

Physical Chemistry for the Life Sciences

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Data section

Table 1 Thermodynamic data for organic compounds (all values relate to 298.15 K)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}^\ominus/$ (J K ⁻¹ mol ⁻¹)	$\Delta_c H^\ominus/$ (kJ mol ⁻¹)
C(s) (graphite)	12.011	0	0	5.740	8.527	-393.51
C(s) (diamond)	12.011	+1.895	+2.900	2.377	6.113	-395.40
CO ₂ (g)	44.010	-393.51	-394.36	213.74	37.11	
<i>Hydrocarbons</i>						
CH ₄ (g), methane	16.04	-74.81	-50.72	186.26	35.31	-890
CH ₃ (g), methyl	15.04	+145.69	+147.92	194.2	38.70	
C ₂ H ₂ (g), ethyne	26.04	+226.73	+209.20	200.94	43.93	-1300
C ₂ H ₄ (g), ethene	28.05	+52.26	+68.15	219.56	43.56	-1411
C ₂ H ₆ (g), ethane	30.07	-84.68	-32.82	229.60	52.63	-1560
C ₃ H ₆ (g), propene	42.08	+20.42	+62.78	267.05	63.89	-2058
C ₃ H ₆ (g), cyclopropane	42.08	-103.85	-23.49	269.91	73.5	-2220
C ₄ H ₈ (g), 1-butene	56.11	-0.13	+71.39	305.71	85.65	-2717
C ₄ H ₈ (g), <i>cis</i> -2-butene	56.11	-6.99	+65.95	300.94	78.91	-2710
C ₄ H ₈ (g), <i>trans</i> -2-butene	56.11	-11.17	+63.06	296.59	87.82	-2707
C ₄ H ₁₀ (g), butane	58.13	-126.15	-17.03	310.23	97.45	-2878
C ₅ H ₁₂ (g), pentane	72.15	-146.44	-8.20	348.40	120.2	-3537
C ₅ H ₁₂ (l)	72.15	-173.1				
C ₆ H ₆ (l), benzene	78.12	+49.0	+124.3	173.3	136.1	-3268
C ₆ H ₆ (g)	78.12	+82.93	+129.72	269.31	81.67	-3320
C ₆ H ₁₂ (l), cyclohexane	84.16	-156	+26.8		156.5	-3902
C ₆ H ₁₄ (l), hexane	86.18	-198.7		204.3		-4163
C ₆ H ₅ CH ₃ (g), methylbenzene (toluene)	92.14	+50.0	+122.0	320.7	103.6	-3953
C ₇ H ₁₆ (l), heptane	100.21	-224.4	+1.0	328.6	224.3	
C ₈ H ₁₈ (l), octane	114.23	-249.9	+6.4	361.1		-5471
C ₈ H ₁₈ (l), iso-octane	114.23	-255.1				-5461
C ₁₀ H ₈ (s), naphthalene	128.18	+78.53				-5157
<i>Alcohols and phenols</i>						
CH ₃ OH(l), methanol	32.04	-238.86	-166.27	126.8	81.6	-726
CH ₃ OH(g)	32.04	-200.66	-166.27	239.81	43.89	-764
C ₂ H ₅ OH(l), ethanol	46.07	-277.69	-174.78	160.7	111.46	-1368
C ₂ H ₅ OH(g)	46.07	-235.10	-168.49	282.70	65.44	-1409
C ₆ H ₅ OH(s), phenol	94.12	-165.0	-50.9	146.0		-3054

(continued)

Table 1 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}^\ominus/$ (J K ⁻¹ mol ⁻¹)	$\Delta_c H^\ominus/$ (kJ mol ⁻¹)
<i>Carboxylic acids, hydroxy acids, and esters</i>						
HCOOH(l), formic	46.03	-424.72	-361.35	128.95	99.04	-255
CH ₃ COOH(l), ethanoic	60.05	-484.3	-389.9	159.8	124.3	-875
CH ₃ COOH(aq)	60.05	-485.76	-396.46	178.7		
CH ₃ CO ₂ ⁻ (aq)	59.05	-486.01	-369.31	86.6	-6.3	
CH ₃ (CO)COOH(l), pyruvic	88.06					-950
CH ₃ (CH ₂) ₂ COOH(l), butanoic	88.10	-533.8				
CH ₃ COOC ₂ H ₅ (l), ethyl acetate	88.10	-479.0	-332.7	259.4	170.1	-2231
(COOH) ₂ (s), oxalic	90.04	-827.2			117	-254
CH ₃ CH(OH)COOH(s), lactic	90.08	-694.0	-522.9			-1344
HOOCCH ₂ CH ₂ COOH(s), succinic	118.09	-940.5	-747.4	153.1	167.3	
C ₆ H ₅ COOH(s), benzoic	122.13	-385.1	-245.3	167.6	146.8	-3227
CH ₃ (CH ₂) ₈ COOH(s), decanoic	172.27	-713.7				
C ₆ H ₈ O ₆ (s), ascorbic	176.12	-1164.6				
HOOCCH ₂ C(OH)(COOH)CH ₂ COOH(s), citric	192.12	-1543.8	-1236.4			-1985
CH ₃ (CH ₂) ₁₀ COOH(s), dodecanoic	200.32	-774.6			404.3	
CH ₃ (CH ₂) ₁₄ COOH(s), hexadecanoic	256.41	-891.5				
C ₁₈ H ₃₆ O ₂ (s), stearic	284.48	-947.7			501.5	
<i>Alkanals and alkanones</i>						
HCHO(g), methanal	30.03	-108.57	-102.53	218.77	35.40	-571
CH ₃ CHO(l), ethanal	44.05	-192.30	-128.12	160.2		-1166
CH ₃ CHO(g)	44.05	-166.19	-128.86	250.3	57.3	-1192
CH ₃ COCH ₃ (l), propanone	58.08	-248.1	-155.4	200.4	124.7	-1790
<i>Sugars</i>						
C ₅ H ₁₀ O ₅ (s), D-ribose	150.1	-1051.1				
C ₅ H ₁₀ O ₅ (s), D-xylose	150.1	-1057.8				
C ₆ H ₁₂ O ₆ (s), α-D-glucose	180.16	-1273.3	-917.2	212.1		-2808
C ₆ H ₁₂ O ₆ (s), β-D-glucose	180.16	-1268				
C ₆ H ₁₂ O ₆ (s), β-D-fructose	180.16	-1265.6				-2810
C ₆ H ₁₂ O ₆ (s), α-D-galactose	180.16	-1286.3	-918.8	205.4		
C ₁₂ H ₂₂ O ₁₁ (s), sucrose	342.30	-2226.1	-1543	360.2		-5645
C ₁₂ H ₂₂ O ₁₁ (s), lactose	342.30	-2236.7	-1567	386.2		
<i>Amino acids</i> ¹						
L-Glycine						
solid	75.07	-528.5	-373.4	103.5	99.2	-969
aqueous solution	75.07	-469.8	-315.0	111.0		
L-Alanine	89.09	-604.0	-369.9	129.2	122.2	-1618
L-Serine	105.09	-732.7	-508.8	149.2	135.6	-1455
L-Proline	115.13	-515.2		164.0	151.2	
L-Valine	117.15	-617.9	-359.0	178.9	168.8	-2922
L-Threonine	119.12	-807.2	-550.2	152.7	147.3	-2053

¹See Table 4 for the molecular structures of the amino acids. Unless otherwise noted, data relate to the substance in the solid state.

(continued)

Table 1 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}^\ominus/$ (J K ⁻¹ mol ⁻¹)	$\Delta_c H^\ominus/$ (kJ mol ⁻¹)
<i>Amino acids¹ (continued)</i>						
L-Cysteine	121.16	-534.1	-340.1	169.9	162.3	-1651
L-Leucine	131.17	-637.4	-347.7	211.8	200.1	-3582
L-Isoleucine	131.17	-637.8	-347.3	208.0	188.3	-3581
L-Asparagine	132.12	-789.4	-530.1	174.5	160.2	-530
L-Aspartic acid	133.10	-973.3	-730.1	170.1	155.2	-1601
L-Glutamine	146.15	-826.4	-532.6	195.0	184.2	-2570
L-Glutamic acid	147.13	-1009.7	-731.4	188.2	175.0	-2244
L-Methionine	149.21	-577.5	-505.8	231.5	290.0	-2782
L-Histidine	155.16	-466.7				
L-Phenylalanine	165.19	-466.9	-211.7	213.6	203.0	-4647
L-Tyrosine	181.19	-685.1	-385.8	214.0	216.4	-4442
L-Tryptophan	204.23	-415.3	-119.2	251.0	238.1	-5628
L-Cystine	240.32	-1032.7	-685.8	280.6	261.9	-3032
<i>Peptides</i>						
NH ₂ CH ₂ CONHCH ₂ COOH(s), glycylglycine	132.12	-747.7	-487.9	180.3	164.0	-1972
NH ₂ CH(CH ₃)CONHCH ₂ COOH, alanylglycine	146.15		-489.9	213.4	182.4	-2619
<i>Other nitrogen compounds</i>						
CH ₃ NH ₂ (g), methylamine	31.06	-22.97	+32.16	243.41	53.1	-1085
(NH ₂) ₂ CO(s), urea	60.06	-333.1	-197.33	104.60	93.14	-632
C ₆ H ₅ NH ₂ (l), aniline	93.13	+31.1				-3393
C ₄ H ₅ N ₃ O(s), cytosine	111.10	-221.3			132.6	
C ₄ H ₄ N ₂ O ₂ (s), uracil	112.09	-429.4				
C ₅ H ₆ N ₂ O ₂ (s), thymine	126.11	-462.8			150.8	
C ₅ H ₅ N ₅ (s), adenine	135.14	+96.9	+299.6	151.1	147.0	
C ₅ H ₅ N ₅ O(s), guanine	151.13	-183.9	+47.4	160.3		

