IAL Chemistry

Data Booklet

Edexcel Advanced Subsidiary Level in IAL Chemistry (XCH01)

Edexcel Advanced Level in IAL Chemistry (YCH01)

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Data from Nuffield Advanced Science Book of Data, Longman 1984

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Contents

Introduction

This data booklet is for use with the Edexcel International Advanced Subsidiary and Advanced Level in Chemistry (XCH01/YCH01) assessments for units 4, 5 and 6.

Students will be provided with a clean copy of this data booklet for these assessments, which should be kept under the same conditions as the assessment papers.

Student may have a copy of this data booklet for their personal use in lessons and for homework, to allow them to become familiar with how to use it.

Selected Elements: Physical and Thermochemical Data

Z	Atomic number	N	Number of atoms per molecule (atomicity) at T_b
St	State under standard conditions	ρ	Density (at 298 K) or density of liquid at T_b for gases
A	Molar mass of element (to one decimal place)	T_b	Boiling temperature (at 1 atm)
T_m	Melting temperature (at 1 atm)	$\Delta H_m^\ominus$	Standard molar enthalpy change of fusion at T_m
$\Delta H_b^\ominus$	Standard molar enthalpy change of vaporization at T_b	$\Delta H_{at}^\ominus$	Standard molar enthalpy change of atomization at 298 K
$S^\ominus$	Standard molar entropy at 298 K		***For this table, the mole applies to single atoms.***

Z	Element		N	St	A /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_m^\ominus$ /kJ mol^{-1}	$\Delta H_b^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	$\Delta H_{at}^\ominus$ /kJ mol^{-1}
1	Hydrogen	H	2	g	1.0	0.07 [20 K]	14	20	0.06	0.45	65.3	218.0
2	Helium	He	1	g	4.0	0.15 [3 K]	1 [26 atm]	4	0.02	0.08	126.0	—
3	Lithium	Li	1	s	6.9	0.53	454	1615	3.02	134.68	29.1	159.4
4	Beryllium	Be	1	s	9.0	1.85	1551	3243	12.50	294.60	9.5	324.3
5	Boron	B	1	s	10.8	2.34	2573	2823 [sub]	22.18	538.90	5.9	562.7
6	Carbon (graphite)	C	1	s	12.0	2.25	3925 -70	5100	—	716.70	5.7	716.7
6	Carbon (diamond)	C	1	s	12.0	3.51	>3823	5100	—	—	2.4	714.8
7	Nitrogen	N	2	g	14.0	0.81 [77 K]	63	77	0.36	2.79	95.8	472.7
8	Oxygen	O	2	g	16.0	1.15 [90 K]	55	90	0.22	3.41	102.5	249.2
9	Fluorine	F	2	g	19.0	1.51 [85 K]	53	85	2.55	3.27	158.6	79.0
10	Neon	Ne	1	g	20.2	1.20 [27 K]	25	27	0.34	1.77	146.2	—
11	Sodium	Na	1	s	23.0	0.97	371	1156	2.60	89.04	51.2	107.3
12	Magnesium	Mg	1	s	24.3	1.74	922	1380	8.95	128.66	32.7	147.7
13	Aluminium	Al	1	s	27.0	2.70	933	2740	10.67	293.72	28.3	326.4
14	Silicon	Si	1	s	28.1	2.33	1683	2628	46.44	376.80	18.8	455.6
15	Phosphorus (red)	P	4	s	31.0	2.34	863 [43 atm]	473	4.71 [143 atm]	30.10 [sub]	22.8	332.2
15	Phosphorus (white)	P	4	s	31.0	1.82	317	553	0.63	12.40	41.1	314.6

Z	Element		N	St	A /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_m^\ominus$ /kJ mol^{-1}	$\Delta H_b^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	$\Delta H_{at}^\ominus$ /kJ mol^{-1}
16	Sulfur (rhombic)	S	8	s	32.1	2.07	386	—	—	—	31.8	278.8
16	Sulfur (monoclinic)	S	8	s	32.1	1.96	392	718	1.41	9.62	32.6	278.5
17	Chlorine	Cl	2	g	35.5	1.56 (238 K)	172	238	3.20	10.20	82.5	121.7
18	Argon	Ar	1	g	39.9	1.40 (87 K)	84	87	1.18	6.52	154.7	—
19	Potassium	K	1	s	39.1	0.86	336	1033	2.32	77.53	64.2	89.2
20	Calcium	Ca	1	s	40.1	1.54	1112	1757	8.66	149.95	41.4	178.2
21	Scandium	Sc	1	s	45.0	2.99	1814	3104	16.11	304.80	34.6	377.8
22	Titanium	Ti	1	s	47.9	4.50	1933	3560	15.48	428.86	30.6	469.9
23	Vanadium	V	1	s	50.9	5.96	2163	3653	17.57	458.57	28.9	514.2
24	Chromium	Cr	1	s	52.0	7.20	2130	2943	13.81	348.78	23.8	396.6
25	Manganese	Mn	1	s	54.9	7.20	1517	2235	14.64	219.74	32.0	280.7
26	Iron	Fe	1	s	55.8	7.86	1808	3023	15.36	351.04	27.3	416.3
27	Cobalt	Co	1	s	58.9	8.90	1768	3143	15.23	382.42	30.0	424.7
28	Nickel	Ni	1	s	58.7	8.90	1728	3003	17.61	371.83	29.9	429.7
29	Copper	Cu	1	s	63.5	8.92	1356	2840	13.05	304.60	33.2	338.3
30	Zinc	Zn	1	s	65.4	7.14	693	1180	7.38	115.31	41.6	130.7
31	Gallium	Ga	1	s	69.7	5.90	303	2676	5.59	256.06	40.9	277.0
32	Germanium	Ge	1	s	72.6	5.35	1210	3103	31.80	334.30	31.1	376.6
33	Arsenic	As	4	s	74.9	5.73	1090 (28 atm)	886 (sub)	27.61 (36 atm)	129.70	35.1	302.5
34	Selenium	Se	2	s	79.0	4.81	490	958	5.44	26.32	42.4	227.1
35	Bromine	Br	2	l	79.9	3.12 (293 K)	266	332	5.27	15.00	174.9	111.9
36	Krypton	Kr	1	g	83.8	2.15 (121 K)	116	121	1.64	9.03	164.0	—
37	Rubidium	Rb	1	s	85.5	1.53	312	959	2.34	69.20	76.8	80.9
38	Strontium	Sr	1	s	87.6	2.60	1042	1657	9.20	138.91	52.3	164.4
42	Molybdenum	Mo	1	s	95.9	10.20	2883	5833	27.61	594.13	28.7	658.1
45	Rhodium	Rh	1	s	102.9	12.40	2239	4000	21.76	495.39	31.5	556.9
46	Palladium	Pd	1	s	106.4	12.02	1827	3243	16.74	393.30	37.6	378.2
47	Silver	Ag	1	s	107.9	10.50	1235	2485	11.30	255.06	42.6	284.6
48	Cadmium	Cd	1	s	112.4	8.64	594	1038	6.07	99.87	51.8	112.0
49	Indium	In	1	s	114.8	7.30	429	2353	3.26	226.35	57.8	243.3

Z	Element		N	St	A	ρ	T_m	T_b	$\Delta H_m^\ominus$	$\Delta H_b^\ominus$	$S^\ominus$	$\Delta H_{at}^\ominus$
					/g mol^{-1}	/g cm^{-3}	/K	/K	/kJ mol^{-1}	/kJ mol^{-1}	/J mol^{-1} K^{-1}	/kJ mol^{-1}
50	Tin (white)	Sn	1	s	118.7	7.28	505	2533	7.20	290.37	51.5	302.1
50	Tin (grey)	Sn	1	s	118.7	5.75	505	2543	—	—	44.1	304.2
51	Antimony	Sb	4	s	121.8	6.68	904	2023	19.83	67.91	45.7	262.3
52	Tellurium	Te	2	s	127.6	6.00	723	1263	17.49	50.63	49.7	196.7
53	Iodine	I	2	s	126.9	4.93	387	457	7.89	20.85	180.7	106.8
54	Xenon	Xe	1	g	131.3	3.52 (164 K)	161	166	2.30	12.64	169.6	—
55	Caesium	Cs	1	s	132.9	1.88	302	942	2.13	65.90	85.2	76.1
56	Barium	Ba	1	s	137.3	3.51	998	1913	7.66	150.92	62.8	180.0
57	Lanthanum	La	1	s	138.9	6.14	1194	3730	11.30	399.57	56.9	431.0
74	Tungsten	W	1	s	183.8	19.35	3683	5933	35.22	799.14	32.6	849.4
75	Rhenium	Re	1	s	186.2	20.53	3453	5900	33.05	707.10	36.9	769.9
76	Osmium	Os	1	s	190.2	22.48	2973	>5570	29.29	627.60	32.6	790.8
77	Iridium	Ir	1	s	192.2	22.42	2683	4403	26.36	563.58	35.5	655.2
78	Platinum	Pt	1	s	195.1	21.45	2045	4100	19.66	510.45	41.6	565.3
79	Gold	Au	1	s	197.0	18.88	1337	3353	12.36	324.43	47.4	366.1
80	Mercury	Hg	1	l	200.6	13.59	234	630	2.30	59.15	76.0	61.3
81	Thallium	Tl	1	s	204.4	11.85	577	1730	4.27	162.09	64.2	182.2
82	Lead	Pb	1	s	207.2	11.34	601	2013	4.77	179.41	64.8	195.0
83	Bismuth	Bi	1	s	(209)	9.80	544	1833	10.88	151.50	56.7	207.1
84	Polonium	Po	2	s	(210)	9.40	527	1235	12.55	60.20	62.8	144.1
85	Astatine	At	2	s	(210)	—	575	610	11.92	45.20	60.7	90.4
86	Radon	Rn	1	g	(222)	4.40 (211 K)	202	211	2.90	16.40	176.1	—
87	Francium	Fr	1	s	(223)	—	300	950	2.09	63.60	95.4	72.8
88	Radium	Ra	1	s	(226)	5.00	973	<1410	8.37	136.82	71.1	161.9
89	Actinium	Ac		s	(227)	10.07	1323	3473	14.23	397.5	56.5	405.9
90	Thorium	Th	1	s	232	11.70	2023	5060	15.65	543.92	53.4	598.3
91	Protactinium	Pa	1	s	(231)	15.37	<1870	4300	14.64	460.2	51.9	606.7
92	Uranium	U	1	s	238	19.05	1405	4091	15.48	422.60	50.2	535.6
94	Plutonium (α)	Pu	1	s	(242)	19.84	914	3505	2.09	317.10	—	—

Infrared Spectroscopy

Correlation of infrared absorption wavenumbers with molecular structure

Intensity: w — weak absorption; m — medium absorption; s — strong absorption; v — variable intensity of absorption; sh — sharp absorption; b — broad absorption.

