 Te 52 2-8-18-18-6	126.905 I 53 2-8-18-18-7	131.29 Xe 54 2-8-18-18-8
95.08 Pt 78 18-32-17-1	196.967 Au 79 -18-32-18-1	200.59 Hg 80 -18-32-18-2	204.383 Tl 81 -18-32-18-3	207.2 Pb 82 -18-32-18-4	208.980 Bi 83 -18-32-18-5	(209) Po 84 -18-32-18-6	(210) At 85 -18-32-18-7	(222) Rn 86 -18-32-18-8
269 Uun* 110	(272) Uuu 111	(277) Uub 112		(285) Uuq 114				

*The systematic names and symbols for elements of atomic numbers above 109 will be used until the approval of trivial names by IUPAC.

51.96 Eu 63	157.25 Gd 64	158.925 Tb 65	162.50 Dy 66	164.930 Ho 67	167.26 Er 68	168.934 Tm 69	173.04 Yb 70	174.967 Lu 71
243 Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

Table S
Properties of Selected Elements

Atomic Number	Symbol	Name	Ionization Energy (kJ/mol)	Electro-negativity	Melting Point (K)	Boiling Point (K)	Density** (g/cm ³)	Atomic Radius (pm)
1	H	hydrogen	1312	2.1	14	20	0.00009	208
2	He	helium	2372	—	1	4	0.000179	50
3	Li	lithium	520	1.0	454	1620	0.534	155
4	Be	beryllium	900	1.6	1551	3243	1.8477	112
5	B	boron	801	2.0	2573	3931	2.340	98
6	C	carbon	1086	2.6	3820	5100	3.513	91
7	N	nitrogen	1402	3.0	63	77	0.00125	92
8	O	oxygen	1314	3.4	55	90	0.001429	65
9	F	fluorine	1681	4.0	54	85	0.001696	57
10	Ne	neon	2081	—	24	27	0.0009	51
11	Na	sodium	496	0.9	371	1156	0.971	190
12	Mg	magnesium	736	1.3	922	1363	1.738	160
13	Al	aluminum	578	1.6	934	2740	2.698	143
14	Si	silicon	787	1.9	1683	2628	2.329	132
15	P	phosphorus	1012	2.2	44	553	1.820	128
16	S	sulfur	1000	2.6	386	718	2.070	127
17	Cl	chlorine	1251	3.2	172	239	0.003214	97
18	Ar	argon	1521	—	84	87	0.001783	88
19	K	potassium	419	0.8	337	1047	0.862	235
20	Ca	calcium	590	1.0	1112	1757	1.550	197
21	Sc	scandium	633	1.4	1814	3104	2.989	162
22	Ti	titanium	659	1.5	1933	3580	4.540	145
23	V	vanadium	651	1.6	2160	3650	6.100	134
24	Cr	chromium	653	1.7	2130	2945	7.190	130
25	Mn	manganese	717	1.6	1517	2235	7.440	135
26	Fe	iron	762	1.8	1808	3023	7.874	126
27	Co	cobalt	760	1.9	1768	3143	8.900	125
28	Ni	nickel	737	1.9	1726	3005	8.902	124
29	Cu	copper	745	1.9	1357	2840	8.960	128
30	Zn	zinc	906	1.7	693	1180	7.133	138
31	Ga	gallium	579	1.8	303	2676	5.907	141
32	Ge	germanium	762	2.0	1211	3103	5.323	137
33	As	arsenic	944	2.2	1090	889	5.780	139
34	Se	selenium	941	2.6	490	958	4.790	140
35	Br	bromine	1140	3.0	266	332	3.122	112
36	Kr	krypton	1351	—	117	121	0.00375	103
37	Rb	rubidium	403	0.8	312	961	1.532	248
38	Sr	strontium	549	1.0	1042	1657	2.540	215
39	Y	yttrium	600	1.2	1795	3611	4.469	178
40	Zr	zirconium	640	1.3	2125	4650	6.506	160