Table 2 Thermodynamic data (all values relate to 298.15 K)*

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Aluminum</i>					
Al(s)	26.98	0	0	28.33	24.35
Al(l)	26.98	+10.56	+7.20	39.55	24.21
Al(g)	26.98	+326.4	+285.7	164.54	21.38
Al ³⁺ (g)	26.98	+5483.17			
Al ³⁺ (aq)	26.98	-531	-485	-321.7	
Al ₂ O ₃ (s, α)	101.96	-1675.7	-1582.3	50.92	79.04
AlCl ₃ (s)	133.24	-704.2	-628.8	110.67	91.84
<i>Argon</i>					
Ar(g)	39.95	0	0	154.84	20.786
<i>Antimony</i>					
Sb(s)	121.75	0	0	45.69	25.23
SbH ₃ (g)	153.24	+145.11	+147.75	232.78	41.05
<i>Arsenic</i>					
As(s, α)	74.92	0	0	35.1	24.64
As(g)	74.92	+302.5	+261.0	174.21	20.79
As ₄ (g)	299.69	+143.9	+92.4	314	
AsH ₃ (g)	77.95	+66.44	+68.93	222.78	38.07
<i>Barium</i>					
Ba(s)	137.34	0	0	62.8	28.07
Ba(g)	137.34	+180	+146	170.24	20.79
Ba ²⁺ (aq)	137.34	-537.64	-560.77	+9.6	
BaO(s)	153.34	-553.5	-525.1	70.43	47.78
BaCl ₂ (s)	208.25	-858.6	-810.4	123.68	75.14
<i>Beryllium</i>					
Be(s)	9.01	0	0	9.50	16.44
Be(g)	9.01	+324.3	+286.6	136.27	20.79
<i>Bismuth</i>					
Bi(s)	208.98	0	0	56.74	25.52
Bi(g)	208.98	+207.1	+168.2	187.00	20.79
<i>Bromine</i>					
Br ₂ (l)	159.82	0	0	152.23	75.689
Br ₂ (g)	159.82	+30.907	+3.110	245.46	36.02
Br(g)	79.91	+111.88	+82.396	175.02	20.786
Br ⁻ (g)	79.91	-219.07			
Br ⁻ (aq)	79.91	-121.55	-103.96	+82.4	-141.8
HBr(g)	90.92	-36.40	-53.45	198.70	29.142

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Cadmium</i>					
Cd(s, γ)	112.40	0	0	51.76	25.98
Cd(g)	112.40	+112.01	+77.41	167.75	20.79
Cd ²⁺ (aq)	112.40	-75.90	-77.612	-73.2	
CdO(s)	128.40	-258.2	-228.4	54.8	43.43
CdCO ₃ (s)	172.41	-750.6	-669.4	92.5	
<i>Calcium</i>					
Ca(s)	40.08	0	0	41.42	25.31
Ca(g)	40.08	+178.2	+144.3	154.88	20.786
Ca ²⁺ (aq)	40.08	-542.83	-553.58	-53.1	
CaO(s)	56.08	-635.09	-604.03	39.75	42.80
CaCO ₃ (s) (calcite)	100.09	-1206.9	-1128.8	92.9	81.88
CaCO ₃ (s) (aragonite)	100.09	-1207.1	-1127.8	88.7	81.25
CaF ₂ (s)	78.08	1219.6	-1167.3	68.87	67.03
CaCl ₂ (s)	110.99	-795.8	-748.1	104.6	72.59
CaBr ₂ (s)	199.90	-682.8	-663.6	130	
<i>Carbon (for "organic" compounds, see Table 1)</i>					
C(s) (graphite)	12.011	0	0	5.740	8.527
C(s) (diamond)	12.011	+1.895	+2.900	2.377	6.133
C(g)	12.011	+716.68	+671.26	158.10	20.838
C ₂ (g)	24.022	+831.90	+775.89	199.42	43.21
CO(g)	28.011	-110.53	-137.17	197.67	29.14
CO ₂ (g)	44.010	-393.51	-394.36	213.74	37.11
CO ₂ (aq)	44.010	-413.80	-385.98	117.6	
H ₂ CO ₃ (aq)	62.03	-699.65	-623.08	187.4	
HCO ₃ ⁻ (aq)	61.02	-691.99	-586.77	+91.2	
CO ₃ ²⁻ (aq)	60.01	-677.14	-527.81	-56.9	
CCl ₄ (l)	153.82	-135.44	-65.21	216.40	131.75
CS ₂ (l)	76.14	+89.70	+65.27	151.34	75.7
HCN(g)	27.03	+135.1	+124.7	201.78	35.86
HCN(l)	27.03	+108.87	+124.97	112.84	70.63
CN ⁻ (aq)	26.02	+150.6	+172.4	+94.1	
<i>Cesium</i>					
Cs(s)	132.91	0	0	85.23	32.17
Cs(g)	132.91	+76.06	+49.12	175.60	20.79
Cs ⁺ (aq)	132.91	-258.28	-292.02	+133.05	-10.5
<i>Chlorine</i>					
Cl ₂ (g)	70.91	0	0	223.07	33.91
Cl(g)	35.45	+121.68	+105.68	165.20	21.840
Cl ⁻ (g)	35.45	-233.13			
Cl ⁻ (aq)	35.45	-167.16	-131.23	+56.5	-136.4
HCl(g)	36.46	-92.31	-95.30	186.91	29.12
HCl(aq)	36.46	-167.16	-131.23	56.5	-136.4

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Chromium</i>					
Cr(s)	52.00	0	0	23.77	23.35
Cr(g)	52.00	+396.6	+351.8	174.50	20.79
CrO ₄ ²⁻ (aq)	115.99	-881.15	-727.75	+50.21	
Cr ₂ O ₇ ²⁻ (aq)	215.99	-1490.3	-1301.1	+261.9	
<i>Copper</i>					
Cu(s)	63.54	0	0	33.150	24.44
Cu(g)	63.54	+338.32	+298.58	166.38	20.79
Cu ⁺ (aq)	63.54	+71.67	+49.98	+40.6	
Cu ²⁺ (aq)	63.54	+64.77	+65.49	-99.6	
Cu ₂ O(s)	143.08	-168.6	-146.0	93.14	63.64
CuO(s)	79.54	-157.3	-129.7	42.63	42.30
CuSO ₄ (s)	159.60	-771.36	-661.8	109	100.0
CuSO ₄ ·H ₂ O(s)	177.62	-1085.8	-918.11	146.0	134
CuSO ₄ ·5H ₂ O(s)	249.68	-2279.7	-1879.7	300.4	280
<i>Deuterium</i>					
D ₂ (g)	4.028	0	0	144.96	29.20
HD(g)	3.022	+0.318	-1.464	143.80	29.196
D ₂ O(g)	20.028	-249.20	-234.54	198.34	34.27
D ₂ O(l)	20.028	-294.60	-243.44	75.94	84.35
HD0(g)	19.022	-245.30	-233.11	199.51	33.81
HD0(l)	19.022	-289.89	-241.86	79.29	
<i>Fluorine</i>					
F ₂ (g)	38.00	0	0	202.78	31.30
F(g)	19.00	+78.99	+61.91	158.75	22.74
F ⁻ (aq)	19.00	-332.63	-278.79	-13.8	-106.7
HF(g)	20.01	-271.1	-273.2	173.78	29.13
<i>Gold</i>					
Au(s)	196.97	0	0	47.40	25.42
Au(g)	196.97	+366.1	+326.3	180.50	20.79
<i>Helium</i>					
He(g)	4.003	0	0	126.15	20.786
<i>Hydrogen (see also deuterium)</i>					
H ₂ (g)	2.016	0	0	130.684	28.824
H(g)	1.008	+217.97	+203.25	114.71	20.784
H ⁺ (aq)	1.008	0	0	0	0
H ₂ O(l)	18.015	-285.83	-237.13	69.91	75.291
H ₂ O(g)	18.015	-241.82	-228.57	188.83	33.58
H ₂ O ₂ (l)	34.015	-187.78	-120.35	109.6	89.1