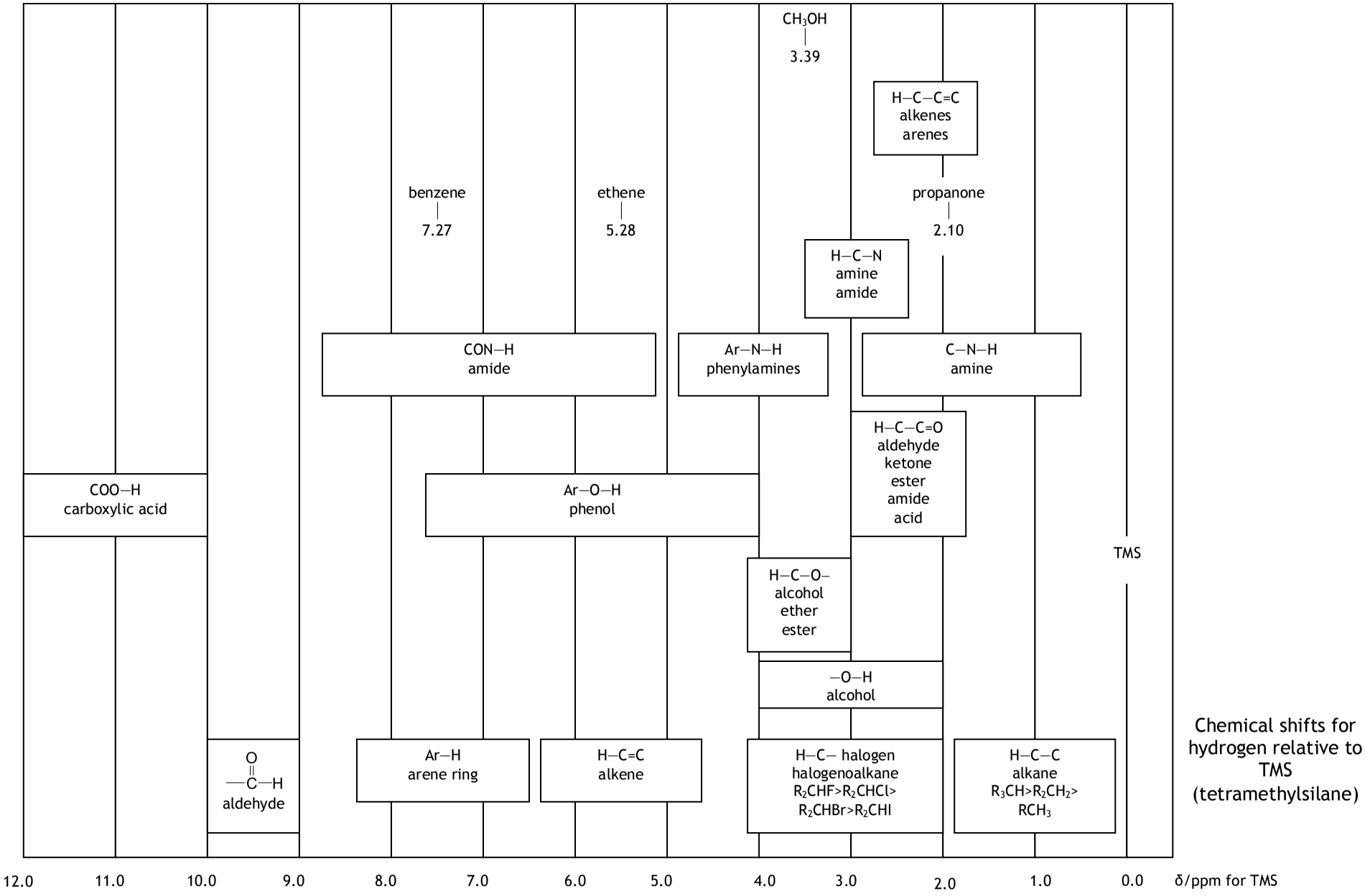
Group		Intensity	Wavenumber range/cm^{-1}
C—H stretching vibrations			
Alkane		m-s	2962-2853
Alkene		m	3095-3010
Alkyne		s	3300
Arene		v	3030
Aldehyde		w and w	2900-2820 and 2775-2700
C—H bending variations			
Alkane		v	1485-1365
Arene	5 adjacent hydrogen atoms	v, s and v, s	750 and 700
	4 adjacent hydrogen atoms	v, s	750
	3 adjacent hydrogen atoms	v, m	780
	2 adjacent hydrogen atoms	v, m	830
	1 adjacent hydrogen atoms	v, m	880
N—H stretching vibrations			
Amine		m	3500-3300
Amide		m	3500-3140
O—H stretching vibrations			
Alcohols and phenols		v, b	3750-3200
Carboxylic acids		w	3300-2500
C—O stretching vibrations			
Esters	methanoates	s	1200-1180
	ethanoates	s	1250-1230
	propanoates	s	1200-1150
	benzoates	s and s	1310-1250 and 1150-1100
Carbon-halogen stretching vibrations			
C—F		s	1400-1000
C—Cl		s	800-600
C—Br		s	600-500
C—I		s	about 500
C=C stretching vibrations			
Isolated alkene		v	1669-1645
Arene		v, m, v, m	1600, 1580, 1500, 1450
C=O stretching vibrations			
Aldehydes, saturated alkyl		s	1740-1720
Ketones, aryl, alkyl		s	1700-1680

Group		Intensity	Wavenumber range/cm^{-1}
Carboxylic acids	alkyl	s	1725-1700
	aryl	s	1700-1680
Carboxylic acid anhydrides		s and s	1850-1800 and 1790-1740
Acyl halides	chlorides	s	1795
	bromides	s	1810
Esters, saturated		s	1750-1735
Amides		s	1700-1630
Triple bond stretching vibrations			
C≡N		m	2260-2215
C≡C		v	2260-2100

Infrared correlation table

Wavenumber range/cm^{-1}	Group
3750-3200	Alcohols and phenols
3500-3300	Amine
3500-3140	Amide
3300	Alkyne
3095-3010	Alkene
3030	Arene
2962-2853	Alkane
2900-2820	Aldehyde
2775-2700	Aldehyde
3300-2500	Carboxylic acid
2260-2215	C≡N
2260-2100	C≡C
1850-1800	Carboxylic acid anhydride
1810	Acyl bromide
1790-1740	Carboxylic acid anhydride
1795	Acyl chloride
1750-1735	Ester
1740-1720	Aldehyde
1730-1717	Aryl ester
1725-1700	Carboxylic acid
1700-1680	Aryl and alkyl ketones, aryl carboxylic acid
1700-1630	Amides
1669-1645	Alkene
1600, 1580, 1500 and 1450	Arene
1485-1365	Alkane
1400-1000	Fluoroalkane
1310-1250	Benzoate
1250-1230	Ethanoate
1200-1180	Methanoate
1200-1150	Propanoate
1150-1100	Benzoate
880-700	Arene
800-600	Chloroalkane
600-500	Bromoalkane
About 500	Iodoalkane

Nuclear Magnetic Resonance



Chemical shifts for hydrogen relative to TMS (tetramethylsilane)

Ionization Energies

		E_{mj}/kJ mol^{-1}													
Z		*j* = 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	H	1312													
2	He	2372	5251												
3	Li	520	7298	11815											
4	Be	900	1757	14849	21007										
5	B	801	2427	3660	25026	32828									
6	C	1086	2353	4621	6223	37832	47278								
7	N	1402	2856	4578	7475	9445	53268	64362							
8	O	1314	3388	5301	7469	10989	13327	71337	84080						
9	F	1681	3374	6051	8408	11022	15164	17868	92040	106437					
10	Ne	2081	3952	6122	9370	12177	15239	19999	23069	115382	131435				
11	Na	496	4563	6913	9544	13352	16611	20115	25491	28934	141367	159079			
12	Mg	738	1451	7733	10541	13629	17995	21704	25657	31644	35463	169996	189371		
13	Al	578	1817	2745	11578	14831	18378	23296	27460	31862	38458	42655	201276	222313	
14	Si	789	1577	3232	4356	16091	19785	23787	29253	33878	38734	45935	50512	235211	257928
15	P	1012	1903	2912	4957	6274	21269	25398	29855	35868	40960	46274	54074	59037	271807
16	S	1000	2251	3361	4564	7012	8496	27107	31671	36579	43140	48706	54483	62876	68232
17	Cl	1251	2297	3822	5158	6542	9362	11018	33606	38601	43963	51068	57119	63364	72342
18	Ar	1521	2666	3931	5771	7238	8781	11996	13842	40761	46188	52003	59654	66201	72920
19	K	419	3051	4412	5877	7975	9649	11343	14942	16964	48577	54433	60701	68896	75950
20	Ca	590	1145	4912	6474	8144	10496	12320	14207	18192	20385	57050			
21	Sc	631	1235	2389	7089	8844	10720	13320	15313	17370	21741	24106			
22	Ti	658	1310	2653	4175	9573	11517	13586	16259	18640	20833	25592			
23	V	650	1414	2828	4507	6294	12362	14490	16760	19860	22240	24609			
24	Cr	653	1592	2987	4740	6686	8738	15540	17822	20200	23580	26130			
25	Mn	717	1509	3249	4940	6985	9200	11508	18956	21400	23960	27600			
26	Fe	759	1561	2958	5290	7236	9600	12100	14576	22679	25290	28020			
27	Co	758	1646	3232	4950	7671	9840	12400	15100	17960	26600	29400			
28	Ni	737	1753	3394	5300	7285	10400	12800	15600	18600	21660	30990			
29	Cu	746	1958	3554	5330	7709	9940	13400	16000	19200	22400	25700			

		E_{mj}/kJ mol^{-1}													
Z		*j* = 1	2	3	4	5	6	7	8	9	10	11	12	13	14
30	**Zn**	906	1733	3833	5730	7970	10400	12900	16800	19600	23000	26400			
31	**Ga**	579	1979	2963	6200										
32	**Ge**	762	1537	3302	4411	9021									
33	**As**	947	1798	2736	4837	6043	12312								
34	**Se**	941	2045	2974	4144	6590	7883	14990							
35	**Br**	1140	2100	3500	4560	5760	8549	9938	18600						
36	**Kr**	1315	2368	3565	5070	6243	7574	10710	12158	22230					
37	**Rb**	403	2632	3900	5080	6850	8144	9572	13100	14500	26740				
38	**Sr**	550	1064	4210	5500	6908	8761	10200	11800	15600	17100	31270			
39	**Y**	616	1181	1980	5960	7429	8973	11200	12400	14137	18400	19900			
40	**Zr**	660	1267	2218	3313	7863	9500								
41	**Nb**	664	1382	2416	3700	4877	9900	12100							
42	**Mo**	685	1558	2621	4480	5905	6600	12230	14800						
43	**Tc**	702	1472	2850											
44	**Ru**	711	1617	2747											
45	**Rh**	720	1745	2997											
46	**Pd**	805	1875	3177											
47	**Ag**	731	2074	3361											
48	**Cd**	868	1631	3616											
49	**In**	558	1821	2705	5200										
50	**Sn**	709	1412	2943	3930	6974									
51	**Sb**	834	1595	2440	4260	5403	10400								
52	**Te**	869	1790	2698	3610	5668	6820	13200							
53	**I**	1008	1846	3200											
54	**Xe**	1170	2047	3100											
55	**Cs**	376	2420	3300											
56	**Ba**	503	965												
78	**Pt**	870	1791												
79	**Au**	890	1980												
80	**Hg**	1007	1810	3300											
86	**Rn**	1037													

Atomic Radii and Pauling Electronegativities

This table is arranged according to the periodic table.