Atomic Number	Symbol	Name	Ionization Energy (kJ/mol)	Electro-negativity	Melting Point (K)	Boiling Point (K)	Density** (g/cm ³)	Atomic Radius (pm)
41	Nb	niobium	652	1.6	2741	5015	8.570	146
42	Mo	molybdenum	684	2.2	2890	4885	10.220	139
43	Tc	technetium	702	1.9	2445	5150	11.500	136
44	Ru	ruthenium	710	2.2	2583	4173	12.370	134
45	Rh	rhodium	720	2.3	2239	4000	12.410	134
46	Pd	palladium	804	2.2	1825	3413	12.020	137
47	Ag	silver	731	1.9	1235	2485	10.500	144
48	Cd	cadmium	868	1.7	594	1038	8.650	171
49	In	indium	558	1.8	429	2353	7.310	166
50	Sn	tin	709	2.0	505	2543	7.310	162
51	Sb	antimony	831	2.1	904	1908	6.691	159
52	Te	tellurium	869	2.1	723	1263	6.240	142
53	I	iodine	1008	2.7	387	458	4.930	132
54	Xe	xenon	1170	2.6	161	166	0.0059	124
55	Cs	cesium	376	0.8	302	952	1.873	267
56	Ba	barium	503	0.9	1002	1910	3.594	222
57	La	lanthanum	538	1.1	1194	3730	6.145	138
Elements 58–71 have been omitted.								
72	Hf	hafnium	659	1.3	2503	5470	13.310	167
73	Ta	tantalum	728	1.5	3269	5698	16.654	149
74	W	tungsten	759	2.4	3680	5930	19.300	141
75	Re	rhenium	756	1.9	3453	5900	21.020	137
76	Os	osmium	814	2.2	3327	5300	22.590	135
77	Ir	iridium	865	2.2	2683	4403	22.560	136
78	Pt	platinum	864	2.3	2045	4100	21.450	139
79	Au	gold	890	2.5	1338	3080	19.320	146
80	Hg	mercury	1007	2.0	234	630	13.546	160
81	Tl	thallium	589	2.0	577	1730	11.850	171
82	Pb	lead	716	2.3	601	2013	11.350	175
83	Bi	bismuth	703	2.0	545	1833	9.747	170
84	Po	polonium	812	2.0	527	1235	9.320	167
85	At	astatine	—	2.2	575	610	—	145
86	Rn	radon	1037	—	202	211	0.00973	134
87	Fr	francium	393	0.7	300	950	—	270
88	Ra	radium	—	0.9	973	1413	5.000	233
89	Ac	actinium	499	1.1	1320	3470	10.060	—
Elements 90 and above have been omitted.								

*Boiling point at standard pressure

**Density at STP

Table T
Important Formulas and Equations

Density	$d = \frac{m}{V}$	d = density m = mass V = volume
Mole Calculations	number of moles = $\frac{\text{given mass (g)}}{\text{gram-formula mass}}$	
Percent Error	% error = $\frac{\text{measured value} - \text{accepted value}}{\text{accepted value}} \times 100$	
Percent Composition	% composition by mass = $\frac{\text{mass of part}}{\text{mass of whole}} \times 100$	
Concentration	parts per million = $\frac{\text{grams of solute}}{\text{grams of solution}} \times 1\,000\,000$	
	molarity = $\frac{\text{moles of solute}}{\text{liters of solution}}$	
Combined Gas Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	P = pressure V = volume T = temperature (K)
Titration	$M_A V_A = M_B V_B$	M_A = molarity of H ⁺ M_B = molarity of OH ⁻ V_A = volume of acid V_B = volume of base
Heat	$q = mC\Delta T$ $q = mH_f$ $q = mH_v$	q = heat m = mass C = specific heat capacity ΔT = change in temperature H_f = heat of fusion H_v = heat of vaporization
Temperature	K = °C + 273	K = kelvin °C = degrees Celsius
Radioactive Decay	fraction remaining = $\left(\frac{1}{2}\right)^{\frac{t}{T}}$ number of half-life periods = $\frac{t}{T}$	t = total time elapsed T = half-life