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Iodine</i>					
I ₂ (s)	253.81	0	0	116.135	54.44
I ₂ (g)	253.81	+62.44	+19.33	260.69	36.90
I(g)	126.90	+106.84	+70.25	180.79	20.786
I ⁻ (aq)	126.90	-55.19	-51.57	+111.3	-142.3
HI(g)	127.91	+26.48	+1.70	206.59	29.158
<i>Iron</i>					
Fe(s)	55.85	0	0	27.28	25.10
Fe(g)	55.85	+416.3	+370.7	180.49	25.68
Fe ²⁺ (aq)	55.85	-89.1	-78.90	-137.7	
Fe ³⁺ (aq)	55.85	-48.5	-4.7	-315.9	
Fe ₃ O ₄ (s) (magnetite)	231.54	-1184.4	-1015.4	146.4	143.43
Fe ₂ O ₃ (s) (hematite)	159.69	-824.2	-742.2	87.40	103.85
FeS(s, α)	87.91	-100.0	-100.4	60.29	50.54
FeS ₂ (s)	119.98	-178.2	-166.9	52.93	62.17
<i>Krypton</i>					
Kr(g)	83.80	0	0	164.08	20.786
<i>Lead</i>					
Pb(s)	207.19	0	0	64.81	26.44
Pb(g)	207.19	+195.0	+161.9	175.37	20.79
Pb ²⁺ (aq)	207.19	-1.7	-24.43	+10.5	
PbO(s, yellow)	223.19	-217.32	-187.89	68.70	45.77
PbO(s, red)	223.19	-218.99	-188.93	66.5	45.81
PbO ₂ (s)	239.19	-277.4	-217.33	68.6	64.64
<i>Lithium</i>					
Li(s)	6.94	0	0	29.12	24.77
Li(g)	6.94	+159.37	+126.66	138.77	20.79
Li ⁺ (aq)	6.94	-278.49	-293.31	+13.4	+68.6
<i>Magnesium</i>					
Mg(s)	24.31	0	0	32.68	24.89
Mg(g)	24.31	+147.70	+113.10	148.65	20.786
Mg ²⁺ (aq)	24.31	-466.85	-454.8	-138.1	
MgO(s)	40.31	-601.70	-569.43	26.94	37.15
MgCO ₃ (s)	84.32	-1095.8	-1012.1	65.7	75.52
MgCl ₂ (s)	95.22	-641.32	-591.79	89.62	71.38
MgBr ₂ (s)	184.13	-524.3	-503.8	117.2	
<i>Mercury</i>					
Hg(l)	200.59	0	0	76.02	27.983
Hg(g)	200.59	+61.32	+31.82	174.96	20.786
Hg ²⁺ (aq)	200.59	+171.1	+164.40	-32.2	

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Mercury (continued)</i>					
Hg ₂ ²⁺ (aq)	401.18	+172.4	+153.52	+84.5	
HgO(s)	216.59	-90.83	-58.54	70.29	44.06
Hg ₂ Cl ₂ (s)	472.09	-265.22	-210.75	192.5	102
HgCl ₂ (s)	271.50	-224.3	-178.6	146.0	
HgS(s, black)	232.65	-53.6	-47.7	88.3	
<i>Neon</i>					
Ne(g)	20.18	0	0	146.33	20.786
<i>Nitrogen</i>					
N ₂ (g)	28.013	0	0	191.61	29.125
N(g)	14.007	+472.70	+455.56	153.30	20.786
NO(g)	30.01	+90.25	+86.55	210.76	29.844
N ₂ O(g)	44.01	+82.05	+104.20	219.85	38.45
NO ₂ (g)	46.01	+33.18	+51.31	240.06	37.20
N ₂ O ₄ (g)	92.01	+9.16	+97.89	304.29	77.28
N ₂ O ₅ (s)	108.01	-43.1	+113.9	178.2	143.1
N ₂ O ₅ (g)	108.01	+11.3	+115.1	355.7	84.5
HNO ₃ (l)	63.01	-174.10	-80.71	155.60	109.87
HNO ₃ (aq)	63.01	-207.36	-111.25	146.4	-86.6
NO ₃ ⁻ (aq)	62.01	-205.0	-108.74	+146.4	-86.6
NH ₃ (g)	17.03	-46.11	-16.45	192.45	35.06
NH ₃ (aq)	17.03	-80.29	-26.50	113.3	
NH ₄ ⁺ (aq)	18.04	-132.51	-79.31	+113.4	+79.9
NH ₂ OH(s)	33.03	-114.2			
HN ₃ (l)	43.03	+264.0	+327.3	140.6	43.68
NH ₃ (g)	43.03	+294.1	+328.1	238.97	98.87
N ₂ H ₄ (l)	32.05	+50.63	+149.43	121.21	139.3
NH ₄ NO ₃ (s)	80.04	-365.56	-183.87	151.08	84.1
NH ₄ Cl(s)	53.49	-314.43	-202.87	94.6	
<i>Oxygen</i>					
O ₂ (g)	31.999	0	0	205.138	29.355
O(g)	15.999	+249.17	+231.73	161.06	21.912
O ₃ (g)	47.998	+142.7	+163.2	238.93	39.20
OH ⁻ (aq)	17.007	-229.99	-157.24	-10.75	-148.5
<i>Phosphorus</i>					
P(s, wh)	30.97	0	0	41.09	23.840
P(g)	30.97	+314.64	+278.25	163.19	20.786
P ₂ (g)	61.95	+144.3	+103.7	218.13	32.05
P ₄ (g)	123.90	+58.91	+24.44	279.98	67.15
PH ₃ (g)	34.00	+5.4	+13.4	210.23	37.11
PCl ₃ (g)	137.33	-287.0	-267.8	311.78	71.84
PCl ₃ (l)	137.33	-319.7	-272.3	217.1	

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Phosphorus (continued)</i>					
PCl ₅ (g)	208.24	-374.9	-305.0	364.6	112.8
PCl ₅ (s)	208.24	-443.5			
H ₃ PO ₃ (s)	82.00	-964.4			
H ₃ PO ₃ (aq)	82.00	-964.8			
H ₃ PO ₄ (s)	94.97	-1279.0	-1119.1	110.50	106.06
H ₃ PO ₄ (l)	94.97	-1266.9			
H ₃ PO ₄ (aq)	94.97	-1277.4	-1018.7	-222	
PO ₄ ³⁻ (aq)	94.97	-1277.4	-1018.7	-222	
P ₄ O ₁₀ (s)	283.89	-2984.0	-2697.0	228.86	211.71
P ₄ O ₆ (s)	219.89	-1640.1			
<i>Potassium</i>					
K(s)	39.10	0	0	64.18	29.58
K(g)	39.10	+89.24	+60.59	160.336	20.786
K ⁺ (g)	39.10	+514.26			
K ⁺ (aq)	39.10	-252.38	-283.27	+102.5	+21.8
KOH(s)	56.11	-424.76	-379.08	78.9	64.9
KF(s)	58.10	-576.27	-537.75	66.57	49.04
KCl(s)	74.56	-436.75	-409.14	82.59	51.30
KBr(s)	119.01	-393.80	-380.66	95.90	52.30
KI(s)	166.01	-327.90	-324.89	106.32	52.93
<i>Silicon</i>					
Si(s)	28.09	0	0	18.83	20.00
Si(g)	28.09	+455.6	+411.3	167.97	22.25
SiO ₂ (s, α)	60.09	-910.93	-856.64	41.84	44.43
<i>Silver</i>					
Ag(s)	107.87	0	0	42.55	25.351
Ag(g)	107.87	+284.55	+245.65	173.00	20.79
Ag ⁺ (aq)	107.87	+105.58	+77.11	+72.68	+21.8
AgBr(s)	187.78	-100.37	-96.90	107.1	52.38
AgCl(s)	143.32	-127.07	-109.79	96.2	50.79
Ag ₂ O(s)	231.74	-31.05	-11.20	121.3	65.86
AgNO ₃ (s)	169.88	-124.39	-33.41	140.92	93.05
<i>Sodium</i>					
Na(s)	22.99	0	0	51.21	28.24
Na(g)	22.99	+107.32	+76.76	153.71	20.79
Na ⁺ (aq)	22.99	-240.12	-261.91	+59.0	+46.4
NaOH(s)	40.00	-425.61	-379.49	64.46	59.54
NaCl(s)	58.44	-411.15	-384.14	72.13	50.50
NaBr(s)	102.90	-361.06	-348.98	86.82	51.38
NaI(s)	149.89	-287.78	-286.06	98.53	52.09

(continued)

Table 2 (continued)