r_v Van der Waals radius r_m Metallic radius for coordination number 12
r_{cov} Covalent radius
r_i Ionic radius for coordination number 6, except where superscript number [4 3 etc] indicates different coordination number (figures in parentheses give charge state)
N_P Pauling electronegativity index

Group		r_v /nm	r_m /nm	r_{cov} /nm	r_i /nm			N_P
1	Li	0.180	0.157	0.134	0.074(+1)			1.0
	Na	0.230	0.191	0.154	0.102(+1)			0.9
	K	0.280	0.235	0.196	0.138(+1)			0.8
	Rb		0.250		0.149(+1)			0.8
	Cs		0.272		0.170(+1)			0.7
	NH_4^+				0.150(+1)			
2	Be		0.112	0.125	0.027(+2)[4]			1.5
	Mg	0.170	0.160	0.145	0.072(+2)			1.2
	Ca		0.197		0.100(+2)			1.0
	Sr		0.215		0.113(+2)			1.0
	Ba		0.224		0.136(+2)			0.9
3	B		0.098	0.090	0.012(+3)[4]			2.0
	Al		0.143	0.130	0.053(+3)			1.5
	Ga	0.190	0.153	0.120	0.062(+3)			1.6
d block	Sc		0.164		0.075(+3)			1.3
	Ti		0.147		0.061(+4)	0.067(+3)	0.086(+2)	1.5
	V		0.135		0.054(+5)	0.059(+4)	0.064(+3) 0.079(+2)	1.6
	Cr		0.129		0.030(+6)[4]	0.062(+3)	0.073(+2)	1.6
	Mn		0.137	0.139	0.026(+7)[4]	0.058(+3)	0.067(+2)	1.5
	Fe		0.126	0.125	0.055(+3)	0.061(+2)		1.8
	Co		0.125	0.126	0.053(+3)	0.065(+2)		1.8
	Ni	0.160	0.125	0.121	0.056(+3)	0.070(+2)		1.8
	Cu	0.140	0.128	0.135	0.073(+2)	0.046(+1)[2]		1.9
	Zn	0.140	0.137	0.120	0.075(+2)			1.6
	Mo		0.140		0.060(+6)	0.065(+4)	0.067(+3)	1.8
	Ag	0.160	0.144	0.152	0.065(+3)[4]	0.115(+1)	0.089(+2)	1.9
	Cd	0.170	0.152	0.148	0.095(+2)			1.7
	Au	0.175	0.144		0.070(+3)[4]	0.137(+1)		2.4
	Hg	0.170	0.155	0.148	0.102(+2)	0.097(+1)[3]		1.9
4	C	0.170	0.092	0.077				2.5
	Si	0.210	0.132	0.118	0.040(+4)			1.8
	Ge		0.139	0.122	0.054(+4)			1.8
	Sn	0.190	0.158	0.140	0.069(+4)	0.122(+2)[8]		1.8

Group		r_v /nm	r_m /nm	r_{cov} /nm	r_i /nm			N_P
	Pb	0.200	0.175		0.078(+4)	0.118(+2)		1.8
5	N	0.155	0.088	0.075	0.171(−3)			3.0
	P	0.185	0.128	0.110	0.017(+5)[4]	0.190(−3)		2.1
	As		0.139	0.122	0.050(+5)	0.220(−3)		2.0
	Sb		0.161	0.143	0.061(+5)	0.080(+3)[5]		1.9
	Bi	0.200	0.182		0.102(+3)			1.9
6	O	0.150	0.089	0.073	0.140(−2)			3.5
	S	0.180	0.127	0.102	0.102(+6)[4]	0.185(−2)		2.5
	Se	0.190	0.140	0.117	0.029(+6)[4]	0.195(−2)		2.4
	Te	0.210	0.143	0.135	0.052(+4)[3]	0.220(−2)		2.1
7	H	0.120	0.078	0.037	0.208(−1)			2.1
	F	0.155		0.071	0.133(−1)			4.0
	Cl	0.180		0.099	0.180(−1)	0.020(+7)[4]	0.012(+5)[3]	3.0
	Br	0.190		0.144	0.195(−1)	0.026(+7)[4]		2.8
	I	0.195		0.133	0.215(−1)	0.095(+5)		2.5
0 (8)	He	0.180						
	Ne	0.160						
	Ar	0.190						
	Kr	0.200						
	Xe	0.220						

Electron Affinities

ΔU Electron affinity*, that is, molar internal energy change (at 0 K) for process: $X^{n-}(g) + e^- \rightarrow X^{(n+1)-}(g)$ (n = zero or positive).

Element	ΔU/kJ mol^{-1}	Element	ΔU/kJ mol^{-1}
H	−72.8	C	−122.3
N	0 (±19)	O	−141.1
O^-	+798	F	−328.0
P	−72	S	−200.4
S^-	+640	Cl	−348.8
Br	−324.6	I	−295.4

* Some chemists define electron affinity for the reverse process.

Reference: Hotop.

Lattice Energies

The lattice energy U of a crystal X_mY_n is the molar internal energy change for the process:

$mX^{n+}(g) + nY^{m-}(g) \rightarrow X_mY_n(s, 1\ atm)$

The main entry in the table is the experimental value of $-U$ (based on the Born-Haber cycle and using data in this booklet); the second entry in parentheses is the theoretical value based on calculations.

Lattice	F^-		Cl^-		Br^-		I^-		O^{2-}		S^{2-}	
	$-U$/kJ mol^{-1}											
Li^+	1031	(1031)	848	(845)	803	(799)	759	(738)	2814	(2799)	2499	(2376)
Na^+	918	(912)	780	(770)	742	(735)	705	(687)	2478	(2481)	2198	(2134)
K^+	817	(807)	711	(702)	679	(674)	651	(636)	2232	(2238)	2052	(1933)
Rb^+	783	(772)	685	(677)	656	(653)	628	(617)	2161	(2163)	1944	(1904)
Cs^+	747	(739)	661	(643)	635	(623)	613	(592)	2063	(—)	1850	(—)
Ag^+	958	(920)	905	(833)	891	(816)	889	(778)	2910	(3002)	2677	(—)
Be^{2+}	3505	(3150)	3020	(3004)	2914	(2950)	2800	(2653)	4443	(4293)	3832	(3841)
Mg^{2+}	2957	(2913)	2526	(2326)	2440	(2097)	2327	(1944)	3791	(3795)	3299	(3318)
Ca^{2+}	2630	(2609)	2258	(2223)	2176	(2132)	2074	(1905)	3401	(3414)	3013	(3038)
Sr^{2+}	2492	(2476)	2156	(2127)	2075	(2008)	1963	(1937)	3223	(3217)	2848	(2874)
Ba^{2+}	2352	(2341)	2056	(2033)	1985	(1950)	1877	(1831)	3054	(3029)	2725	(2711)
Zn^{2+}	3032	(2930)	2734	(2690)	2678	(2632)	2605	(2549)	3971	(4142)	3322	(—)
Cd^{2+}	2809	(2740)	2552	(2526)	2507	(2468)	2441	(2406)	—	(3806)	3121	(—)
Hg^{2+}	—	(2757)	2651	(2569)	2628	(2598)	2610	(2569)	—	(3907)	3037	(—)
Pb^{2+}	2522	(2460)	2269	(2229)	2219	(2169)	2163	(2086)	—	(3502)	—	(—)
Mn^{2+}	—	(2644)	2537	(2368)	2471	(2304)	—	(2212)	3745	(3724)	3238	(3376)
Cu^{2+}	—	(—)	993	(904)	976	(870)	963	(833)	3189	(3273)	2865	(—)
NH_4^+	829	(834)	705	(688)	673	(658)	641	(629)	—	(—)	2026	(2008)

Bond Lengths and Bond Energies

L	Bond length
***E*(X-Y)**	Bond energy

	Bond	in	L /nm	*E*(X-Y) /kJ mol^{-1}		Bond	in	L /nm	*E*(X-Y) /kJ mol^{-1}
1	Br—Br	Br_2	0.228	192.9	**33**	O—Si	SiO_2(s)	0.161	466
2	Br—H	HBr	0.141	366.3	**34**	O=Si	SiO_2(g)		638
3	Cl—Cl	Cl_2	0.199	243.4	**35**	O≡Si	SiO		805
4	Cl—H	HCl	0.127	432.0	**36**	P—P	P_4	0.221	198
5	F—F	F_2	0.142	158	**37**	P≡P	P_2	0.189	485
6	F—H	HF	0.092	568.0	**38**	C—C	average	0.154	347
7	I—I	I_2	0.267	151.2	**39**	C=C	average	0.134	612
8	H—I	HI	0.161	298.3	**40**	C≡C	average	0.120	838
9	H—H	H_2	0.074	435.9	**41**	C—H	average	0.108	413
10	H—Si	SiH_4	0.148	318	**42**	C—H	CH_4	0.109	435
11	H—Ge	GeH_4	0.153	285	**43**	C—F	average	0.138	467
12	H—N	NH_3	0.101	391	**44**	C—F	CH_3F	0.139	452
13	H—P	PH_3	0.144	321	**45**	C—F	CF_4	0.132	485
14	H—As	AsH_3	0.152	297	**46**	C—Cl	average	0.177	346
15	H—O	H_2O	0.096	464	**47**	C—Cl	CCl_4	0.177	327
16	H—S	H_2S	0.134	364	**48**	C…Cl	C_6H_5Cl	0.170	—
17	H—Se	H_2Se	0.146	313	**49**	C—Br	average	0.194	290
18	Na—Na	Na_2	0.308	72	**50**	C—Br	CBr_4	0.194	285
19	K—K	K_2	0.392	49	**51**	C—I	average	0.214	228
20	N—N	N_2H_4	0.145	158	**52**	C—I	CH_3I	0.214	234
21	N=N	$C_6H_{14}N_2$	0.120	410	**53**	C—N	average	0.147	286
22	N≡N	N_2	0.110	945.4	**54**	C=N	average	0.130	615
23	N—O	HNO_2	0.120	214	**55**	C≡N	average	0.116	887
24	N=O	NOF, NOCl	0.114	587	**56**	C…N	phenylamine	0.135	—
25	N≡P	PN	0.149	582	**57**	C—O	average	0.143	358
26	O—O	H_2O_2	0.148	144	**58**	C—O	CH_3OH	0.143	336
27	O—O	O_3	0.128	302	**59**	C=O	CO_2	0.116	805
28	O=O	O_2	0.121	498.3	**60**	C=O	HCHO	0.121	695
29	S—S	S_8	0.205	266	**61**	C=O	aldehydes	0.122	736
30	S=S	S_2	0.189	429.2	**62**	C=O	ketones	0.122	749
31	O—Si	SO_3	0.143	469	**63**	C≡O	CO	0.113	1077
32	Si—Si	Si(s), SiH_4	0.235	226	**64**	C—Si	$(CH_3)_4Si$, SiC(s)	0.187	307

References: Sutton, Johnson, Cottrell.