Gas Laws

- $PV = nRT$

- $M = \frac{DRT}{P}$

$D = \text{density}; M = \text{molar mass}$

Constants

$$R = 0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$$

$$S.P = 1 \text{ atm} = 101.3 \text{ kPa} = 760. \text{ torr} = 760. \text{ mm Hg}$$

$$GMV = 22.4 \text{ L/mol}$$

U

RELATIVE STRENGTHS OF ACIDS IN AQUEOUS SOLUTION AT 1 atm AND 298 K

Conjugate Pairs		K_a
ACID	BASE	
HI	$= H^+ + I^-$	very large
HBr	$= H^+ + Br^-$	very large
HCl	$= H^+ + Cl^-$	very large
HNO ₃	$= H^+ + NO_3^-$	very large
H ₂ SO ₄	$= H^+ + HSO_4^-$	large
H ₂ O + SO ₂	$= H^+ + HSO_3^-$	1.5×10^{-2}
HSO ₄ ⁻	$= H^+ + SO_4^{2-}$	1.2×10^{-2}
H ₃ PO ₄	$= H^+ + H_2PO_4^-$	7.5×10^{-3}
Fe(H ₂ O) ₆ ³⁺	$= H^+ + Fe(H_2O)_5(OH)^{2+}$	8.9×10^{-4}
HNO ₂	$= H^+ + NO_2^-$	4.6×10^{-4}
HF	$= H^+ + F^-$	3.5×10^{-4}
Cr(H ₂ O) ₆ ³⁺	$= H^+ + Cr(H_2O)_5(OH)^{2+}$	1.0×10^{-4}
CH ₃ COOH	$= H^+ + CH_3COO^-$	1.8×10^{-5}
Al(H ₂ O) ₆ ³⁺	$= H^+ + Al(H_2O)_5(OH)^{2+}$	1.1×10^{-5}
H ₂ O + CO ₂	$= H^+ + HCO_3^-$	4.3×10^{-7}
HSO ₃ ⁻	$= H^+ + SO_3^{2-}$	1.1×10^{-7}
H ₂ S	$= H^+ + HS^-$	9.5×10^{-8}
H ₂ PO ₄ ⁻	$= H^+ + HPO_4^{2-}$	6.2×10^{-8}
NH ₄ ⁺	$= H^+ + NH_3$	5.7×10^{-10}
HCO ₃ ⁻	$= H^+ + CO_3^{2-}$	5.6×10^{-11}
HPO ₄ ²⁻	$= H^+ + PO_4^{3-}$	2.2×10^{-13}
HS ⁻	$= H^+ + S^{2-}$	1.3×10^{-14}
H ₂ O	$= H^+ + OH^-$	1.0×10^{-14}
OH ⁻	$= H^+ + O^{2-}$	$< 10^{-36}$
NH ₃	$= H^+ + NH_2^-$	very small

Note: $H^+(aq) = H_3O^+$
 Sample equation: $HI + H_2O = H_3O^+ + I^-$

V

CONSTANTS FOR VARIOUS EQUILIBRIA AT 1 atm AND 298 K

$H_2O(l) = H^+(aq) + OH^-(aq)$	$K_w = 1.0 \times 10^{-14}$
$H_2O(l) + H_2O(l) = H_3O^+(aq) + OH^-(aq)$	$K_w = 1.0 \times 10^{-14}$
$CH_3COO^-(aq) + H_2O(l) = CH_3COOH(aq) + OH^-(aq)$	$K_b = 5.6 \times 10^{-10}$
$NaF(aq) + H_2O(l) = Na^+(aq) + OH^-(aq) + HF(aq)$	$K_b = 1.5 \times 10^{-11}$
$NH_3(aq) + H_2O(l) = NH_4^+(aq) + OH^-(aq)$	$K_b = 1.8 \times 10^{-5}$
$CO_3^{2-}(aq) + H_2O(l) = HCO_3^-(aq) + OH^-(aq)$	$K_b = 1.8 \times 10^{-4}$
$Ag(NH_3)_2^+(aq) = Ag^+(aq) + 2NH_3(aq)$	$K_{eq} = 8.9 \times 10^{-8}$
$N_2(g) + 3H_2(g) = 2NH_3(g)$	$K_{eq} = 6.7 \times 10^5$
$H_2(g) + I_2(g) = 2HI(g)$	$K_{eq} = 3.5 \times 10^{-1}$