	$M/$ (g mol ⁻¹)	$\Delta_f H^\ominus/$ (kJ mol ⁻¹)	$\Delta_f G^\ominus/$ (kJ mol ⁻¹)	$S_m^\ominus/$ (J K ⁻¹ mol ⁻¹)	$C_{p,m}/$ (J K ⁻¹ mol ⁻¹)
<i>Sulfur</i>					
S(s, α) (rhombic)	32.06	0	0	31.80	22.64
S(s, β) (monoclinic)	32.06	+0.33	+0.1	32.6	23.6
S(g)	32.06	+278.81	+238.25	167.82	23.673
S ₂ (g)	64.13	+128.37	+79.30	228.18	32.47
S ²⁻ (aq)	32.06	+33.1	+85.8	-14.6	
SO ₂ (g)	64.06	-296.83	-300.19	248.22	39.87
SO ₃ (g)	80.06	-395.72	-371.06	256.76	50.67
H ₂ SO ₄ (l)	98.08	-813.99	-690.00	156.90	138.9
H ₂ SO ₄ (aq)	98.08	-909.27	-744.53	20.1	-293
SO ₄ ²⁻ (aq)	96.06	-909.27	-744.53	+20.1	-293
HSO ₄ ⁻ (aq)	97.07	-887.34	-755.91	+131.8	-84
H ₂ S(g)	34.08	-20.63	-33.56	205.79	34.23
H ₂ S(aq)	34.08	-39.7	-27.83	121	
HS ⁻ (aq)	33.072	-17.6	+12.08	+62.08	
SF ₆ (g)	146.05	-1209	-1105.3	291.82	97.28
<i>Tin</i>					
Sn(s, β)	118.69	0	0	51.55	26.99
Sn(g)	118.69	+302.1	+267.3	168.49	20.26
Sn ²⁺ (aq)	118.69	-8.8	-27.2	-17	
SnO(s)	134.69	-285.8	-256.8	56.5	44.31
SnO ₂ (s)	150.69	-580.7	+519.6	52.3	52.59
<i>Xenon</i>					
Xe(g)	131.30	0	0	169.68	20.786
<i>Zinc</i>					
Zn(s)	65.37	0	0	41.63	25.40
Zn(g)	65.37	+130.73	+95.14	160.98	20.79
Zn ²⁺ (aq)	65.37	-153.89	-147.06	-112.1	+46
ZnO(s)	81.37	-348.28	-318.30	43.64	40.25

*Entropies and heat capacities of ions are relative to H⁺(aq) and are given with a sign.

Table 3a Standard potentials at 298.15 K in electrochemical order

Reduction half-reaction	$E^\ominus/V$	Reduction half-reaction	$E^\ominus/V$
<i>Strongly oxidizing</i>		$\text{Cu}^{2+} + \text{e}^- \longrightarrow \text{Cu}^+$	+0.16
$\text{H}_4\text{XeO}_6 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{XeO}_3 + 3 \text{H}_2\text{O}$	+3.0	$\text{Sn}^{4+} + 2 \text{e}^- \longrightarrow \text{Sn}^{2+}$	+0.15
$\text{F}_2 + 2 \text{e}^- \longrightarrow 2 \text{F}^-$	+2.87	$\text{AgBr} + \text{e}^- \longrightarrow \text{Ag} + \text{Br}^-$	+0.07
$\text{O}_3 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{O}_2 + \text{H}_2\text{O}$	+2.07	$\text{Ti}^{4+} + \text{e}^- \longrightarrow \text{Ti}^{3+}$	0.00
$\text{S}_2\text{O}_8^{2-} + 2 \text{e}^- \longrightarrow 2 \text{SO}_4^{2-}$	+2.05	$2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{H}$	0, by definition
$\text{Ag}^{2+} + \text{e}^- \longrightarrow \text{Ag}^+$	+1.98	$\text{Fe}^{3+} + 3 \text{e}^- \longrightarrow \text{Fe}$	-0.04
$\text{Co}^{3+} + \text{e}^- \longrightarrow \text{Co}^{2+}$	+1.81	$\text{O}_2 + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{HO}_2^- + \text{OH}^-$	-0.08
$\text{HO}_2 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}$	+1.78	$\text{Pb}^{2+} + 2 \text{e}^- \longrightarrow \text{Pb}$	-0.13
$\text{Au}^+ + \text{e}^- \longrightarrow \text{Au}$	+1.69	$\text{In}^+ + \text{e}^- \longrightarrow \text{In}$	-0.14
$\text{Pb}^{4+} + 2 \text{e}^- \longrightarrow \text{Pb}^{2+}$	+1.67	$\text{Sn}^{2+} + 2 \text{e}^- \longrightarrow \text{Sn}$	-0.14
$2 \text{HClO} + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Cl}_2 + 2 \text{H}_2\text{O}$	+1.63	$\text{AgI} + \text{e}^- \longrightarrow \text{Ag} + \text{I}^-$	-0.15
$\text{Ce}^{4+} + \text{e}^- \longrightarrow \text{Ce}^{3+}$	+1.61	$\text{Ni}^{2+} + 2 \text{e}^- \longrightarrow \text{Ni}$	-0.23
$2 \text{HBrO} + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Br}_2 + 2 \text{H}$	+1.60	$\text{Co}^{2+} + 2 \text{e}^- \longrightarrow \text{Co}$	-0.28
$\text{MnO}_4^- + 8 \text{H}^+ + 5 \text{e}^- \longrightarrow \text{Mn}^{2+} + 4 \text{H}_2\text{O}$	+1.51	$\text{In}^{3+} + 3 \text{e}^- \longrightarrow \text{In}$	-0.34
$\text{Mn}^{3+} + \text{e}^- \longrightarrow \text{Mn}^{2+}$	+1.51	$\text{Tl}^+ + \text{e}^- \longrightarrow \text{Tl}$	-0.34
$\text{Au}^{3+} + 3 \text{e}^- \longrightarrow \text{Au}$	+1.40	$\text{PbSO}_4 + 2 \text{e}^- \longrightarrow \text{Pb} + \text{SO}_4^{2-}$	-0.36
$\text{Cl}_2 + 2 \text{e}^- \longrightarrow 2 \text{Cl}^-$	+1.36	$\text{Ti}^{3+} + \text{e}^- \longrightarrow \text{Ti}^{2+}$	-0.37
$\text{Cr}_2\text{O}_7^{2-} + 14 \text{H}^+ + 6 \text{e}^- \longrightarrow 2 \text{Cr}^{3+} + 7 \text{H}_2\text{O}$	+1.33	$\text{Cd}^{2+} + 2 \text{e}^- \longrightarrow \text{Cd}$	-0.40
$\text{O}_3 + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{O}_2 + 2 \text{OH}^-$	+1.24	$\text{In}^{2+} + \text{e}^- \longrightarrow \text{In}^+$	-0.40