Standard Electrode Potentials

$E^{\ominus}$ Standard electrode potential of aqueous system at 298 K, that is, standard emf of electrochemical cell in which Pt [H2(g)]|2H+(aq) forms the left-hand side electrode system

	Right-hand electrode system	$E^{\ominus}$ /V
1	$Li^+(aq)\|Li(s)$	−3.03
2	$Rb^+(aq)\|Rb(s)$	−2.93
3	$K^+(aq)\|K(s)$	−2.92
4	$Ca^{2+}(aq)\|Ca(s)$	−2.87
5	$Na^+(aq)\|Na(s)$	−2.71
6	$Mg^{2+}(aq)\|Mg(s)$	−2.37
7	$Ce^{3+}(aq)\|Ce(s)$	−2.33
8	$U^{3+}(aq)\|U(s)$	−1.80
9	$Al^{3+}(aq)\|Al(s)$	−1.66
10	$Mn^{2+}(aq)\|Mn(s)$	−1.19
11	$V^{2+}(aq)\|V(s)$	−1.18
12	$[SO_4^{2-}(aq) + H_2O(l)], [SO_3^{2-}(aq) + 2OH^-(aq)]\|Pt$	−0.93
13	$Zn^{2+}(aq)\|Zn(s)$	−0.76
14	$Cr^{3+}(aq)\|Cr(s)$	−0.74
15	$[As(s) + 3H^+(aq)], AsH_3(g)\|Pt$	−0.60
16	$[2SO_3^{2-}(aq) + 3H_2O(l)], [S_2O_3^{2-}(aq) + 6OH^-(aq)]\|Pt$	−0.58
17	$Fe(OH)_3(s), [Fe(OH)_2(s) + OH^-(aq)]\|Pt$	−0.56
18	$S(s), S^{2-}(aq)\|Pt$	−0.48
19	$Fe^{2+}(aq)\|Fe(s)$	−0.44
20	$Cr^{3+}(aq), Cr^{2+}(aq)\|Pt$	−0.41
21	$Cd^{2+}(aq)\|Cd(s)$	−0.40
22	$[Se(s) + 2H^+(aq)], H_2Se(g)\|Pt$	−0.40
23	$PbSO_4(s), [Pb(s) + SO_4^{2-}(aq)]\|Pt$	−0.36
24	$Co^{2+}(aq)\|Co(s)$	−0.28
25	$[H_3PO_4(aq) + 2H^+(aq)], [H_3PO_3(aq) + H_2O(l)]\|Pt$	−0.28
26	$V^{3+}(aq), V^{2+}(aq)\|Pt$	−0.26
27	$Ni^{2+}(aq)\|Ni(s)$	−0.25
28	$Sn^{2+}(aq)\|Sn(white, s)$	−0.14
29	$Pb^{2+}(aq)\|Pb(s)$	−0.13
30	$[CrO_4^{2-}(aq) + 4H_2O(l)], [Cr(OH)_3(s) + 5OH^-(aq)]\|Pt$	−0.13

	Right-hand electrode system	$E^{\ominus}$ /V
31	$2H^+(aq)\|[H_2(g)]Pt$	0
32	$½S_4O_6^{2-}(aq), S_2O_3^{2-}(aq)\|Pt$	+0.09
33	$[2H^+(aq) + S(s)], H_2S(aq)\|Pt$	+0.14
34	$[Sn^{4+}(aq)1.0M\ HCl], [Sn^{2+}(aq)(1.0M\ HCl)]\|Pt$	+0.15
35	$Cu^{2+}(aq), Cu^+(aq)\|Pt$	+0.15
36	$[4H^+(aq) + SO_4^{2-}(aq)], [H_2SO_3(aq) + H_2O(l)]\|Pt$	+0.17
37	$AgCl(s), [Ag(s) + Cl^-(aq)]\|Pt$	+0.22
38	$[PbO_2(s) + 2H_2O(l)], [Pb(OH)_2(s) + 2OH^-(aq)]\|Pt$	+0.25
39	$Hg_2Cl_2(s), [2Hg(s) + 2Cl^-(aq)]\|Pt$	+0.27
40	$[PbO_2(s) + H_2O(l)], [PbO(s) + 2OH^-(aq)]\|Pt$	+0.28
41	$Cu^{2+}(aq)\|Cu(s)$	+0.34
42	$[VO^{2+}(aq) + 2H^+(aq)], [V^{3+}(aq) + H_2O(l)]\|Pt$	+0.34
43	$Fe(CN)_6^{3-}(aq), Fe(CN)_6^{4-}(aq)\|Pt$	+0.36
44	$[O_2(g) + 2H_2O(l)], 4OH^-(aq)\|Pt$	+0.40
45	$[2H_2SO_3(aq) + 2H^+(aq)], [S_2O_3^{2-}(aq) + 3H_2O(l)]\|Pt$	+0.40
46	$[S_2O_3^{2-}(aq) + 6H^+(aq)], [2S(s) + 3H_2O(l)]\|Pt$	+0.47
47	$[IO^-(aq) + H_2O(l)], [I^-(aq) + 2OH^-(aq)]\|Pt$	+0.49
48	$[4H_2SO_3(aq) + 4H^+(aq)], [S_4O_6^{2-}(aq) + 6H_2O(l)]\|Pt$	+0.51
49	$Cu^+(aq)\|Cu(s)$	+0.52
50	$I_2(aq), 2I^-(aq)\|Pt$	+0.54
51	$[MnO_4^{2-}(aq) + 2H_2O(l)], [MnO_2(s) + 4OH^-(aq)]\|Pt$	+0.59
52	$[2H^+(aq) + O_2(g)], H_2O_2(aq)\|Pt$	+0.68
53	$[C_6H_4O_2(aq) + 2H^+(aq)], C_6H_4(OH)_2(aq)\|Pt$	+0.70
54	$Fe^{3+}(aq), Fe^{2+}(aq)\|Pt$	+0.77
55	$½Hg_2^{2+}(aq)\|Hg(s)$	+0.79
56	$Ag^+(aq)\|Ag(s)$	+0.80
57	$[2NO_3^-(aq) + 4H^+(aq)], [N_2O_4(g) + 2H_2O(l)]\|Pt$	+0.80
58	$[ClO^-(aq) + H_2O(l)], [Cl^-(aq) + 2OH^-(aq)]\|Pt$	+0.89
59	$2Hg^{2+}(aq), Hg_2^{2+}(aq)\|Pt$	+0.92
60	$[NO_3^-(aq) + 3H^+(aq)], [HNO_2(aq) + H_2O(l)]\|Pt$	+0.94

	Right-hand electrode system	$E^{\ominus}$ /V
61	$[HNO_2(aq) + H^+(aq)], [NO(g) + H_2O(l)]\|Pt$	+0.99
62	$[HIO(aq) + H^+(aq)], [I^-(aq) + H_2O(l)]\|Pt$	+0.99
63	$[VO_2^+(aq) + 2H^+(aq)], [VO^{2+}(aq) + H_2O(l)]\|Pt$	+1.00
64	$[N_2O_4(g) + 4H^+(aq)], [2NO(g) + 2H_2O(l)]\|Pt$	+1.03
65	$Br_2(l), 2Br^-(aq)\|Pt$	+1.07
66	$Br_2(aq), 2Br^-(aq)\|Pt$	+1.09
67	$[2IO_3^-(aq) + 12H^+(aq)], [I_2(aq) + 6H_2O(l)]\|Pt$	+1.19
68	$[MnO_2(s) + 4H^+(aq)], [Mn^{2+}(aq) + 2H_2O(l)]\|Pt$	+1.23
69	$[Cr_2O_7^{2-}(aq) + 14H^+(aq)], [2Cr^{3+}(aq) + 7H_2O(l)]\|Pt$	+1.33
70	$Cl_2(aq), 2Cl^-(aq)\|Pt$	+1.36
71	$[PbO_2(s) + 4H^+(aq)], [Pb^{2+}(aq) + 4H_2O(l)]\|Pt$	+1.46
72	$Mn^{3+}(aq), Mn^{2+}(aq)\|Pt$	+1.49
73	$[MnO_4^-(aq) + 8H^+(aq)], [Mn^{2+}(aq) + 4H_2O(l)]\|Pt$	+1.51
74	$2BrO_3^-(aq), [Br_2(aq) + 6H_2O(l)]\|Pt$	+1.52
75	$[2HBrO(aq) + 2H^+(aq)], [Br_2(aq) + 2H_2O(l)]\|Pt$	+1.57
76	$[2HClO(aq) + 2H^+(aq)], [Cl_2(aq) + 2H_2O(l)]\|Pt$	+1.59
77	$[2HBrO(aq) + 2H^+(aq)], [Br_2(l) + 2H_2O(l)]\|Pt$	+1.60
78	$[H_5IO_6(aq) + H^+(aq)], [IO_3^-(aq) + 3H_2O(l)]\|Pt$	+1.60
79	$[2HClO(aq) + 2H^+(aq)], [Cl_2(g) + 2H_2O(l)]\|Pt$	+1.63
80	$[2HCl(aq) + 6H^+(aq)], [Cl_2(g) + 4H_2O(l)]\|Pt$	+1.64
81	$Pb^{4+}(aq), Pb^{2+}(aq)\|Pt$	+1.66 (in 1.1M $HClO_4$)
82	$[2ClO_2^-(aq) + 8H^+(aq)], [Cl_2(g) + 4H_2O(l)]\|Pt$	+1.68
83	$[Cl_2O(g) + 2H^+(aq)], [Cl_2(g) + H_2O(l)]\|Pt$	+1.68
84	$[PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq)], [PbSO_4(s) + 2H_2O(l)]\|Pt$	+1.69
85	$[MnO_4^-(aq) + 4H^+(aq)], [MnO_2(s) + 2H_2O(l)]\|Pt$	+1.70
86	$Ce^{4+}(aq), Ce^{3+}(aq)\|Pt$	+1.70 (in M $HClO_4$)
87	$[H_2O_2(aq) + 2H^+(aq)], 2H_2O(l)\|Pt$	+1.77
88	$Co^{3+}(aq), Co^{2+}(aq)\|Pt$	+1.81 (in M HNO_3)
89	$Ag^{2+}(aq), Ag^+(aq)\|Pt$	+1.98
90	$S_2O_8^{2-}(aq), 2SO_4^{2-}(aq)\|Pt$	+2.01
91	$[O_3(g) + 2H^+(aq)], [O_2(g) + H_2O(l)]\|Pt$	+2.08
92	$[F_2O(g) + 2H^+(aq)], [2F^-(aq) + H_2O(l)]\|Pt$	+2.15
93	$F_2(g), 2F^-(aq)\|Pt$	+2.87

References: Latimer, de Bethune, Parsons, US National Bureau of Standards.

Standard Reduction Potentials

Values at 298K (in alphabetical order).

