CHAPTER 2

Tables

These tables are from

Understanding the properties of matter

by Michael de Podesta.

Table 2.1 The properties of particles that are treated as fundamental in this book. The most important properties of the particles for understanding the properties of matter are the first two rows of the table: mass and electric charge. The internal angular momentum (spin) and magnetic moment of the particles are discussed in the text below.

Property	Units	Electron	Neutron	Proton
Mass	Atomic mass units $u = 1.661 \times 10^{-27}$ kg	5.485×10^{-4} $\approx 1/1836$	1.0085	1.0071
Electric charge	Proton charge $e = 1.602 \times 10^{-19}$ C	–1	0	+1
Magnetic moment	Bohr magneton $\mu_B = 9.274 \times 10^{-24}$ J T^{-1}	1.001	1.0419×10^{-3}	1.521×10^{-3}
Magnetic moment	Nuclear magneton $\mu_N = 5.051 \times 10^{-27}$ J T^{-1}	1837.8	1.913	2.793
Intrinsic (spin) angular momentum	Planck constant divided by 2π $\hbar = 1.054 \times 10^{-34}$ J s	½	½	½
Electric dipole moment	Cm	0	0	0
Lifetime		Stable	Stable within nuclei half life ≈ 15 minutes in free space.	Stable

Table 2.2. The elements with atomic numbers up to 105 together with their date of discovery. The term 'Old' as a date of discovery indicates that the element was known in antiquity. The names of the elements tell many fascinating stories about their discovery.

Z	Element, symbol, date of discovery	Origin of name
1	Hydrogen, H, (1766)	Greek: *Hydros Genes*: meaning Water Forming
2	Helium, He, (1895)	Greek: *Helios* meaning Sun
3	Lithium, Li, (1817)	Greek: *Lithos* meaning Stone
4	Beryllium, Be, (1797)	Greek: *Beryllos* meaning Beryl
5	Boron, B, (1808)	Arabic: *Buraq*
6	Carbon, C, (Old)	Latin: *Carbo* meaning Charcoal
7	Nitrogen, N, (1772)	Greek: *Nitron* Genes meaning Nitre Forming
8	Oxygen, O, (1774)	Greek: *Oxy Genes* meaning Acid Forming
9	Fluorine, F, (1886)	Latin: *Fluere* meaning To Flow
10	Neon, Ne, (1898)	Greek: *Neos* meaning New
11	Sodium, Na, (1807)	English: Soda: The symbol comes from the Latin *Natrium*
12	Magnesium, Mg, (1755)	Greek: Magnesia, a district in Thessaly
13	Aluminium, Al, (1825)	Latin: *alumen* meaning alum
14	Silicon, Si, , (1824)	Latin: *Silicis* meaning Flint
15	Phosphorus, P, (1669)	Greek: Phosphorus meaning Bringer of Light
16	Sulphur, S, (Old)	Sanskrit: *Sulvere* meaning Sulphur
17	Chlorine, Cl, (1774)	Greek: *Chloros* meaning Pale Green
18	Argon, Ar, (1894)	Greek: *Argos* meaning Inactive
19	Potassium, K, (1807)	English: Potash: The symbol comes from the Latin *Kalium*
20	Calcium, Ca, (1808)	Latin: *Calix* meaning Lime
21	Scandium, Sc, (1879)	Latin: *Scandia* meaning Scandinavia
22	Titanium, Ti, (1791)	*Titans*, Sons of the Earth Goddess.
23	Vanadium, V, (1801)	*Vanadis*, Scandinavian goddess
24	Chromium, Cr, (1780)	Greek: *Chroma* meaning Colour
25	Manganese, Mn, (1774)	Latin: *Magnes* meaning Magnet
26	Iron, Fe, (Old)	Saxon: Iron: The symbol comes from the Latin *Ferrum*
27	Cobalt, Co, (1735)	German: *kobald* meaning Goblin
28	Nickel, Ni, (1751)	German: *Kupfernickel* meaning either Devil's Copper or St Nicholas' Copper
29	Copper, Cu, (Old)	Latin: *Cuprum* meaning Cyprus
30	Zinc, Zn, (1400)	German: *Zink*
31	Gallium, Ga, (1875)	Latin: *Gallia* meaning France
32	Germanium, Ge, (1886)	Latin: *Germania* meaning German
33	Arsenic, As, (1280)	Greek: *Arsenikon* meaning Yellow Orpiment
34	Selenium, Se, (1817)	Greek: *Selene* meaning Moon
35	Bromine, Br, (1826)	Greek: *Bromos* meaning Stench
36	Krypton, Kr, (1898)	Greek: *Kryptos* meaning Hidden
37	Rubidium, Rb, (1861)	Latin: *Rubidius* meaning Deepest Red
38	Strontium, Sr, (1790)	English: *Strontian* in Scotland
39	Yttrium, Y, (1794)	The town of Ytterby in Sweden
40	Zirconium, Zr, (1789)	Arabic: *Zargun* meaning Gold Colour
41	Niobium, Nb, (1801)	Greek: *Niobe*, a daughter of Tantalus: Also called Columbium in USA
42	Molybdenum, Mo, (1781)	Greek: *Molybdos* meaning Lead
43	Technetium, Tc, (1937)	Greek: *Technikos* meaning Artificial
44	Ruthenium, Ru, (1808)	Latin: *Ruthenia* meaning Russia
45	Rhodium, Rh, (1803)	Greek: *Rhodon* meaning Rose
46	Palladium, Pd, (1803)	The asteroid *Pallas*
47	Silver, Ag, (Old)	Saxon: *Siolfur* meaning Silver: The symbol comes from the Latin *Argentum*
48	Cadmium, Cd, (1817)	Latin: *Cadmia* meaning *Calomine*
49	Indium, In, (1863)	Indigo
50	Tin, Sn, (Old)	Saxon: Tin: The symbol comes from the Latin *Stannum*
51	Antimony, Sb, (Old)	Greek: *Anti+Monos* meaning not alone. The symbol is from Latin *Stibium*
52	Tellurium, Te, (1783)	Latin: *Tellus* meaning Earth
53	Iodine, I, (1811)	Greek: *Iodes* meaning Violet
54	Xenon, Xe, (1898)	Greek: *Xenos* meaning Stranger
55	Caesium, Cs, (1860)	Latin: *Caesius* meaning Sky Blue
56	Barium, Ba, (1808)	Greek: *Barys* meaning Heavy
57	Lanthanum, La, (1839)	Greek: *Lanthanein* meaning To Lie Hidden
58	Cerium, Ce, (1803)	*Ceres*, an asteroid discovered in 1801
59	Praseodymium, Pr, (1885)	Greek: *Prasios Didymos* meaning Green Twin
60	Neodymium, Nd, (1885)	Greek: *Neos Didymos* meaning New Twin
61	Promethium, Pm, (1945)	Greek: *Prometheus*
62	Samarium, Sm, (1879)	The mineral Samarskite
63	Europium, Eu, (1901)	Europe
64	Gadolinium, Gd, (1880)	J. Gadolin, a Finnish chemist
65	Terbium, Tb, (1843)	The town of Ytterby in Sweden
66	Dysprosium, Dy, (1886)	Greek: *Dysprositos* meaning Hard To Obtain