$\text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}$	+1.23	$\text{Cr}^{3+} + \text{e}^- \longrightarrow \text{Cr}^{2+}$	-0.41
$\text{ClO}_4^- + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{ClO}_3^- + \text{H}_2\text{O}$	+1.23	$\text{Fe}^{2+} + 2 \text{e}^- \longrightarrow \text{Fe}$	-0.44
$\text{MnO}_2 + 4 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Mn}^{2+} + 2 \text{H}_2\text{O}$	+1.23	$\text{In}^{3+} + 2 \text{e}^- \longrightarrow \text{In}^+$	-0.44
$\text{Br}_2 + 2 \text{e}^- \longrightarrow 2 \text{Br}^-$	+1.09	$\text{S} + 2 \text{e}^- \longrightarrow \text{S}^{2-}$	-0.48
$\text{Pu}^{4+} + \text{e}^- \longrightarrow \text{Pu}^{3+}$	+0.97	$\text{In}^{3+} + \text{e}^- \longrightarrow \text{In}^{2+}$	-0.49
$\text{NO}_3^- + 4 \text{H}^+ + 3 \text{e}^- \longrightarrow \text{NO} + 2 \text{H}_2\text{O}$	+0.96	$\text{U}^{4+} + \text{e}^- \longrightarrow \text{U}^{3+}$	-0.61
$2 \text{Hg}^{2+} + 2 \text{e}^- \longrightarrow \text{Hg}_2^{2+}$	+0.92	$\text{Cr}^{3+} + 3 \text{e}^- \longrightarrow \text{Cr}$	-0.74
$\text{ClO}^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{Cl}^- + 2 \text{OH}^-$	+0.89	$\text{Zn}^{2+} + 2 \text{e}^- \longrightarrow \text{Zn}$	-0.76
$\text{Hg}_2^{2+} + 2 \text{e}^- \longrightarrow \text{Hg}$	+0.86	$\text{Cd}(\text{OH})_2 + 2 \text{e}^- \longrightarrow \text{Cd} + 2 \text{OH}^-$	-0.81
$\text{NO}_3^- + 2 \text{H}^+ + \text{e}^- \longrightarrow \text{NO}_2 + \text{H}_2\text{O}$	+0.80	$2 \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{H}_2 + 2 \text{OH}^-$	-0.83
$\text{Ag}^+ + \text{e}^- \longrightarrow \text{Ag}$	+0.80	$\text{Cr}^{2+} + 2 \text{e}^- \longrightarrow \text{Cr}$	-0.91
$\text{Hg}_2^{2+} + 2 \text{e}^- \longrightarrow 2 \text{Hg}$	+0.79	$\text{Mn}^{2+} + 2 \text{e}^- \longrightarrow \text{Mn}$	-1.18
$\text{Fe}^{3+} + \text{e}^- \longrightarrow \text{Fe}^{2+}$	+0.77	$\text{V}^{2+} + 2 \text{e}^- \longrightarrow \text{V}$	-1.19
$\text{BrO}^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{Br}^- + 2 \text{OH}^-$	+0.76	$\text{Ti}^{2+} + 2 \text{e}^- \longrightarrow \text{Ti}$	-1.63
$\text{Hg}_2\text{SO}_4 + 2 \text{e}^- \longrightarrow 2 \text{Hg} + \text{SO}_4^{2-}$	+0.62	$\text{Al}^{3+} + 3 \text{e}^- \longrightarrow \text{Al}$	-1.66
$\text{MnO}_4^{2-} + 2 \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{MnO}_2 + 4 \text{OH}^-$	+0.60	$\text{U}^{3+} + 3 \text{e}^- \longrightarrow \text{U}$	-1.79
$\text{MnO}_4^- + \text{e}^- \longrightarrow \text{MnO}_4^{2-}$	+0.56	$\text{Mg}^{2+} + 2 \text{e}^- \longrightarrow \text{Mg}$	-2.36
$\text{I}_2 + 2 \text{e}^- \longrightarrow 2 \text{I}^-$	+0.54	$\text{Ce}^{3+} + 3 \text{e}^- \longrightarrow \text{Ce}$	-2.48
$\text{Cu}^+ + \text{e}^- \longrightarrow \text{Cu}$	+0.52	$\text{La}^{3+} + 3 \text{e}^- \longrightarrow \text{La}$	-2.52
$\text{I}_3^- + 2 \text{e}^- \longrightarrow 3 \text{I}^-$	+0.53	$\text{Na}^+ + \text{e}^- \longrightarrow \text{Na}$	-2.71
$\text{NiOOH} + \text{H}_2\text{O} + \text{e}^- \longrightarrow \text{Ni}(\text{OH})_2\text{OH}^-$	+0.49	$\text{Ca}^{2+} + 2 \text{e}^- \longrightarrow \text{Ca}$	-2.87
$\text{IAg}_2\text{CrO}_4 + 2 \text{e}^- \longrightarrow 2 \text{Ag} + \text{CrO}_4^{2-}$	+0.45	$\text{Sr}^{2+} + 2 \text{e}^- \longrightarrow \text{Sr}$	-2.89
$\text{O}_2 + 2 \text{H}_2\text{O} + 4 \text{e}^- \longrightarrow 4 \text{OH}^-$	+0.40	$\text{Ba}^{2+} + 2 \text{e}^- \longrightarrow \text{Ba}$	-2.91
$\text{ClO}_4^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{ClO}_3^- + 2 \text{OH}^-$	+0.36	$\text{Ra}^{2+} + 2 \text{e}^- \longrightarrow \text{Ra}$	-2.92
$[\text{Fe}(\text{CN})_6]^{3-} + \text{e}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{4-}$	+0.36	$\text{Cs}^+ + \text{e}^- \longrightarrow \text{Cs}$	-2.92
$\text{Cu}^{2+} + 2 \text{e}^- \longrightarrow \text{Cu}$	+0.34	$\text{Rb}^+ + \text{e}^- \longrightarrow \text{Rb}$	-2.93
$\text{Hg}_2\text{Cl}_2 + 2 \text{e}^- \longrightarrow 2 \text{Hg} + 2 \text{Cl}^-$	+0.27	$\text{K}^+ + \text{e}^- \longrightarrow \text{K}$	-2.93
$\text{AgCl} + \text{e}^- \longrightarrow \text{Ag} + \text{Cl}^-$	+0.22	$\text{Li}^+ + \text{e}^- \longrightarrow \text{Li}$	-3.05
$\text{Bi}^{3+} + 3 \text{e}^- \longrightarrow \text{Bi}$	+0.20	<i>Strongly reducing</i>	