Electrode reaction	E°/V
$Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$	+0.80
$Al^{3+}(aq) + 3e^{-} \rightleftharpoons Al(s)$	−1.66
$Ba^{2+}(aq) + 2e^{-} \rightleftharpoons Ba(s)$	−2.90
$\frac{1}{2}Br_2(l) + e^{-} \rightleftharpoons Br^{-}(aq)$	+1.07
$Ca^{2+}(aq) + 2e^{-} \rightleftharpoons Ca(s)$	−2.87
$\frac{1}{2}Cl_2(g) + e^{-} \rightleftharpoons Cl^{-}(aq)$	+1.36
$HClO(g) + H^{+}(aq) + e^{-} \rightleftharpoons \frac{1}{2}Cl_2(g) + H_2O(l)$	+1.59
$Cr^{3+}(aq) + e^{-} \rightleftharpoons Cr^{2+}(aq)$	−0.41
$Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Cu^{+}(aq) + e^{-} \rightleftharpoons Cu(s)$	+0.52
$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$	+0.34
$Cu^{2+}(aq) + e^{-} \rightleftharpoons Cu^{+}(aq)$	+0.15
$\frac{1}{2}F_2(g) + e^{-} \rightleftharpoons F^{-}(aq)$	+2.87
$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)$	−0.44
$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq)$	+0.77
$H^{+}(aq) + e^{-} \rightleftharpoons \frac{1}{2}H_2(g)$	+0.00
$\frac{1}{2}I_2(s) + e^{-} \rightleftharpoons I^{-}(aq)$	+0.54
$Li^{+}(aq) + e^{-} \rightleftharpoons Li(s)$	−3.03
$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$MnO_4^{-}(aq) + e^{-} \rightleftharpoons MnO_4^{2-}(aq)$	+0.56
$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^{-} \rightleftharpoons MnO_2(s) + 4OH^{-}(aq)$	+0.59
$\frac{1}{2}H_2O_2(aq) + H^{+}(aq) + e^{-} \rightleftharpoons H_2O(l)$	+1.77
$\frac{1}{2}O_2(g) + 2H^{+}(aq) + 2e^{-} \rightleftharpoons H_2O(l)$	+1.23
$O_2(g) + 2H^{+}(aq) + 2e^{-} \rightleftharpoons H_2O_2(aq)$	+0.68
$Pb^{4+}(aq) + 2e^{-} \rightleftharpoons Pb^{2+}(aq)$	+1.66
$Sn^{4+}(aq) + 2e^{-} \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S + 2H^{+} + 2e^{-} \rightleftharpoons H_2S$	+0.14
$Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s)$	−0.76

Equilibrium Constants for Acids and Bases in Aqueous Solution

Acid or ion	Equilibrium (all in aqueous solution)	K_a (298 K) /mol dm^{-3}	pK_a (at 298 K)
Sulfuric	$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$	Very large	
Nitric	$HNO_3 \rightleftharpoons H^+ + NO_3^-$	40	−1.4
Chromic(VI)	$H_2CrO_4 \rightleftharpoons H^+ + HCrO_4^-$	10	−1.0
Trichlororethanoic	$CCl_3CO_2H \rightleftharpoons H^+ + CCl_3CO_2^-$	2.3×10^{-1}	0.7
Iodic(V)	$HIO_3 \rightleftharpoons H^+ + IO_3^-$	1.7×10^{-1}	0.8
Dichloroethanoic	$CHCl_2CO_2H \rightleftharpoons H^+ + CHCl_2CO_2^-$	5.0×10^{-2}	1.3
Sulfurous	$H_2SO_3 \rightleftharpoons H^+ + HSO_3^-$	1.5×10^{-2}	1.8
Phosphonic	$H_3PO_3 \rightleftharpoons H^+ + H_2PO_3^-$	1.6×10^{-2}	1.8
Chloric(III)	$HClO_2 \rightleftharpoons H^+ + ClO_2^-$	1.0×10^{-2}	2.0
Hydrogensulfate ion	$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$	1.0×10^{-2}	2.0
Phosphoric(V)	$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$	7.9×10^{-3}	2.1
Chloroethanoic	$CH_2ClCO_2H \rightleftharpoons H^+ + CH_2ClCO_2^-$	1.3×10^{-3}	2.9
Nitrous	$HNO_2 \rightleftharpoons H^+ + NO_2^-$	4.7×10^{-4}	3.3
Methanoic	$HCO_2H \rightleftharpoons H^+ + HCO_2^-$	1.6×10^{-4}	3.8
Benzoic	$C_6H_5CO_2H \rightleftharpoons H^+ + C_6H_5CO_2^-$	6.3×10^{-5}	4.2
Phenylammonium ion	$C_6H_5NH_3^+ \rightleftharpoons H^+ + C_6H_5NH_2$	2.0×10^{-5}	4.6
Ethanoic	$CH_3CO_2H \rightleftharpoons H^+ + CH_3CO_2^-$	1.7×10^{-5}	4.8
Butanoic	$CH_3(CH_2)_2CO_2H \rightleftharpoons H^+ + CH_3(CH_2)_2CO_2^-$	1.5×10^{-5}	4.8
Propanoic	$CH_3CH_2CO_2H \rightleftharpoons H^+ + CH_3CH_2CO_2^-$	1.3×10^{-5}	4.9
Dihydrogen phosphonate ion	$H_2PO_3^- \rightleftharpoons H^+ + HPO_3^{2-}$	6.3×10^{-7}	6.2
Carbonic	$H_2O + CO_2 \rightleftharpoons H^+ + HCO_3^-$	4.5×10^{-7}	6.4
Hydrogen sulfide	$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8}	7.1
Hydrogensulfite ion	$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$	6.2×10^{-8}	7.2
Dihydrogenphosphate(V) ion	$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$	6.2×10^{-8}	7.2
Chloric(I)	$HClO \rightleftharpoons H^+ + ClO^-$	3.7×10^{-8}	7.4
Bromic(I)	$HBrO \rightleftharpoons H^+ + BrO^-$	2.1×10^{-9}	8.7
Boric	$H_3BO_3 \rightleftharpoons H^+ + H_2BO_3^-$	5.8×10^{-10}	9.2
Ammonium ion	$NH_4^+ \rightleftharpoons H^+ + NH_3$	5.6×10^{-10}	9.3
Hydrocyanic	$HCN \rightleftharpoons H^+ + CN^-$	4.9×10^{-10}	9.3
Ethane-1,2-diammonium ion	$CH_2NH_2CH_2NH_3^+ \rightleftharpoons H^+ + CH_2NH_2CH_2NH_2$	1.3×10^{-10}	9.9
Phenol	$C_6H_5OH \rightleftharpoons H^+ + C_6H_5O^-$	1.3×10^{-10}	9.9
Hydrogencarbonate ion	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	4.8×10^{-11}	10.3
Butylammonium ion	$C_4H_9NH_3^+ \rightleftharpoons H^+ + C_4H_9NH_2$		10.8
Hydrogen peroxide	$H_2O_2 \rightleftharpoons H^+ + HO_2^-$	2.4×10^{-12}	11.6
Hydrogenphosphate(V) ion	$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$	4.4×10^{-13}	12.4
Hydrogensulfide ion	$HS^- \rightleftharpoons H^+ + S^{2-}$	1.2×10^{-13}	12.9
Water	$H_2O \rightleftharpoons H^+ + OH^-$	1.0×10^{-14}	14.0

Indicators

		pK_{in} (at 298 K)	pH range *acid*		*alkaline*
1	Methyl violet	0.8	yellow	0.0—1.6	blue
2	Malachite green	1.0	yellow	0.2—1.8	blue/green
3	Thymol blue (acid)	1.7	red	1.2—2.8	yellow
4	Methyl yellow (in ethanol)	3.5	red	2.9—4.0	yellow
5	Methyl orange—xylene cyanole solution	3.7	purple	3.2—4.2	green
6	Methyl orange	3.7	red	3.2—4.4	yellow
7	Bromophenol blue	4.0	yellow	2.8—4.6	blue
8	Congo red	4.0	violet	3.0—5.0	red
9	Bromocresol green	4.7	yellow	3.8—5.4	blue
10	Methyl red	5.1	red	4.2—6.3	yellow
11	Azolitmin (litmus)		red	5.0—8.0	blue
12	Bromocresol purple	6.3	yellow	5.2—6.8	purple
13	Bromothymol blue	7.0	yellow	6.0—7.6	blue
14	Phenol red	7.9	yellow	6.8—8.4	red
15	Thymol blue (base)	8.9	yellow	8.0—9.6	blue
16	Phenolphthalein (in ethanol)	9.3	colourless	8.2—10.0	red
17	Thymolphthalein	9.7	colourless	8.3—10.6	blue
18	Alizarin yellow R	12.5	yellow	10.1—13.0	orange/red

Note: Most indicators are 0.1% solutions in H_2O unless stated otherwise.

Warning: Certain indicators are poisonous and should be handled carefully, particularly when concentrated.

Organic Compounds: Physical and Thermochemical Data

St	State: s solid, l liquid, g gas	M	Molar mass
ρ	Density at 298 K or density of liquid at just below T_b for gases, unless otherwise indicated		
T_m	Melting temperature (at 1 atm unless stated)	T_b	Boiling temperature (at 1 atm unless stated)
$\Delta H_c^\ominus$	Standard molar enthalpy change of combustion at 298 K	$\Delta H_f^\ominus$	Standard molar enthalpy change of formation at 298 K
$S^\ominus$	Standard molar entropy at 298 K (the values of standard entropy of diatomic gaseous elements is for ½ mol of the element)	p	Dipole moment in the gas phase (debye D)

Compound	Formula	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_c^\ominus$ /kJ mol^{-1}	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	p /D
Carbon monoxide	CO	g	28.0	1.25 x 10^{-3} gas	74.1	81.6	−283.0	−110.5	197.6	—
Carbon dioxide	CO_2	g	44.0	1.98 x 10^{-3} gas	216.5	194.0	—	−393.5	213.6	—
Straight chain alkanes										
Methane	CH_4	g	16.0	0.466^{liq}	91.1	109.1	−890.3	−74.8	186.2	0
Ethane	CH_3CH_3	g	30.1	0.572^{liq}	89.8	184.5	−1559.7	−84.7	229.5	0
Propane	$CH_3CH_2CH_3$	g	44.1	0.585^{liq}	83.4	231.0	−2219.2	−104.5	269.9	0
Butane	$CH_3(CH_2)_2CH_3$	g	58.1	0.601^{liq}	134.7	272.6	−2876.5	−126.5	310.1	0
Pentane	$CH_3(CH_2)_3CH_3$	l	72.2	0.626	143.1	309.2	−3509.1	−173.2	261.2	0
Hexane	$CH_3(CH_2)_4CH_3$	l	86.2	0.660	178.1	342.1	−4163.0	−198.6	295.9	0
Heptane	$CH_3(CH_2)_5CH_3$	l	100.2	0.684	182.5	371.5	−4816.9	−224.0	328.5	0
Octane	$CH_3(CH_2)_6CH_3$	l	114.2	0.703	216.3	398.8	−5470.2	−250.0	361.1	0
Decane	$CH_3(CH_2)_8CH_3$	l	142.3	0.730	243.4	447.2	−6777.9	−300.9	425.9	0
Eicosane	$CH_3(CH_2)_{18}CH_3$	s	282.6	0.789	309.9	616.9	—	—	—	0
Branched alkanes										
2-methylpropane	$(CH_3)_2CHCH_3$	g	58.1	0.557^{liq}	113.7	261.4	−2868.5	−134.5	294.6	0
2-methylbutane	$(CH_3)_2CHCH_2CH_3$	l	72.2	0.620	113.2	301.0	−3503.4	−178.9	260.4	—
2-methylpentane	$(CH_3)_2CH(CH_2)_2CH_3$	l	86.2	0.653	119.4	333.4	−4157.0	−204.6	—	—
2-methylhexane	$(CH_3)_2CH(CH_2)_3CH_3$	l	100.2	0.679	154.8	363.1	−4811.4	−229.5	—	—
2-methylheptane	$(CH_3)_3CH(CH_2)_4CH_3$	l	114.2	0.698	164.1	390.7	−5465.2	−255.0	—	—
2,2-dimethylpropane	$C(CH_3)_4$	g	72.2	0.591^{liq}	256.6	282.6	−3492.5	−189.8	306.4	—

