

The Periodic Table of the Elements

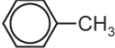
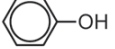
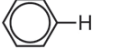
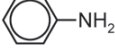
Group																	
I	II																0
6.9 Li lithium 3	9.0 Be beryllium 4		<div>Key</div> <div>relative atomic mass atomic symbol name atomic number</div>														4.0 He helium 2
23.0 Na sodium 11	24.3 Mg magnesium 12																20.2 Ne neon 10
39.1 K potassium 19	40.1 Ca calcium 20	45.0 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	— Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La lanthanum 57	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	— Po polonium 84	— At astatine 85	— Rn radon 86
— Fr francium 87	— Ra radium 88	— Ac actinium 89	— Rf rutherfordium 104	— Db dubnium 105	— Sg seaborgium 106	— Bh bohrium 107	— Hs hassium 108	— Mt meitnerium 109	— Un ununnilium 110	— Uuu unununium 111	— Uub ununbium 112		— Uuq ununquadium 114		— Uuh ununhexium 116		— Uuo ununoctium 118

lanthanides *		140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	— 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
actinides *		— Th thorium 90	— Pa protactinium 91	— U uranium 92	— Np neptunium 93	— Pu plutonium 94	— Am americium 95	— Cm curium 96	— Bk berkelium 97	— Cf californium 98	— Es einsteinium 99	— Fm fermium 100	— Md mendelevium 101	— No nobelium 102	— Lw lawrencium 103

Data Booklet (9647)

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Typical proton chemical shift value (δ) relative to T.M.S.=0	
Type of proton	Chemical shift (ppm)
R—CH ₃	0.9
R—CH ₂ —R	1.3
R ₃ CH	1.4–1.7
CH ₃ —C(=O)OR	2.0
R—C(=O)CH ₃	2.1
	2.3
R—C≡C—H	1.8–3.1
R—CH ₂ —Hal	3.2–3.7
R—O—CH ₃	3.3–4.0
R—O—H	0.5–6.0*
R ₂ C=CH—	4.5–6.0
	4.5–7.0*
	6.0–9.0
R—C(=O)H	9.0–10.0
R—C(=O)O—H	9.0–13.0*
R—NH ₂	1.0–5.0*
	3.0–6.0*
R—C(=O)NH—	5.0–12.0*
*Sensitive to solvent, concentration	