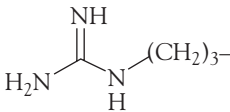
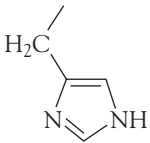
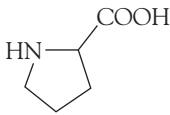
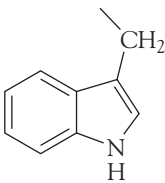
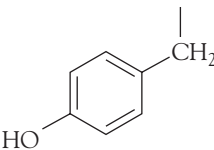
Table 3b Standard potentials at 298.15 K in alphabetical order

Reduction half-reaction	$E^\ominus/V$	Reduction half-reaction	$E^\ominus/V$
$\text{Ag}^+ + \text{e}^- \longrightarrow \text{Ag}$	+0.80	$\text{I}_2 + 2 \text{e}^- \longrightarrow 2 \text{I}^-$	+0.54
$\text{Ag}^{2+} + \text{e}^- \longrightarrow \text{Ag}^+$	+1.98	$\text{I}_3^- + 2 \text{e}^- \longrightarrow 3 \text{I}^-$	+0.53
$\text{AgBr} + \text{e}^- \longrightarrow \text{Ag} + \text{Br}^-$	+0.0713	$\text{In}^+ + \text{e}^- \longrightarrow \text{In}$	-0.14
$\text{AgCl} + \text{e}^- \longrightarrow \text{Ag} + \text{Cl}^-$	+0.22	$\text{In}^{2+} + \text{e}^- \longrightarrow \text{In}^+$	-0.40
$\text{Ag}_2\text{CrO}_4 + 2 \text{e}^- \longrightarrow 2 \text{Ag} + \text{CrO}_4^{2-}$	+0.45	$\text{In}^{3+} + 2 \text{e}^- \longrightarrow \text{In}^+$	-0.44
$\text{AgF} + \text{e}^- \longrightarrow \text{Ag} + \text{F}^-$	+0.78	$\text{In}^{3+} + 3 \text{e}^- \longrightarrow \text{In}$	-0.34
$\text{AgI} + \text{e}^- \longrightarrow \text{Ag} + \text{I}^-$	-0.15	$\text{In}^{3+} + \text{e}^- \longrightarrow \text{In}^{2+}$	-0.49
$\text{Al}^{3+} + 3 \text{e}^- \longrightarrow \text{Al}$	-1.66	$\text{K}^+ + \text{e}^- \longrightarrow \text{K}$	-2.93
$\text{Au}^+ + \text{e}^- \longrightarrow \text{Au}$	+1.69	$\text{La}^{3+} + 3 \text{e}^- \longrightarrow \text{La}$	-2.52
$\text{Au}^{3+} + 3 \text{e}^- \longrightarrow \text{Au}$	+1.40	$\text{Li}^+ + \text{e}^- \longrightarrow \text{Li}$	-3.05
$\text{Ba}^{2+} + 2 \text{e}^- \longrightarrow \text{Ba}$	-2.91	$\text{Mg}^{2+} + 2 \text{e}^- \longrightarrow \text{Mg}$	-2.36
$\text{Be}^{2+} + 2 \text{e}^- \longrightarrow \text{Be}$	-1.85	$\text{Mn}^{2+} + 2 \text{e}^- \longrightarrow \text{Mn}$	-1.18
$\text{Bi}^{3+} + 3 \text{e}^- \longrightarrow \text{Bi}$	+0.20	$\text{Mn}^{3+} + \text{e}^- \longrightarrow \text{Mn}^{2+}$	+1.51
$\text{Br}_2 + 2 \text{e}^- \longrightarrow 2 \text{Br}^-$	+1.09	$\text{MnO}_2 + 4 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Mn}^{2+} + 2 \text{H}_2\text{O}$	+1.23
$\text{BrO}^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{Br}^- + 2 \text{OH}^-$	+0.76	$\text{MnO}_4^- + 8 \text{H}^+ + 5 \text{e}^- \longrightarrow \text{Mn}^{2+} + 4 \text{H}_2\text{O}$	+1.51
$\text{Ca}^{2+} + 2 \text{e}^- \longrightarrow \text{Ca}$	-2.87	$\text{MnO}_4^- + \text{e}^- \longrightarrow \text{MnO}_4^{2-}$	+0.56
$\text{Cd}(\text{OH})_2 + 2 \text{e}^- \longrightarrow \text{Cd} + 2 \text{OH}^-$	-0.81	$\text{MnO}_4^{2-} + 2 \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{MnO}_2 + 4 \text{OH}^-$	+0.60
$\text{Cd}^{2+} + 2 \text{e}^- \longrightarrow \text{Cd}$	-0.40	$\text{Na}^+ + \text{e}^- \longrightarrow \text{Na}$	-2.71
$\text{Ce}^{3+} + 3 \text{e}^- \longrightarrow \text{Ce}$	-2.48	$\text{Ni}^{2+} + 2 \text{e}^- \longrightarrow \text{Ni}$	-0.23
$\text{Ce}^{4+} + \text{e}^- \longrightarrow \text{Ce}^{3+}$	+1.61	$\text{NiOOH} + \text{H}_2\text{O} + \text{e}^- \longrightarrow \text{Ni}(\text{OH})_2 + \text{OH}^-$	+0.49
$\text{Cl}_2 + 2 \text{e}^- \longrightarrow 2 \text{Cl}^-$	+1.36	$\text{NO}_3^- + 2 \text{H}^+ + \text{e}^- \longrightarrow \text{NO}_2 + \text{H}_2\text{O}$	+0.80
$\text{ClO}^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{Cl}^- + 2 \text{OH}^-$	+0.89	$\text{NO}_3^- + 3 \text{H}^+ + 3 \text{e}^- \longrightarrow \text{NO} + 2 \text{H}_2\text{O}$	+0.96
$\text{ClO}_4^- + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{ClO}_3^- + \text{H}_2\text{O}$	+1.23	$\text{NO}_3^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{NO}_2^- + 2 \text{OH}^-$	+0.10
$\text{ClO}_4^- + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{ClO}_3^- + 2 \text{OH}^-$	+0.36	$\text{O}_2 + 2 \text{H}_2\text{O} + 4 \text{e}^- \longrightarrow 4 \text{OH}^-$	+0.40
$\text{Co}^{2+} + 2 \text{e}^- \longrightarrow \text{Co}$	-0.28	$\text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}$	+1.23
$\text{Co}^{3+} + \text{e}^- \longrightarrow \text{Co}^{2+}$	+1.81	$\text{O}_2 + \text{e}^- \longrightarrow \text{O}_2^-$	-0.56
$\text{Cr}^{2+} + 2 \text{e}^- \longrightarrow \text{Cr}$	-0.91	$\text{O}_2 + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{HO}_2^- + \text{OH}^-$	-0.08
$\text{Cr}_2\text{O}_7^{2-} + 14 \text{H}^+ + 6 \text{e}^- \longrightarrow 2 \text{Cr}^{3+} + 7 \text{H}_2\text{O}$	+1.33	$\text{O}_3 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{O}_2 + \text{H}_2\text{O}$	+2.07
$\text{Cr}^{3+} + 3 \text{e}^- \longrightarrow \text{Cr}$	-0.74	$\text{O}_3 + \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{O}_2 + 2 \text{OH}^-$	+1.24
$\text{Cr}^{3+} + \text{e}^- \longrightarrow \text{Cr}^{2+}$	-0.41	$\text{Pb}^{2+} + 2 \text{e}^- \longrightarrow \text{Pb}$	-0.13
$\text{Cs}^+ + \text{e}^- \longrightarrow \text{Cs}$	-2.92	$\text{Pb}^{4+} + 2 \text{e}^- \longrightarrow \text{Pb}^{2+}$	+1.67
$\text{Cu}^+ + \text{e}^- \longrightarrow \text{Cu}$	+0.52	$\text{PbSO}_4 + 2 \text{e}^- \longrightarrow \text{Pb} + \text{SO}_4^{2-}$	-0.36
$\text{Cu}^{2+} + 2 \text{e}^- \longrightarrow \text{Cu}$	+0.34	$\text{Pt}^{2+} + 2 \text{e}^- \longrightarrow \text{Pt}$	+1.20
$\text{Cu}^{2+} + \text{e}^- \longrightarrow \text{Cu}^+$	+0.16	$\text{Pu}^{4+} + \text{e}^- \longrightarrow \text{Pu}^{3+}$	+0.97
$\text{F}_2 + 2 \text{e}^- \longrightarrow 2 \text{F}^-$	+2.87	$\text{Ra}^{2+} + 2 \text{e}^- \longrightarrow \text{Ra}$	-2.92
$\text{Fe}^{2+} + 2 \text{e}^- \longrightarrow \text{Fe}$	-0.44	$\text{Rb}^+ + \text{e}^- \longrightarrow \text{Rb}$	-2.93
$\text{Fe}^{3+} + 3 \text{e}^- \longrightarrow \text{Fe}$	-0.04	$\text{S} + 2 \text{e}^- \longrightarrow \text{S}^{2-}$	-0.48
$\text{Fe}^{3+} + \text{e}^- \longrightarrow \text{Fe}^{2+}$	+0.77	$\text{S}_2\text{O}_8^{2-} + 2 \text{e}^- \longrightarrow 2 \text{SO}_4^{2-}$	+2.05
$[\text{Fe}(\text{CN})_6]^{3-} + \text{e}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{4-}$	+0.36	$\text{Sn}^{2+} + 2 \text{e}^- \longrightarrow \text{Sn}$	-0.14
$2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{H}_2$	0, by definition	$\text{Sn}^{4+} + 2 \text{e}^- \longrightarrow \text{Sn}^{2+}$	+0.15
$2 \text{H}_2\text{O} + 2 \text{e}^- \longrightarrow \text{H}_2 + 2 \text{OH}^-$	-0.83	$\text{Sr}^{2+} + 2 \text{e}^- \longrightarrow \text{Sr}$	-2.89
$2 \text{HBrO} + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Br}_2 + 2 \text{H}_2\text{O}$	+1.60	$\text{Ti}^{2+} + 2 \text{e}^- \longrightarrow \text{Ti}$	-1.63
$2 \text{HClO} + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{Cl}_2 + 2 \text{H}_2\text{O}$	+1.63	$\text{Ti}^{3+} + \text{e}^- \longrightarrow \text{Ti}^{2+}$	-0.37
$\text{H}_2\text{O}_2 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}$	+1.78	$\text{Ti}^{4+} + \text{e}^- \longrightarrow \text{Ti}^{3+}$	0.00
$\text{H}_4\text{XeO}_6 + 2 \text{H}^+ + 2 \text{e}^- \longrightarrow \text{XeO}_3 + 3 \text{H}_2\text{O}$	+3.0	$\text{Tl}^+ + \text{e}^- \longrightarrow \text{Tl}$	-0.34
$\text{Hg}_2^{2+} + 2 \text{e}^- \longrightarrow 2 \text{Hg}$	+0.79	$\text{U}^{3+} + 3 \text{e}^- \longrightarrow \text{U}$	-1.79
$\text{Hg}_2\text{Cl}_2 + 2 \text{e}^- \longrightarrow 2 \text{Hg} + 2 \text{Cl}^-$	+0.27	$\text{U}^{4+} + \text{e}^- \longrightarrow \text{U}^{3+}$	-0.61
$\text{Hg}^{2+} + 2 \text{e}^- \longrightarrow \text{Hg}$	+0.86	$\text{V}^{2+} + 2 \text{e}^- \longrightarrow \text{V}$	-1.19
$2 \text{Hg}^{2+} + 2 \text{e}^- \longrightarrow \text{Hg}_2^{2+}$	+0.92	$\text{V}^{3+} + \text{e}^- \longrightarrow \text{V}^{2+}$	-0.26
$\text{Hg}_2\text{SO}_4 + 2 \text{e}^- \longrightarrow 2 \text{Hg} + \text{SO}_4^{2-}$	+0.62	$\text{Zn}^{2+} + 2 \text{e}^- \longrightarrow \text{Zn}$	-0.76