Compound	Formula	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_c^\ominus$ /kJ mol^{-1}	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	p /D
Cyclo-alkanes										
Cyclopropane	$(CH_2)_3$	g	42.1	—	145.5	240.4	−2091.4	+53.3	—	0
Cyclobutane	$(CH_2)_4$	g	56.1	0.694^{liq}	182.4	285.1	−2720.9	+3.7	—	—
Cyclopentane	$CH_2(CH_2)_3CH_3$	l	70.1	0.745	179.2	322.3	−3289.4	−107.1	204.3	0
Cyclohexane	$CH_2(CH_2)_4CH_3$	l	84.2	0.779	279.6	353.8	−3919.5	−156.3	204.4	—
Alkenes										
Ethene	$CH_2=CH_2$	g	28.1	0.610^{liq}	104.1	169.4	−1410.8	+52.2	219.5	0
Propene	$CH_2=CHCH_3$	g	42.1	0.514^{liq}	87.9	225.7	−2058.1	+20.2	266.9	0.35
But-1-ene	$CH_2=CHCH_2CH_3$	g	56.1	0.595^{liq}	87.8	266.8	−2716.8	−0.4	305.6	0.38
E-But-2-ene (trans-But-2-ene)	$CH_3CH=CHCH_3$	g	56.1	0.604^{liq}	167.6	274.0	−2705.0	−12.2	296.4	0
Z-But-2-ene (cis-But-2-ene)	$CH_3CH=CHCH_3$	g	56.1	0.621^{liq}	134.2	276.8	−2709.4	−7.8	300.8	—
Cyclohexene	$CH_2(CH_2)_3CH=CH$	l	81.2	0.811	169.6	356.5	−3751.9	−38.1	—	0.55
Phenylethene (styrene)	$C_6H_5CH=CH_2$	l	104.2	0.906	242.5	418.3	−4395.0	+103.8	345.1	0
Alkynes										
Ethyne (acetylene)	$CH\equiv CH$	g	26.0	0.618^{liq}	192.3	189.1	−1300.8	+228.0	200.8	0
Arenes										
Benzene	C_6H_6	l	78.1	0.879	278.6	353.2	−3267.4	+49.0	172.8	0
Naphthalene	$C_{10}H_8$	s	128.2	1.101	353.6	491.1	−5155.9	+77.7	—	—
Methylbenzene (toluene)	$C_6H_5CH_3$	l	92.1	0.867	178.1	383.7	−3909.8	+12.1	319.7	0.36
Amines										
Methylamine	CH_3NH_2	g	31.1	0.660^{liq}	179.6	266.8	−1085.0	−23.0	243.3	1.30
Dimethylamine	$(CH_3)_2NH$	g	45.1	0.656^{liq}	180.1	280.5	−1768.8	−18.5	280.5	0.93
Trimethylamine	$(CH_3)_3N$	g	59.1	0.633^{liq}	155.9	276.0	−2442.9	−23.7	287.0	0.71
Ethylamine	$CH_3CH_2NH_2$	g	45.1	0.683^{liq}	192.1	289.7	−1739.8	−47.5	—	0.99
1-Aminobutane	$CH_3(CH_2)_3NH_2$	l	73.1	0.739	224.0	350.9	−3018.3	−127.6	—	1.32
2-Aminobutane	$CH_3CH_2CHNH_2CH_3$	l	73.1	0.734	201.1	336.6	−3008.4	−137.5	—	—
Phenylamine (aniline)	$C_6H_5NH_2$	l	93.1	1.022	266.8	457.1	−3392.6	+31.3	—	1.53
Halogenocompounds										
Fluoromethane	CH_3F	g	34.0	0.557^{liq}	131.3	194.7	—	−247.0	—	—
Chloromethane	CH_3Cl	g	50.5	0.916^{liq}	176.0	248.9	−764.0	−82.0	234.5	1.86
Bromomethane	CH_3Br	g	94.9	1.676^{liq}	179.5	276.7	−769.9	−37.2	246.3	1.79

Compound	Formula	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_c^\ominus$ /kJ mol^{-1}	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	p /D
Iodomethane	CH_3I	l	141.9	2.279	206.7	315.5	−814.6	−15.5	163.2	1.64
Dichloromethane	CH_2Cl_2	l	84.9	1.316	178.0	313.1	−605.8	−124.1	177.8	1.54
Trichloromethane	$CHCl_3$	l	119.4	1.479	209.6	334.8	−474.0	−135.1	201.8	1.02
Tetrachloromethane	CCl_4	l	153.8	1.594	250.1	349.6	−359.9	−129.6	216.4	0
Tetraiodomethane	CI_4	s	519.6	4.320	—	403-13^{sub}	—	—	—	0
1-Chlorobutane	$CH_3(CH_2)_3Cl$	l	92.6	0.886	150.0	351.5	−2704.1	−187.9	—	2.16
1-Bromobutane	$CH_3(CH_2)_3Br$	l	137.0	1.276	160.7	374.7	−2716.5	−143.8	—	1.93
1-Iodobutane	$CH_3(CH_2)_3I$	l	184.0	1.615	170.1	403.6	—	—	—	1.88
2-Chloro-2-methylpropane	$(CH_3)_2CClCH_3$	l	92.6	0.842	247.7	323.8	−2692.8	−191.1	—	2.13
2-Bromo-2-methylpropane	$(CH_3)_2CBrCH_3$	l	137.0	1.221	256.9	346.4	—	−163.4	—	—
2-Iodo-2-methylpropane	$(CH_3)_2ClCH_3$	l	184.0	1.571	234.9	373.1	—	−107.4	—	—
Chlorobenzene	C_6H_5Cl	l	112.6	1.106	227.5	405.1	−3111.6	+11.0	—	1.67
Alcohols										
Methanol	CH_3OH	l	32.0	0.793	179.2	338.1	−726.0	−239.1	239.7	1.70
Ethanol	C_2H_5OH	l	46.1	0.789	155.8	351.6	−1367.3	−277.1	160.7	1.69
Propan-1-ol	$CH_3CH_2CH_2OH$	l	60.1	0.804	146.6	370.5	−2021.0	−302.7	196.6	1.66
Propan-2-ol	$CH_3CHOHCH_3$	l	60.1	0.787	183.6	355.5	−2005.8	−317.9	180.5	1.68
Butan-1-ol	$CH_3(CH_2)_2CH_2OH$	l	74.1	0.810	183.6	390.3	−2675.6	−327.4	228.0	1.66
Pentan-1-ol	$CH_3(CH_2)_3CH_2OH$	l	88.2	0.815	194.1	411.1	−3328.7	−353.6	259.0	—
Hexan-1-ol	$CH_3(CH_2)_4CH_2OH$	l	102.2	0.820	226.4	431.1	−3983.8	−377.8	289.5	1.60
Ethane-1,2-diol	CH_2OHCH_2OH	l	62.1	1.114	261.6	471.1	−1179.5	−454.8	166.9	2.00
Propan-1,2,3-triol	$CH_2OHCHOHCH_2OH$	l	92.1	1.260	293.1	563.1	−1655.2	−668.5	—	—
2-Methylpropan-2-ol	$(CH_3)_3COH$	l	74.1	0.789	298.6	355.4	−2643.8	−359.2	—	—
Cyclohexanol	$CH_2(CH_2)_4CHOH$	s	100.2	0.962	298.2	434.2	−3727.0	−348.8	—	—
Aldehydes										
Methanal (formaldehyde)	$HCHO$	g	30.0	0.815	181.1	252.1	−570.6	−108.7	218.7	2.27
Ethanal (acetaldehyde)	CH_3CHO	g	44.1	0.778	152.1	293.9	−1167.1	−191.5	160.2	2.49
Propanal	CH_3CH_2CHO	l	58.1	0.797	192.1	321.9	−1820.8	−217.1	—	2.54
Butanal	$CH_3CH_2CH_2CHO$	l	72.1	0.801	174.1	348.8	−2476.0	−241.2	—	2.57
Benzaldehyde	C_6H_5CHO	l	106.1	1.050	247.1	451.1	−3525.1	−86.8	—	2.96
Ketones										
Propanone (acetone)	CH_3COCH_3	l	58.1	0.789	177.8	329.3	−1816.5	−248.0	—	2.95

Compound	Formula	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_c^\ominus$ /kJ mol^{-1}	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}	p /D
Butanone	$CH_3CH_2COCH_3$	l	72.1	0.805	186.8	352.7	−2441.5	−275.7	—	—
Cyclohexanone	$CH_2(CH_2)_4CO$	l	98.1	0.948	256.7	428.7	−3519.3	−270.7	—	—
Carboxylic acids										
Methanoic (formic)	HCO_2H	l	46.0	1.220	281.5	373.7	−254.3	−425.0	129.0	1.52
Ethanoic (acetic)	CH_3CO_2H	l	60.1	1.049	289.7	391.0	−874.1	−484.5	159.8	1.74
Propanoic	$CH_3CH_2CO_2H$	l	74.1	0.993	252.3	414.1	−1527.2	−510.7	—	1.74
Butanoic	$CH_3CH_2CH_2CO_2H$	l	88.1	0.958	268.6	438.6	−2183.3	−533.9	—	—
Chloroethanoic	$ClCH_2CO_2H$	s	94.5	1.404	336.1	460.9	−715.5	—	—	—
Dichloroethanoic	Cl_2CHCO_2H	l	128.9	1.563	286.6	467.1	—	—	—	—
Trichloroethanoic	Cl_3CCO_2H	s	163.4	1.617	331.1	470.6	−388.3	−513.8	—	—
1-Aminoethanoic (Glycine)	$NH_2CH_2CO_2H$	s	75.1	1.607	535^{dec}	—	−981.1	−528.6	—	—
2-Hydroxypropanoic (lactic)	$CH_3CHOHCO_2H$	l	90.1	1.206	326.1	376.1	−1343.9	−694.0	—	—
Ethanedioic (oxalic)	CO_2HCO_2H	s	90.0	1.653	—	430^{sub}	−243.3	−829.5	—	—
Hexanedioic (adipic)	$CO_2H(CH_2)_4CO_2H$	s	146.1	1.360	426.0	dec	−2795.7	−994.3	—	—
Benzenesulfonic	$C_6H_5SO_3H$	s	158.2	—	338.1	—	—	—	—	—
Benzene-1,4-dicarboxylic	$C_6H_4(CO_2H)_2$	s	166.1	—	Sub	7573^{sub}	−3189.3	−816.1	—	—
Benzoic (benzenecarboxylic)	$C_6H_5CO_2H$	s	122.1	1.266	395.3	522.0	−3227.0	−384.9	—	1.71
Carboxylic acid derivatives										
Ethanoyl chloride	CH_3COCl	l	78.5	1.104	161.1	324.0	—	−272.9	200.8	2.45
Ethanamide (acetamide)	CH_3CONH_2	s	59.1	1.159	355.4	494.3	−1184.6	−317.0	—	3.44
Ethanoic anhydride	$(CH_3CO)_2O$	l	102.1	1.082	200.0	412.7	−1794.2	−637.2	—	2.80
Esters										
Ethyl ethanoate	$CH_3CO_2CH_2CH_3$	l	88.1	0.900	189.6	350.2	−2237.9	−479.3	—	1.78
Miscellaneous										
Carbamide (urea)	NH_2CONH_2	s	60.1	1.320	408.1	dec	−632.2	−332.9	104.6	4.56
Nitrobenzene	$C_6H_5NO_2$	l	123.1	1.203	278.8	483.9	−3087.9	+12.4	—	4.22
Phenol	C_6H_5OH	s	94.1	1.076	316.1	454.8	−3053.4	−165.0	—	1.45
Glucose	$C_6H_{12}O_6$	s	180.2	1.562	423.1	—	−2802.5	−1273.3	—	—
Sucrose	$C_{12}H_{22}O_{11}$	s	342.3	1.580	458.0	—	−5639.7	−2226.1	—	—