			Successive IEs			Diatomic molecules		Electrode reaction			E^{\ominus}/V					
	Proton Number					Bond	Energy/kJ mol ^{−1}									
H	1	1310	-	-	-	H—H	436	Ag ⁺ + e [−]	≡	Ag	+0.80	NO ₃ [−] + 3H ⁺ + 2e [−]	≡	HNO ₂ + H ₂ O	+0.94	
He	2	2370	5250	-	-	D—D	442	Al ³⁺ + 3e [−]	≡	Al	−1.66	NO ₃ [−] + 10H ⁺ + 8e [−]	≡	NH ₄ ⁺ + 3H ₂ O	+0.87	
Li	3	519	7300	11800	-	N≡N	994	Ba ²⁺ + 2e [−]	≡	Ba	−2.90	Na ⁺ + e [−]	≡	Na	−2.71	
Be	4	900	1760	14800	21000	O=O	496	Br ₂ + 2e [−]	≡	2Br [−]	+1.07	Ni ²⁺ + 2e [−]	≡	Ni	−0.25	
B	5	799	2420	3660	25000	F—F	158	Ca ²⁺ + 2e [−]	≡	Ca	−2.87	[Ni(NH ₃) ₆] ²⁺ + 2e [−]	≡	Ni + 6NH ₃	−0.51	
C	6	1090	2350	4610	6220	Cl—Cl	244	Cl ₂ + 2e [−]	≡	2Cl [−]	+1.36	H ₂ O ₂ + 2H ⁺ + 2e [−]	≡	2H ₂ O	+1.77	
N	7	1400	2860	4590	7480	Br—Br	193	2HOC ^l + 2H ⁺ + 2e [−]	≡	Cl ₂ + 2H ₂ O	+1.64	O ₂ + 4H ⁺ + 4e [−]	≡	2H ₂ O	+1.23	
O	8	1310	3390	5320	7450	I—I	151	Co ²⁺ + 2e [−]	≡	Co	−0.28	O ₂ + 2H ₂ O + 4e [−]	≡	4OH [−]	+0.40	
F	9	1680	3370	6040	8410	H—F	562	Co ³⁺ + e [−]	≡	Co ²⁺	+1.82	O ₂ + 2H ⁺ + 2e [−]	≡	H ₂ O ₂	+0.68	
Ne	10	2080	3950	6150	9290	H—Cl	431	[Co(NH ₃) ₆] ²⁺ + 2e [−]	≡	Co + 6NH ₃	−0.43	2H ₂ O + 2e [−]	≡	H ₂ + 2OH [−]	−0.83	
Na	11	494	4560	6940	9540	H—Br	366	Cr ²⁺ + 2e [−]	≡	Cr	−0.91	Pb ²⁺ + 2e [−]	≡	Pb	−0.13	
Mg	12	736	1450	7740	10500	H—I	299	Cr ³⁺ + 3e [−]	≡	Cr	−0.74	Pb ⁴⁺ + 2e [−]	≡	Pb ²⁺	+1.69	
Al	13	577	1820	2740	11600	Polyatomic molecules		Cr ³⁺ + e [−]	≡	Cr ²⁺	−0.41	PbO ₂ + 4H ⁺ + 2e [−]	≡	Pb ²⁺ + 2H ₂ O	+1.47	
Si	14	786	1580	3230	4360	Bond	Energy/kJ mol ^{−1}	Cr ₂ O ₇ ^{2−} + 14H ⁺ + 6e [−]	≡	2Cr ³⁺ + 7H ₂ O	+1.33	SO ₄ ^{2−} + 4H ⁺ + 2e [−]	≡	SO ₂ + 2H ₂ O	+0.17	
P	15	1060	1900	2920	4960	C—C	350	Cu ⁺ + e [−]	≡	Cu	+0.52	S ₂ O ₈ ^{2−} + 2e [−]	≡	2SO ₄ ^{2−}	+2.01	
S	16	1000	2260	3390	4540	C=C	610	Cu ²⁺ + 2e [−]	≡	Cu	+0.34	S ₄ O ₆ ^{2−} + 2e [−]	≡	2S ₂ O ₃ ^{2−}	+0.09	
Cl	17	1260	2300	3850	5150	C≡C	840	Cu ²⁺ + e [−]	≡	Cu ⁺	+0.15	Sn ²⁺ + 2e [−]	≡	Sn	−0.14	
Ar	18	1520	2660	3950	5770	C ^{•••} C (benzene)	520	[Cu(NH ₃) ₄] ²⁺ + 2e [−]	≡	Cu + 4NH ₃	−0.05	Sn ⁴⁺ + 2e [−]	≡	Sn ²⁺	+0.15	
K	19	418	3070	4600	5860	C—H	410	F ₂ + 2e [−]	≡	2F [−]	+2.87	V ²⁺ + 2e [−]	≡	V	−1.20	
Ca	20	590	1150	4940	6480	C—Cl	340	Fe ²⁺ + 2e [−]	≡	Fe	−0.44	V ³⁺ + e [−]	≡	V ²⁺	−0.26	
Sc	21	632	1240	2390	7110	C—Br	280	Fe ³⁺ + 3e [−]	≡	Fe	−0.04	VO ²⁺ + 2H ⁺ + e [−]	≡	V ³⁺ + H ₂ O	+0.34	
Ti	22	661	1310	2720	4170	C—I	240	Fe ³⁺ + e [−]	≡	Fe ²⁺	+0.77	VO ₂ ⁺ + 2H ⁺ + e [−]	≡	VO ²⁺ + H ₂ O	+1.00	
V	23	648	1370	2870	4600	C—O	360	[Fe(CN) ₆] ^{3−} + e [−]	≡	[Fe(CN) ₆] ^{4−}	+0.36	VO ₃ [−] + 4H ⁺ + e [−]	≡	VO ²⁺ + 2H ₂ O	+1.00	
Cr	24	653	1590	2990	4770	C=O	740	Fe(OH) ₃ + e [−]	≡	Fe(OH) ₂ + OH [−]	−0.56	Zn ²⁺ + 2e [−]	≡	Zn	−0.76	
Mn	25	716	1510	3250	5190	C—N	305	2H ⁺ + 2e [−]	≡	H ₂	0.00	<div><div>Characteristic ranges</div><div>Wavenumber</div><div>(reciprocal wavelength)</div><div>/cm^{−1}</div></div> <div><div>Bond</div><div>C—Cl</div><div>700 to 800</div></div> <div><div>C—O</div><div>alcohols, ethers, esters</div><div>1000 to 1300</div></div> <div><div>C=C</div><div></div><div>1610 to 1680</div></div> <div><div>C=O</div><div>aldehydes, ketones, acids, esters</div><div>1680 to 1750</div></div> <div><div>C≡C</div><div></div><div>2070 to 2250</div></div> <div><div>C≡N</div><div></div><div>2200 to 2280</div></div> <div><div>O—H</div><div>'hydrogen-bonded' in acids</div><div>2500 to 3300</div></div> <div><div>C—H</div><div>alkanes, alkenes, arenes</div><div>2840 to 3095</div></div> <div><div>O—H</div><div>'hydrogen-bonded' in alcohols, phenols</div><div>3230 to 3550</div></div> <div><div>N—H</div><div>primary amines</div><div>3350 to 3500</div></div> <div><div>O—H</div><div>'free'</div><div>3580 to 3650</div></div>				
Fe	26	762	1560	2960	5400	C=N	610	I ₂ + 2e [−]	≡	2I [−]	+0.54					
Co	27	757	1640	3230	5100	C≡N	890	K ⁺ + e [−]	≡	K	−2.92					
Ni	28	736	1750	3390	5400	N—H	390	Li ⁺ + e [−]	≡	Li	−3.04					
Cu	29	745	1960	3350	5690	N=N	410	Mg ²⁺ + 2e [−]	≡	Mg	−2.38					
Zn	30	908	1730	3828	5980	O—H	460	Mn ²⁺ + 2e [−]	≡	Mn	−1.18					
Ga	31	577	1980	2960	6190	O—O	150	Mn ³⁺ + e [−]	≡	Mn ²⁺	+1.49					
Ge	32	762	1540	3300	4390	Si—Cl	359	MnO ₂ + 4H ⁺ + 2e [−]	≡	Mn ²⁺ + 2H ₂ O	+1.23					
Br	35	1140	2080	3460	4850	Si—H	320	MnO ₄ [−] + e [−]	≡	MnO ₄ ^{2−}	+0.56					
Sr	38	548	1060	4120	5440	Si—O	444	MnO ₄ [−] + 4H ⁺ + 3e [−]	≡	MnO ₂ + 2H ₂ O	+1.67					
Sn	50	707	1410	2940	3930	Si—Si	222	MnO ₄ [−] + 8H ⁺ + 5e [−]	≡	Mn ²⁺ + 4H ₂ O	+1.52					
I	53	1010	1840	2040	4030	S—Cl	250	NO ₃ [−] + 2H ⁺ + e [−]	≡	NO ₂ + H ₂ O	+0.81					
Ba	56	502	966	3390	-	S—H	347									
Pb	82	716	1450	3080	4080	S—S	264									