Table 3c Biological standard potentials at 298.15 K in electrochemical order

Reduction half-reaction	$E^\ominus/V$
$O_2 + 4 H^+ + 4 e^- \longrightarrow 2 H_2O$	+0.81
$NO_3^- + 2 H^+ + 2 e^- \longrightarrow NO_2^- + H_2O$	+0.42
$Fe^{3+}(\text{cyt } f) + e^- \longrightarrow Fe^{2+}(\text{cyt } f)$	+0.36
$Cu^{2+}(\text{plastocyanin}) + e^- \longrightarrow Cu^+(\text{plastocyanin})$	+0.35
$Cu^{2+}(\text{azurin}) + e^- \longrightarrow Cu^+(\text{azurin})$	+0.30
$O_2 + 2 H^+ + 2 e^- \longrightarrow H_2O_2$	+0.30
$Fe^{3+}(\text{cyt } c_{551}) + e^- \longrightarrow Fe^{2+}(\text{cyt } c_{551})$	+0.29
$Fe^{3+}(\text{cyt } c) + e^- \longrightarrow Fe^{2+}(\text{cyt } c)$	+0.25
$Fe^{3+}(\text{cyt } b) + e^- \longrightarrow Fe^{2+}(\text{cyt } b)$	+0.08
Dehydroascorbic acid + $2 H^+ + 2 e^- \longrightarrow$ ascorbic acid	+0.08
Coenzyme Q + $2 H^+ + 2 e^- \longrightarrow$ coenzyme QH_2	+0.04
Fumarate $^{2-}$ + $2 H^+ + 2 e^- \longrightarrow$ succinate $^{2-}$	+0.03
Vitamin $K_1(\text{ox}) + 2 H^+ + 2 e^- \longrightarrow$ vitamin $K_1(\text{red})$	-0.05
Oxaloacetate $^{2-}$ + $2 H^+ + 2 e^- \longrightarrow$ malate $^{2-}$	-0.17
Pyruvate $^-$ + $2 H^+ + 2 e^- \longrightarrow$ lactate $^-$	-0.18
Ethanal + $2 H^+ + 2 e^- \longrightarrow$ ethanol	-0.20
Riboflavin(ox) + $2 H^+ + 2 e^- \longrightarrow$ riboflavin (red)	-0.21
FAD + $2 H^+ + 2 e^- \longrightarrow$ FADH $_2$	-0.22
Glutathione (ox) + $2 H^+ + 2 e^- \longrightarrow$ glutathione (red)	-0.23
Lipoic acid (ox) + $2 H^+ + 2 e^- \longrightarrow$ lipoic acid (red)	-0.29
NAD $^+$ + $H^+ + 2 e^- \longrightarrow$ NADH	-0.32
Cystine + $2 H^+ + 2 e^- \longrightarrow$ 2 cysteine	-0.34
Acetyl-CoA + $2 H^+ + 2 e^- \longrightarrow$ ethanal + CoA	-0.41
$2H_2O + 2 e^- \longrightarrow H_2 + 2 OH^-$	-0.42
Ferredoxin (ox) + $e^- \longrightarrow$ ferredoxin (red)	-0.43
$O_2 + e^- \longrightarrow O_2^-$	-0.45

Table 4 The amino acids

Amino acid, R—CH(NH ₂)COOH	Structure, R =	Abbreviations Three-letter	One-letter
Alanine	CH ₃ —	Ala	A
Arginine		Arg	R
Asparagine	H ₂ NCOCH ₂ —	Asn	N
Aspartic acid	HOOCCH ₂ —	Asp	D
<i>Asparagine or aspartic acid</i>		Asx	B
Cysteine	HSCH ₂ —	Cys	C
Glutamine	H ₂ NCO(CH ₂) ₂ —	Gln	Q
Glutamic acid	HOOC(CH ₂) ₂ —	Glu	E
<i>Glutamine or glutamic acid</i>		Glx	Z
Glycine	H—	Gly	G
Histidine		His	H
Isoleucine	CH ₃ CH ₂ CH(CH ₃)—	Ile	I
Leucine	(CH ₃) ₂ CHCH ₂ —	Leu	L
Lysine	NH ₂ (CH ₂) ₄ —	Lys	K
Methionine	CH ₃ SCH ₂ CH ₂ —	Met	M
Phenylalanine	C ₆ H ₅ CH ₂ —	Phe	F
Proline		Pro	P
Serine	[complete acid] HOCH ₂ —	Ser	S
Threonine	HOCH(CH ₃)—	Thr	T
Tryptophan		Trp	W
Tyrosine		Tyr	Y
Valine	(CH ₃) ₂ CH—	Val	V

Useful relations

Ar 298.15 K

$$RT = 2.4790 \text{ kJ mol}^{-1}$$

$$RT \ln 10/F = 59.160 \text{ mV}$$

$$kT/e = 25.693 \text{ meV}$$

$$RT/F = 25.693 \text{ mV}$$

$$kT/hc = 207.23 \text{ cm}^{-1}$$

$$V_{\text{m}}^{\ominus} = 2.4790 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$$

$$= 24.790 \text{ L mol}^{-1}$$

Selected derived units

Name	Symbol	Definition	Name	Symbol	Definition
newton	1 N	1 kg m s ⁻²	joule	1 J	1 kg m ² s ⁻²
pascal	1 Pa	1 kg m ⁻¹ s ⁻²	watt	1 W	1 J s ⁻¹
volt	1 V	1 J C ⁻¹	ampere	1 A	1 C s ⁻¹
tesla	1 T	1 kg s ⁻² A ⁻¹	poise	1 P	10 ⁻¹ kg m ⁻¹ s ⁻¹
ohm	1 Ω	1 V A ⁻¹	siemens	1 S	1 A V ⁻¹ (= 1 Ω ⁻¹)

Conversion factors

$$1 \text{ eV} = 1.602 \text{ 18} \times 10^{-19} \text{ J}$$

$$96.485 \text{ kJ mol}^{-1}$$

$$8065.5 \text{ cm}^{-1}$$

$$1 \text{ cal} = 4.184^* \text{ J}$$

$$1 \text{ atm} = 101.325^* \text{ kPa}$$

$$760^* \text{ Torr}$$

$$1 \text{ cm}^{-1} = 1.9864 \times 10^{-23} \text{ J}$$

$$1 \text{ D} = 3.335 \text{ 64} \times 10^{-30} \text{ C m}$$

$$1 \text{ Å} = 10^{-10} \text{ m}^*$$

*Exact value.

Mathematical relations

$$\pi = 3.141 \text{ 592 653 59} \dots$$

$$e = 2.718 \text{ 281 828 46} \dots$$

Logarithms and exponentials

$$\ln x + \ln y + \dots = \ln xy \dots$$

$$e^x e^y e^z \dots = e^{x+y+z} \dots$$

$$\ln x - \ln y = \ln(x/y)$$

$$e^x/e^y = e^{x-y}$$

$$a \ln x = \ln x^a$$

$$(e^x)^a = e^{ax}$$

$$\ln x = (\ln 10) \log x = (2.302 \text{ 585} \dots) \log x$$

$$e^{\pm ix} = \cos x \pm i \sin x$$

Taylor expansions

$$f(x) = \sum_{n=0}^{\infty} \frac{1}{n!} \left(\frac{d^n f}{dx^n} \right)_a (x-a)^n$$

$$e^x = 1 + x + \frac{1}{2}x^2 + \dots$$

$$\ln x = (x-1) - \frac{1}{2}(x-1)^2 + \frac{1}{3}(x-1)^3 - \frac{1}{4}(x-1)^4 + \dots$$

$$\ln(1+x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \dots$$

$$\frac{1}{1+x} = 1 - x + x^2 - \dots$$

Derivatives

$$d(f+g) = df + dg$$

$$d(fg) = f dg + g df$$

$$d \frac{f}{g} = \frac{1}{g} df - \frac{f}{g^2} dg$$

$$\frac{df}{dt} = \frac{df}{dg} \frac{dg}{dt}$$

$$dx^n/dx = nx^{n-1}$$

$$de^{ax}/dx = ae^{ax}$$

$$d \ln x/dx = 1/x$$

Integrals

$$\int x^n dx = \frac{x^{n+1}}{n+1} + \text{constant}$$

$$\int \frac{1}{x} dx = \ln x + \text{constant}$$

$$\int_0^{\infty} x^n e^{-ax} dx = \frac{n!}{a^{n+1}}$$

$$\int \sin^2 ax dx = \frac{1}{2}x - (1/4a) \sin 2ax + \text{constant}$$

$$\int \sin ax \sin bx dx = \frac{\sin(a-b)x}{2(a-b)} - \frac{\sin(a+b)x}{2(a+b)} + \text{constant, if } a^2 \neq b^2$$

Prefixes

z	a	f	p	n	μ	m	c	d	Da	k	M	G	T
zepto	atto	femto	pico	nano	micro	milli	centi	deci	deka	kilo	mega	giga	tera
10 ^{−21}	10 ^{−18}	10 ^{−15}	10 ^{−12}	10 ^{−9}	10 ^{−6}	10 ^{−3}	10 ^{−2}	10 ^{−1}	10 ¹	10 ³	10 ⁶	10 ⁹	10 ¹²

Greek alphabet

A, α	alpha	N, ν	nu
B, β	beta	Ξ, ξ	xi
Γ, γ	gamma	O, o	omicron
Δ, δ	delta	Π, π	pi
E, ε	epsilon	P, ρ	rho
Z, ζ	zeta	Σ, σ	sigma
H, η	eta	T, τ	tau
Θ, θ	theta	Υ, υ	upsilon
I, ι	iota	Φ, φ	phi
K, κ	kappa	X, χ	chi
Λ, λ	lambda	Ψ, ψ	psi
M, μ	mu	Ω, ω	omega