^{sub} Sublimes ^{liq} Liquid ^{dec} Decomposes

Selected Inorganic Compounds: Physical and Thermochemical Data

St State: s solid, l liquid, g gas
M Molar mass
ρ Density at 298 K or density of liquid at just below T_b for gases, unless otherwise indicated
T_m Melting temperature
T_b Boiling temperature (both at 1 atm unless otherwise stated)
$\Delta H_f^\ominus$ Standard molar enthalpy change of formation at 298 K
$S^\ominus$ Standard molar entropy at 298 K (the values of standard entropy of diatomic gaseous elements is for ½ mol of the element)
sub Sublime
dec Decomposes
dhd Dehydrated

Compound	St	*M* /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}
Aluminium							
$AlCl_3$	s	133.3	2.44	463 2.5 atm	451 sub	−704.2	110.7
$AlBr_3$	s	266.7	—	371	536	−527.2	163.2
Al_2O_3	s	102.0	3.97	2345	3253	−1675.7	50.9
$Al(OH)_3$	s	78.0	2.42	573 dhd	—	−1287.4	85.4
$Al(NO_3)_3.6H_2O$	s	321.1	—	—	—	−2850.5	467.8
$Al_2(SO_4)_3$	s	342.1	2.71	1043 dec	—	−3440.8	239.3
Barium							
$BaCl_2$	s	208.2	3.91	1236	1833	−858.6	123.7
BaO	s	153.3	5.72	2191	2273	−553.5	70.4
BaO_2	s	169.3	4.96	723	1073 dec	−634.3	65.7
$Ba(OH)_2$	s	171.3	4.50	681	dec	−944.7	99.7
$BaCO_3$	s	197.3	4.43	1123 dec	—	−1216.3	112.1
$Ba(NO_3)_2$	s	261.3	3.24	865	dec	−992.1	213.8
$BaSO_4$	s	233.4	4.50	1853	—	−1473.2	132.2
Bismuth							
$BiCl_3$	s	315.3	4.75	505	720	−379.1	177.0
BiOCl	s	260.4	7.72	—	—	−366.9	120.5
Boron							
B_2H_6	g	27.7	0.45	108	181	35.6	232.0
BF_3	g	67.8	2.99	129	173	−1137.0	254.0
BCl_3	g	117.2		166	286	−403.7	290.0
B_2O_3	s	69.6	2.46	723	2133	−1272.8	54.0
BN	s	24.8	2.25	3300 sub	—	−254.4	14.8
Caesium							
CsF	s	151.9	4.11	955	1524	−553.5	92.8
CsCl	s	168.4	3.99	918	1563	−443.0	101.2
CsBr	s	212.8	4.44	909	1573	−405.8	113.1
CsI	s	259.8	4.51	899	1553	−346.6	123.1
Calcium							
CaH_2	s	42.1	1.90	1089 in H_2	873 dec	−186.2	42.0
CaF_2	s	78.1	3.18	1696	2773	−1219.6	68.9
$CaCl_2$	s	111.0	2.15	1055	1873	−795.8	104.6
$CaCl_2.6H_2O$	s	219.1	1.71	303	—	−2607.9	284.9
$CaBr_2$	s	199.9	3.35	1003	1083	−682.8	130.0
CaO	s	56.1	3.35	2887	3123	−635.1	39.7
$Ca(OH)_2$	s	74.1	2.24	853 dhd	dec	−986.1	83.4
CaC_2	s	64.1	2.22	720	2573	−59.8	69.9

Compound	St	M	ρ	T_m		T_b		$\Delta H_f^\ominus$	$S^\ominus$
		/g mol^{-1}	/g cm^{-3}	/K		/K		/kJ mol^{-1}	/J mol^{-1} K^{-1}
$CaCO_3$ (calcite)	s	100.1	2.71	1612	1025atm	1172	dec	−1206.9	92.9
$Ca(NO_3)_2$	s	164.1	2.50	834		—		−938.4	193.3
$CaSO_4$	s	136.1	2.96	1723		—		−1434.1	106.7
$CaSO_4.½H_2O$	s	145.1	—	436	dhd	—		−1576.7	130.5
$CaSO_4.2H_2O$	s	172.2	2.32	401	dhd 1.5	436	dhd	−2022.6	194.1
$Ca_3(PO_4)_2$	s	310.2	3.14	1943		—		−4120.8	236.0
Carbon									
HCN	l	27.0	0.70	259		299		108.9	112.8
C_2N_2	g	52.0	—	245		252		307.9	242.1
CS_2	l	76.1	1.26	162		319		89.7	151.3
Chlorine									
Cl_2O	g	86.9	3.89^{273K}	253		277	exp	80.3	266.1
ClO_2	g	67.4	3.01^{214K}	214		283	exp	102.5	256.7
Chromium									
$CrCl_3$	s	158.3	2.76	1423		1573	sub	−556.5	115.3
CrO_2Cl_2	l	154.9	1.91	177		390		−579.5	221.8
Cr_2O_3	s	152.0	5.21	2538		4273		−1139.7	81.2
$Cr_2(SO_4)_3.18H_2O$	s	716.4	1.70	373	dhd 12	—		−8339.5	—
Cobalt									
$CoCl_2$	s	129.8	3.36	997	in HCl	1322		−312.5	109.2
$CoCl_2.6H_2O$	s	237.9	1.92	359		383	dhd	−2115.4	343.0
CoO	s	74.9	6.45	2078		—		−237.9	53.0
$Co(OH)_2$	s	92.9	3.60	dec		—		−539.7	79.0
$CoSO_4$	s	155.0	3.71	1008	dec	—		−888.3	118.0
$CoSO_4.7H_2O$	s	281.1	1.95	370		693	dhd	−2979.9	406.1
Copper									
CuCl	s	99.0	4.14	703		1763		−137.2	86.2
$CuCl_2$	s	134.4	3.39	893		1266	dec	−220.1	108.1
CuI	s	190.4	5.62	878		1563		−67.7	96.7
Cu_2O	s	143.1	6.0	1508		2073	dec	−168.6	93.1
CuO	s	79.5	6.40	1599		—		−157.3	42.6
$Cu(OH)_2$	s	97.6	3.37	dec		—		−449.8	75.0
$Cu(NO_3)_2.6H_2O$	s	295.6	2.07	299.4	dhd 3	—		−2110.8	—
Cu_2S	s	159.1	5.6	1373		—		−79.0	120.9
CuS	s	95.6	4.6	376		493	dec	−53.1	66.5
$CuSO_4$	s	159.6	3.60	473		923	dec	−771.4	109.0
$CuSO_4.5H_2O$	s	249.7	2.28	383	dhd 4	423	dhd	−2279.6	300.4
Fluorine									
F_2O	g	54.0	$1.90^{40\ k}$	49		128		−21.7	247.3
Hydrogen									
HF	g	20.0	0.99	190		293		−271.1	173.7
HCl	g	36.5	1.64^{159K}	158		188		−92.3	186.8
HBr	g	80.9	2.77^{206K}	185		206		−36.4	198.6
HI	g	127.9	2.85^{268K}	222		238		26.5	206.5
HIO_3	s	175.9	4.63	383	dec	—		−230.1	118.0
H_2O	l	18.0	1.00	273		373		−285.8	69.9
H_2O	g	18.0	—	273		373		−241.8	188.7
H_2O_2	l	34.0	1.44	273		323		−187.8	109.6
HNO_3	l	63.0	1.50	231		356		−174.1	266.3
H_2S	g	34.1	1.54^{188K}	188		212		−20.6	205.7
H_2SO_4	l	98.1	1.84	283		611		−814.0	156.9

Compound	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}
H_3PO_4	s	98.0	1.83	316	486 dhd½	−1279.0	110.5
H_3BO_3	s	61.8	1.44	442	573 dhd1½	−1094.3	88.8
Iodine							
ICl	s	162.3	3.18	300	371	−35.1	—
ICl_3	s	233.3	3.12	374 16 atm	350 dec	−89.5	167.4
I_2O_5	s	333.8	4.80	573 dec	—	−158.1	—
Iron							
$FeCl_2$	s	126.7	3.16	945	sub	−341.8	117.9
$FeCl_3$	s	162.2	2.90	579	588 dec	−399.5	142.3
$FeCl_3.6H_2O$	s	270.3	—	310	553-558	−2223.8	—
FeO	s	71.8	5.7	1642	—	−271.9	58.5
Fe_2O_3	s	159.7	5.24	1838	—	−824.2	87.4
Fe_3O_4	s	231.5	5.18	1867	—	−1118.4	146.4
$Fe(OH)_2$	s	89.9	3.4	dec	—	−569.0	88.0
$Fe(OH)_3$	s	106.8	—	—	—	−823.0	106.7
$FeCO_3$	s	115.8	3.8	dec	—	−740.6	92.9
FeS	s	87.9	4.74	1468	dec	−100.0	60.3
$FeSO_4.7H_2O$	s	278.0	1.90	337	363 dhd 6	−3014.6	409.2
$Fe_2(SO_4)_3$	s	399.9	3.10	753 dec	—	−2581.5	261.7
Lead							
$PbCl_2$	s	278.1	5.85	774	1223	−359.4	136.0
$PbCl_4$	l	349.0	3.18	258	378	−329.2	—
PbI_2	s	461.0	6.16	675	1127	−175.5	174.8
PbO	s	223.2	9.53	1159	1745	−217.3	68.7
Pb_3O_4	s	685.6	9.1	773 dec	—	−718.4	211.3
PbO_2	s	239.2	9.37	563 dec	—	−277.4	68.6
$PbCO_3$	s	267.2	6.6	588 dec	—	−700.0	131.0
$Pb(NO_3)_2$	s	331.2	4.53	743 dec	—	−451.9	213.0
PbS	s	239.2	7.5	1387	1553	−100.4	91.2
$PbSO_4$	s	303.2	6.2	1443	—	−919.9	148.6
$PbCrO_4$	s	323.2	6.12	1117	dec	−899.6	152.7
$Pb(CH_3CO_2)_2.3H_2O$	s	379.3	2.55	348 dhd 1	473 dec	−1851.5	—
$Pb(C_2H_5)_4$	l	323.4	1.66	137	473 dec	52.7	472.5
Lithium							
LiH	s	7.9	0.82	953	—	−90.5	20.0
LiF	s	25.9	2.64	1118	1949	−616.0	35.6
LiCl	s	42.4	2.07	878	1613	−408.6	59.3
LiBr	s	86.8	3.46	823	1538	−351.2	74.3
LiI	s	133.8	4.08	722	1444	−270.4	86.8
Li_2O	s	29.9	2.01	>1973	—	−597.9	37.6
LiOH	s	23.9	1.46	723	1197 dec	−484.9	42.8
Li_2CO_3	s	73.9	2.11	996	1583 dec	−1215.9	90.4
$LiNO_3$	s	68.9	2.38	537	873 dec	−483.1	90.0
Li_2SO_4	s	109.9	2.22	—	1118	−1436.5	115.1
$LiAlH_4$	s	37.9	0.92	398 dec	—	−116.3	78.7
Magnesium							
$MgCl_2$	s	95.2	2.32	987	1685	−641.3	89.6
$MgCl_2.6H_2O$	s	203.3	1.57	390 dec	—	−2499.0	366.1
MgO	s	40.3	3.58	3125	3873	−601.7	26.9
$MgCO_3$	s	84.3	2.96	623 dec	1173 $-CO_2$	−1095.8	65.7
Mg_3N_2	s	100.9	2.71	1073 dec	973 dec	−460.7	90.0