Compound	K_{sp}	Compound	K_{sp}
AgBr	5.0×10^{-13}	Li ₂ CO ₃	2.5×10^{-2}
AgCl	1.8×10^{-10}	PbCl ₂	1.6×10^{-5}
Ag ₂ CrO ₄	1.1×10^{-12}	PbCO ₃	7.4×10^{-14}
AgI	8.3×10^{-17}	PbCrO ₄	2.8×10^{-13}
BaSO ₄	1.1×10^{-10}	PbI ₂	7.1×10^{-9}
CaSO ₄	9.1×10^{-6}	ZnCO ₃	1.4×10^{-11}



STANDARD ENERGIES OF FORMATION OF COMPOUNDS AT 1 atm AND 298 K		
Compound	Heat (Enthalpy) of Formation * kJ/mol (ΔH_f°)	Free Energy of Formation kJ/mol (ΔG_f°)
Aluminum oxide $\text{Al}_2\text{O}_3(\text{s})$	-1674.1	-1580.9
Ammonia $\text{NH}_3(\text{g})$	-46.0	-16.3
Barium sulfate $\text{BaSO}_4(\text{s})$	-1471.8	-1361.0
Calcium hydroxide $\text{Ca}(\text{OH})_2(\text{s})$	-985.2	-897.9
Carbon dioxide $\text{CO}_2(\text{g})$	-393.3	-394.2
Carbon monoxide $\text{CO}(\text{g})$	-110.4	-137.1
Copper (II) sulfate $\text{CuSO}_4(\text{s})$	-770.8	-661.3
Ethane $\text{C}_2\text{H}_6(\text{g})$	-84.4	-33.0
Ethene (ethylene) $\text{C}_2\text{H}_4(\text{g})$	52.3	68.1
Ethyne (acetylene) $\text{C}_2\text{H}_2(\text{g})$	226.6	209.0
Hydrogen fluoride $\text{HF}(\text{g})$	-270.9	-273.0
Hydrogen iodide $\text{HI}(\text{g})$	26.3	1.7
Iodine chloride $\text{ICl}(\text{g})$	18.0	-5.4
Lead (II) oxide $\text{PbO}(\text{s})$	-215.3	-188.1
Magnesium oxide $\text{MgO}(\text{s})$	-601.1	-568.9
Nitrogen monoxide $\text{NO}(\text{g})$	90.3	86.5
Nitrogen dioxide $\text{NO}_2(\text{g})$	33.0	51.4
Potassium chloride $\text{KCl}(\text{s})$	-436.4	-408.8
Sodium chloride $\text{NaCl}(\text{s})$	-410.9	-383.7
Sulfur dioxide $\text{SO}_2(\text{g})$	-296.4	-299.7
Water $\text{H}_2\text{O}(\text{g})$	-241.6	-228.2
Water $\text{H}_2\text{O}(\ell)$	-285.5	-237.0

* Minus sign indicates an exothermic reaction.
Sample equations:
 $2\text{Al}(\text{s}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{Al}_2\text{O}_3(\text{s}) + 1674.1 \text{ kJ}$
 $2\text{Al}(\text{s}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{Al}_2\text{O}_3(\text{s}) \quad \Delta H = -1674.1 \text{ kJ/mol}$