General data and fundamental constants

Quantity	Symbol	Value	Power of 10	Units
Speed of light	<i>c</i>	2.997 924 58*	10 ⁸	m s ^{−1}
Elementary charge	<i>e</i>	1.602 177	10 ^{−19}	C
Faraday’s constant	<i>F</i> = <i>N</i> _A <i>e</i>	9.648 53	10 ⁴	C mol ^{−1}
Boltzmann’s constant	<i>k</i>	1.380 66	10 ^{−23}	J K ^{−1}
Gas constant	<i>R</i> = <i>N</i> _A <i>k</i>	8.314 51		J K ^{−1} mol ^{−1}
		8.314 51	10 ^{−2}	L bar K ^{−1} mol ^{−1}
		8.205 78	10 ^{−2}	L atm K ^{−1} mol ^{−1}
		6.236 40	10	L Torr K ^{−1} mol ^{−1}
Planck’s constant	<i>h</i>	6.626 08	10 ^{−34}	J s
	<i>ħ</i> = <i>h</i> /2π	1.054 57	10 ^{−34}	J s
Avogadro’s constant	<i>N</i> _A	6.022 14	10 ²³	mol ^{−1}
Atomic mass unit	<i>u</i>	1.660 54	10 ^{−27}	kg
Mass				
electron	<i>m</i> _e	9.109 39	10 ^{−31}	kg
proton	<i>m</i> _p	1.672 62	10 ^{−27}	kg
neutron	<i>m</i> _n	1.674 93	10 ^{−27}	kg
Vacuum permittivity	<i>ε</i> ₀	8.854 19	10 ^{−12}	J ^{−1} C ² m ^{−1}
	4π <i>ε</i> ₀	1.112 65	10 ^{−10}	J ^{−1} C ² m ^{−1}
Magneton				
Bohr	μ _B = <i>eħ</i> /2 <i>m</i> _e	9.274 02	10 ^{−24}	J T ^{−1}
nuclear	μ _N = <i>eħ</i> /2 <i>m</i> _p	5.050 79	10 ^{−27}	J T ^{−1}
<i>g</i> value	<i>g</i> _e	2.002 32		
Bohr radius	<i>a</i> ₀ = 4π <i>ε</i> ₀ <i>ħ</i> ² / <i>m</i> _e <i>e</i> ²	5.291 77	10 ^{−11}	m
Standard acceleration				
of free fall	<i>g</i>	9.806 65*		m s ^{−2}
Gravitational constant	<i>G</i>	6.672 59	10 ^{−11}	N m ² kg ^{−2}

*Exact value.

PERIODIC TABLE OF THE ELEMENTS

Group

1	2
I	II
IA	IIA

Period 1

1	H
	hydrogen
	1.0079
	1s ¹

Period

2	3 Li lithium 6.94 2s ¹	4 Be beryllium 9.01 2s ²							
3	11 Na sodium 22.99 3s ¹	12 Mg magnesium 24.31 3s ²	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII
4	19 K potassium 39.10 4s ¹	20 Ca calcium 40.08 4s ²	21 Sc scandium 44.96 3d ¹ 4s ²	22 Ti titanium 47.87 3d ² 4s ²	23 V vanadium 50.94 3d ³ 4s ²	24 Cr chromium 52.00 3d ⁵ 4s ¹	25 Mn manganese 54.94 3d ⁵ 4s ²	26 Fe iron 55.84 3d ⁶ 4s ²	27 Co cobalt 58.93 3d ⁷ 4s ²
5	37 Rb rubidium 85.47 5s ¹	38 Sr strontium 87.62 5s ²	39 Y yttrium 88.91 4d ¹ 5s ²	40 Zr zirconium 91.22 4d ² 5s ²	41 Nb niobium 92.91 4d ⁴ 5s ¹	42 Mo molybdenum 95.94 4d ⁵ 5s ¹	43 Tc technetium (98) 4d ⁵ 5s ²	44 Ru ruthenium 101.07 4d ⁷ 5s ¹	45 Rh rhodium 102.90 4d ⁸ 5s ¹
6	55 Cs cesium 132.91 6s ¹	56 Ba barium 137.33 6s ²	57 La lanthanum 138.91 5d ¹ 6s ²	72 Hf hafnium 178.49 5d ² 6s ²	73 Ta tantalum 180.95 5d ³ 6s ²	74 W tungsten 183.84 5d ⁴ 6s ²	75 Re rhenium 186.21 5d ⁵ 6s ²	76 Os osmium 190.23 5d ⁶ 6s ²	77 Ir iridium 192.22 5d ⁷ 6s ²
7	87 Fr francium (223) 7s ¹	88 Ra radium (226) 7s ²	89 Ac actinium (227) 6d ¹ 7s ²	104 Rf rutherfordium (261) 6d ² 7s ²	105 Db dubnium (262) 6d ³ 7s ²	106 Sg seaborgium (263) 6d ⁴ 7s ²	107 Bh bohrium (262) 6d ⁵ 7s ²	108 Hs hassium (265) 6d ⁶ 7s ²	109 Mt meitnerium (266) 6d ⁷ 7s ²

Molar masses (atomic weights)
quoted to the number of
significant figures given
here can be regarded as
typical of most naturally
occurring samples.

6	58 Ce cerium 140.12 4f ¹ 5d ¹ 6s ²	59 Pr praseo- dymium 140.91 4f ³ 6s ²	60 Nd neodmium 144.24 4f ⁴ 6s ²	61 Pm promethium (145) 4f ⁵ 6s ²	62 Sm samarium 150.36 4f ⁶ 6s ²	63 Eu europium 151.96 4f ⁷ 6s ²
7	90 Th thorium 232.04 6d ² 7s ²	91 Pa protactinium 231.04 5f ² 6d ¹ 7s ²	92 U uranium 238.03 5f ³ 6d ¹ 7s ²	93 Np neptunium (237) 5f ⁴ 6d ¹ 7s ²	94 Pu plutonium (244) 5f ⁶ 7s ²	95 Am americium (243) 5f ⁷ 7s ²

										18 VIII VIIA
										2 He helium 4.00 $1s^2$
										13 III IIIA
										14 IV IVA
										15 V VA
										16 VI VIA
										17 VII VIIA
										10 Ne neon 20.18 $2s^2 2p^6$
										18 Ar argon 39.95 $3s^2 3p^6$
										13 Al aluminum 26.98 $3s^2 3p^1$
										14 Si silicon 28.09 $3s^2 3p^2$
										15 P phosphorus 30.97 $3s^2 3p^3$
										16 S sulfur 32.06 $3s^2 3p^4$
										17 Cl chlorine 35.45 $3s^2 3p^5$
10	11 IB	12 IIB								
28 Ni nickel 58.69 $3d^8 4s^2$	29 Cu copper 63.55 $3d^{10} 4s^1$	30 Zn zinc 65.39 $3d^{10} 4s^2$	31 Ga gallium 69.72 $4s^2 4p^1$	32 Ge germanium 72.64 $4s^2 4p^2$	33 As arsenic 74.92 $4s^2 4p^3$	34 Se selenium 78.96 $4s^2 4p^4$	35 Br bromine 79.90 $4s^2 4p^5$	36 Kr krypton 83.80 $4s^2 4p^6$		
46 Pd palladium 106.42 $4d^{10}$	47 Ag silver 107.87 $4d^{10} 5s^1$	48 Cd cadmium 112.41 $4d^{10} 5s^2$	49 In indium 114.82 $5s^2 5p^1$	50 Sn tin 118.71 $5s^2 5p^2$	51 Sb antimony 121.76 $5s^2 5p^3$	52 Te tellurium 127.60 $5s^2 5p^4$	53 I iodine 126.90 $5s^2 5p^5$	54 Xe xenon 131.29 $5s^2 5p^6$		
78 Pt platinum 195.08 $5d^9 6s^1$	79 Au gold 196.97 $5d^{10} 6s^1$	80 Hg mercury 200.59 $5d^{10} 6s^2$	81 Tl thallium 204.38 $6s^2 6p^1$	82 Pb lead 207.2 $6s^2 6p^2$	83 Bi bismuth 208.98 $6s^2 6p^3$	84 Po polonium (209) $6s^2 6p^4$	85 At astatine (210) $6s^2 6p^5$	86 Rn radon (222) $6s^2 6p^6$		
110 Ds darm- stadtium (?)	111 Rg roent- genium (?)	112	113	114	115	116	117	118		

64 Gd gadolinium 157.25 $4f^7 5d^1 6s^2$	65 Tb terbium 158.93 $4f^9 6s^2$	66 Dy dysprosium 162.50 $4f^{10} 6s^2$	67 Ho holmium 164.93 $4f^{11} 6s^2$	68 Er erbium 167.26 $4f^{12} 6s^2$	69 Tm thulium 168.93 $4f^{13} 6s^2$	70 Yb ytterbium 173.04 $4f^{14} 6s^2$	71 Lu lutetium 174.97 $5d^1 6s^2$	Lanthanoids (lanthanides)
96 Cm curium (247) $5f^7 6d^1 7s^2$	97 Bk berkelium (247) $5f^9 7s^2$	98 Cf californium (251) $5f^{10} 7s^2$	99 Es einsteinium (252) $5f^{11} 7s^2$	100 Fm fermium (257) $5f^{12} 7s^2$	101 Md mendelevium (258) $5f^{13} 7s^2$	102 No nobelium (259) $5f^{14} 7s^2$	103 Lr lawrencium (262) $6d^1 7s^2$	Actinoids (actinides)