Compound	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K		T_b /K		$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}
$Mg(NO_3)_2.6H_2O$	s	256.4	1.64	362		603	dec	−2613.3	452.0
$MgSO_4$	s	120.4	2.66	1397	dec	—		−1284.9	91.6
$MgSO_4.7H_2O$	s	246.5	1.68	423	dhd 6	473	dhd	−3388.7	372.0
Mg_2Si	s	76.7	1.94	1375		—		−77.8	75.0
Manganese									
MnO_2	s	86.9	5.03	808	dec	—		−520.0	53.1
$MnSO_4$	s	151.0	3.25	973		1123	dec	−1065.2	112.1
Mercury									
Hg_2Cl_2	s	472.1	7.15	673	sub	—		−265.2	192.5
$HgCl_2$	s	271.5	5.44	549		575		−224.3	146.0
HgS red	s	232.6	8.10	857	sub	—		−58.2	82.4
Nickel									
$NiCl_2$	s	129.6	3.55	1274		1246	sub	−305.3	97.7
$NiSO_4$	s	154.8	3.68	1121	dec	—		−872.9	92.0
$NiSO_4.7H_2O$	s	280.9	1.95	372		376	dhd 6	−2976.3	378.9
$Ni(CO)_4$	l	170.7	1.32	248		316		−633.0	313.4
Nitrogen									
N_2H_4	l	32.0	1.01	275		387		50.6	121.2
N_2O	g	44.0	$1.98^{182\ K}$	182		185		82.0	219.7
NO	g	30.0	$1.27^{123\ K}$	110		121		90.2	210.7
N_2O_3	g	76.0	$1.45^{171\ K}$	171		277	dec	83.7	312.2
NO_2	g	46.0	$1.49^{262\ K}$	262		294		33.2	240.0
N_2O_4	g	92.0	$1.45^{262\ K}$	262		294		9.2	304.2
N_2O_5	s	108.0	1.64	303		320	dec	−41.3	178.2
Ammonia									
NH_3	g	17.0	0.77^{195K}	195		240		−46.1	192.3
NH_4Cl	s	53.5	1.53	613	sub	793	>1 atm	−314.4	94.6
NH_4Br	s	97.9	2.43	725	sub	508	vac	−270.8	113.0
NH_4I	s	144.9	2.51	824	sub	493	vac	−201.4	117.0
NH_4NO_3	s	80.0	1.72	443		483		−365.6	151.1
$(NH_4)_2SO_4$	s	132.1	1.77	508	dec	786	>1 atm	−1180.9	220.1
Oxygen									
O_3	g	48.0	2.14^{81K}	81		161		142.7	238.8
Phosphorus									
PH_3	g	34.0	—	140		185		5.4	210.1
PCl_3	l	137.3	1.57	161		349		−319.7	217.1
PCl_5	s	208.2	2.12	435	sub	440	dec	−443.5	166.5
$POCl_3$	l	153.3	1.67	275		378		−597.1	222.5
P_4O_6	s	219.9	2.13	297		448		−1640.1	—
P_4O_{10}	s	283.9	2.39	853	>1 atm	573	sub	−2984.0	228.9
Potassium									
KF	s	58.1	2.48	1131		1778		−567.3	66.6
KCl	s	74.6	1.98	1043		1773	sub	−436.7	82.6
$KClO_3$	s	122.5	2.32	629		673	dec	−397.7	143.1
$KClO_4$	s	138.5	2.52	883		673	dec	−432.8	151.0
KBr	s	119.0	2.75	1007		1708		−393.8	95.9
KI	s	166.0	3.13	954		1603		−327.9	106.3
KIO_3	s	214.0	3.93	833		373	dec	−501.4	151.5
KIO_4	s	230.0	3.62	855		573	dec	−467.2	176.0
K_2O	s	94.2	2.32	623	sub	—		−361.4	—
KO_2	s	71.1	2.14	653		dec		−284.9	116.7

Compound	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}
KOH	s	56.1	2.04	633	1593	−424.8	78.9
K_2CO_3	s	138.2	2.43	1164	dec	−1151.0	155.5
$KHCO_3$	s	100.1	2.17	373 dec	—	−963.2	115.5
KNO_2	s	85.1	1.92	713	dec	−369.8	152.1
KNO_3	s	101.1	2.11	607	673 dec	−494.6	133.1
KCN	s	65.1	1.52	908	—	−113.0	128.5
KCNS	s	97.2	1.89	446	773 dec	−200.2	124.3
K_2SO_4	s	174.3	2.66	1342	1962	−1437.8	175.6
$KMnO_4$	s	158.0	2.70	<513 dec	—	−837.2	171.7
K_2CrO_4	s	194.2	2.73	1241	—	−1403.7	200.1
$K_2Cr_2O_7$	s	294.2	2.68	671	773 dec	−2061.4	291.2
$KAl(SO_4)_2.12H_2O$	s	474.4	1.76	366	473 dhd	−6061.8	687.4
$K_3Fe(CN)_6$	s	329.3	1.85	dec	—	−249.8	426.1
$K_4Fe(CN)_6$	s	368.3	—	dec	—	−594.1	418.8
Rubidium							
RbCl	s	120.9	2.80	991	1663	−435.3	95.9
Silicon							
SiH_4	g	32.1	0.68$^{188\ K}$	88	161	34.3	204.5
$SiCl_4$	l	169.9	1.48	203	331	−687.0	239.7
SiO_2 (quartz)	s	60.1	2.65	1883	2503	−910.9	41.8
Sodium							
NaH	s	24.0	0.92	1073 dec	—	−56.3	40.0
NaF	s	42.0	2.56	1266	1968	−573.6	51.5
NaCl	s	58.4	2.17	1074	1686	−411.2	72.1
$NaClO_3$	s	106.4	2.49	521-534	dec	−365.8	123.4
$NaClO_4$	s	122.4	—	755 dec	dec	−383.3	142.3
NaBr	s	102.9	3.20	1020	1663	−361.1	86.8
NaI	s	149.9	3.67	934	1577	−287.8	98.5
Na_2O	s	62.0	2.27	1548 sub	—	−414.2	75.1
Na_2O_2	s	78.0	2.81	733 dec	930 dec	−510.9	95.0
NaOH	s	40.0	2.13	592	1663	−425.6	64.5
Na_2CO_3	s	106.0	2.53	1124	dec	−1130.7	135.0
$Na_2CO_3.10H_2O$	s	286.1	1.44	306-8	306 dhd	−4081.3	564.0
$NaHCO_3$	s	84.0	2.16	543 dec	—	−950.8	101.7
$NaNO_2$	s	69.0	2.17	544	593 dec	−358.7	103.8
$NaNO_3$	s	85.0	2.26	580	653 dec	−467.9	116.5
Na_2S	s	78.0	1.86	1453	—	−364.8	83.7
Na_2SO_4	s	142.0	—	1157	—	−1387.1	149.6
$Na_2SO_4.10H_2O$	s	322.2	1.46	306	373 dhd	−4327.3	592.0
$NaHSO_4$	s	120.1	2.43	588	dec	−1125.5	113.0
$Na_2S_2O_3$	s	158.1	1.67	—	—	−1123.0	155.0
$Na_2S_2O_3.5H_2O$	s	248.2	1.73	313-318	373 dhd	−2607.9	372.4
Na_3PO_4	s	164.1	—	—	—	−1917.4	173.8
Na_2SiO_3 (water glass)	s	122.1	2.4	1361	—	−1554.9	113.8

Compound	St	M /g mol^{-1}	ρ /g cm^{-3}	T_m /K	T_b /K	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$ /J mol^{-1} K^{-1}
Sulphur							
SF_4	g	108.1	—	149	233	−774.9	291.9
SF_6	g	146.1	1.88$^{223\ K}$	223 m	209 sub	−12.9.0	291.7
SCl_2	g	103.0	1.62	195	332 dec	−19.7	282.2
$SOCl_2$	l	119.0	1.66	168	352	−245.6	307.9
SO_2Cl_2	l	135.0	1.67	219	342	−394.1	216.7
SO_2	g	64.1	1.43$^{200\ K}$	200	263	−296.8	248.1
SO_3	l	80.1	1.97	290	318	−441.0	95.6
Tin							
$SnCl_2$	s	189.6	3.95	519	925	−325.1	—
$SnCl_4$	l	260.5	2.23	240	387	−511.3	258.6
SnO_2 (cassiterite)	s	150.7	6.95	1903	2123 sub	−580.7	52.3
Titanium							
TiO_2	s	79.9	3.84	2103	—	−939.7	49.9
Xenon							
XeF_2	s	169.3	4.3	413	—	−133.9	133.9
XeF_4	s	207.2	4.1	387	—	−261.5	146.4
XeF_6	s	245.3	—	319	—	−380.7	—
XeO_3	s	179.3	4.6	dec	—	401.7	—
Uranium							
UF_6	g	352.0	4.68	338	329	−2112.9	379.7
$UO_2(NO_3)_2$	s	394.0	—	—	—	−1377.4	276.1
Vanadium							
VCl_2	s	121.8	3.23	—	—	−452.0	97.1
VCl_3	s	157.3	3.00	dec	—	−580.7	131.0
VCl_4	l	192.8	1.82	245	422	−569.4	255.2
VO_2	s	82.9	4.34	2240	—	—	—
V_2O_5	s	181.9	3.36	963	2023 dec	−1550.6	131.0
Zinc							
$ZnCl_2$	s	136.3	2.91	556	1005	−415.1	111.5
ZnO	s	319.2	4.74	719	897	−348.3	43.6
$ZnCO_3$	s	125.4	4.40	573 dec	—	−812.8	82.4
$Zn(NO_3)_2$	s	189.4	—	—	—	−483.7	—
ZnS (blende)	s	97.4	4.10	1293	—	−206.0	65.3
$ZnSO_4$	s	161.4	3.54	873 dec	—	−982.8	119.7

The Periodic Table of the Elements

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

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