$$\Delta G = \Delta H - T\Delta S$$

Periodic Table of the Elements

Period	1																										18							
	1.00794 H 1 1																										4.00260 He 2 2							
																	Group																	
																	13	14	15	16	17	18												
																	10.81 B 5 2-3	12.0111 C 6 2-4	14.0067 N 7 2-5	15.9994 O 8 2-6	18.998403 F 9 2-7	20.179 Ne 10 2-8												
																	26.98154 Al 13 2-8-3	28.0855 Si 14 2-8-4	30.97376 P 15 2-8-5	32.06 S 16 2-8-6	35.453 Cl 17 2-8-7	39.948 Ar 18 2-8-8												
																	39.0983 K 19 2-8-8-1	40.08 Ca 20 2-8-8-2	44.9559 Sc 21 2-8-9-2	47.88 Ti 22 2-8-10-2	50.9415 V 23 2-8-11-2	51.996 Cr 24 2-8-13-1	54.9380 Mn 25 2-8-13-2	55.847 Fe 26 2-8-14-2	58.9332 Co 27 2-8-15-2	58.69 Ni 28 2-8-16-2	63.546 Cu 29 2-8-18-1	65.39 Zn 30 2-8-18-2	69.72 Ga 31 2-8-18-3	72.59 Ge 32 2-8-18-4	74.9216 As 33 2-8-18-5	78.96 Se 34 2-8-18-6	79.904 Br 35 2-8-18-7	83.80 Kr 36 2-8-18-8
																	85.4678 Rb 37 2-8-18-8-1	87.62 Sr 38 2-8-18-8-2	88.9059 Y 39 2-8-18-9-2	91.224 Zr 40 2-8-18-10-2	92.9064 Nb 41 2-8-18-12-1	95.94 Mo 42 2-8-18-13-1	(98) Tc 43 2-8-18-14-1	101.07 Ru 44 2-8-18-15-1	102.906 Rh 45 2-8-18-16-1	106.42 Pd 46 2-8-18-18	107.868 Ag 47 2-8-18-18-1	112.41 Cd 48 2-8-18-18-2	114.82 In 49 2-8-18-18-3	118.71 Sn 50 2-8-18-18-4	121.75 Sb 51 2-8-18-18-5	127.60 Te 52 2-8-18-18-6	126.905 I 53 2-8-18-18-7	131.29 Xe 54 2-8-18-18-8
																	132.905 Cs 55 2-8-18-18-8-1	137.33 Ba 56 2-8-18-18-8-2	138.906 La 57 2-8-18-18-9-2	178.49 Hf 72 **18-32-10-2	180.948 Ta 73 -18-32-11-2	183.85 W 74 -18-32-12-2	186.207 Re 75 -18-32-13-2	190.2 Os 76 -18-32-14-2	192.22 Ir 77 -18-32-15-2	195.08 Pt 78 -18-32-17-1	196.967 Au 79 -18-32-18-1	200.59 Hg 80 -18-32-18-2	204.383 Tl 81 -18-32-18-3	207.2 Pb 82 -18-32-18-4	208.980 Bi 83 -18-32-18-5	(209) Po 84 -18-32-18-6	(210) At 85 -18-32-18-7	(222) Rn 86 -18-32-18-8
																	(223) Fr 87 -18-32-18-8-1	226.025 Ra 88 -18-32-18-8-2	227.028 Ac 89 -18-32-18-9-2	(261) Rf 104	(262) Db 105	(263) Sg 106	(264) Bh 107	(265) Hs 108	(268) Mt 109	(269) Uun 110	(272) Uuu 111	(277) Uub 112		(285) Uuq 114				

KEY

Atomic Mass → 12.011 ← Selected Oxidation States

Symbol → **C**

Atomic Number → 6

Electron Configuration → 2-4

Relative atomic masses are based on ¹²C = 12.000

Note: Mass numbers in parentheses are mass numbers of the most stable or common isotope.

**Denotes the presence of (2-8-) for elements 72 and above

*The systematic names and symbols for elements of atomic numbers above 109 will be used until the approval of trivial names by IUPAC.

140.12 Ce 58	140.908 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.925 Tb 65	162.50 Dy 66	164.930 Ho 67	167.26 Er 68	168.934 Tm 69	173.04 Yb 70	174.967 Lu 71
232.038 Th 90	231.036 Pa 91	238.029 U 92	237.048 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103