Period 3		atomic		ionic
Na	metalloid	0.186	+	0.095
Mg		0.160	2+	0.065
Al		0.143	3+	0.050
Si		0.117	4+	0.041
P		0.110	3−	0.212
S	single covalent	0.104	2−	0.184
Cl		0.099	−	0.181
Ar	van der Waals	0.192		
Group II		atomic		ionic
Be		0.112	2+	0.031
Mg		0.160	2+	0.065
Ca		0.197	2+	0.099
Sr		0.215	2+	0.113
Ba		0.217	2+	0.135
Ra		0.220	2+	0.140
Group IV		atomic		ionic
C	single covalent	0.077		
Si		0.117	4+	0.041
Ge		0.122	2+	0.093
Sn	metalloid	0.162	2+	0.112
Pb		0.175	2+	0.120
Group VII		atomic		ionic
F	single covalent	0.072	−	0.136
Cl		0.099	−	0.181
Br		0.114	−	0.195
I		0.133	−	0.216
At		0.140		
First row TM		atomic		ionic
Sc		0.144	3+	0.081
Ti		0.132	2+	0.090
V		0.122	3+	0.074
Cr		0.117	3+	0.069
Mn		0.117	2+	0.080
Fe	single covalent	0.116	2+	0.076
Co		0.116	2+	0.064
Ni		0.115	2+	0.078
Cu		0.117	2+	0.069
Zn		0.125	2+	0.074

R

=

8.31 J K^{−1} mol^{−1}

F

=

9.65 × 10⁴ C mol^{−1}

L

=

6.02 × 10²³ mol^{−1}

q_e

=

−1.60 × 10^{−19} C

K_w

=

1.00 × 10^{−14} mol² dm^{−6}
298 K (25 °C)

V_M

=

22.4 dm³ mol^{−1}
stp 101 kPa, 273 K (0 °C)

=

24 dm³ mol^{−1}
rtp 101 kPa, 298 K (25 °C)

C

=

4.18 kJ kg^{−1} K^{−1}
4.18 J g^{−1} K^{−1}