Z	Element, symbol, date of discovery	Origin of name
67	Holmium, Ho, (1878)	Latin: *Holmia* meaning Stockholm
68	Erbium, Er, (1842)	The town of Ytterby in Sweden
69	Thulium, Tm, (1879)	*Thule*, meaning Ancient Scandinavia: The Uttermost North
70	Ytterbium, Yb, (1878)	The town of Ytterby in Sweden
71	Lutetium, Lu, (1907)	Latin: *Lutetia* meaning Paris
72	Hafnium, Hf, (1923)	Latin: *Hafnia* meaning Copenhagen
73	Tantalum, Ta, (1802)	Greek: *Tantalos*, the father of *Niobe*
74	Tungsten, W, (1783)	Swedish: *Tung Sten* meaning Heavy Stone: The symbol comes from the alternative name Wolfram
75	Rhenium, Re, (1925)	Latin: *Rhenus* meaning Rhine
76	Osmium, Os, (1803)	Greek: *Osme* meaning Smell
77	Iridium, Ir, (1803)	Latin: Iris meaning Rainbow
78	Platinum, Pt, (Old)	Spanish: *Platina* meaning Silver
79	Gold, Au, (Old)	Saxon: Gold
80	Mercury, Hg, (Old)	Latin: The planet Mercury: The symbol comes from the Latin *Hydragyrum* meaning Liquid Silver
81	Thallium, Tl, (1861)	Greek: *Thallos* meaning Green Twig
82	Lead, Pb, (Old)	Saxon: Lead: The symbol comes from the Latin *Plumbum*
83	Bismuth, Bi, (1450)	German: *Bisemutem*
84	Polonium, Po, (1898)	Poland
85	Astatine, At, (1940)	Greek: *Astatos* meaning unstable
86	Radon, Rn, (1900)	Radium
87	Francium, Fr, (1939)	France
88	Radium, Ra, (1898)	Latin: Radius meaning Ray
89	Actinium, Ac, (1899)	Greek: *aktinos* meaning Ray
90	Thorium, Th, (1815)	*Thor* The Scandinavian god of war
91	Protractinium, Pa, (1917)	Greek: *Protos* meaning First
92	Uranium, U, (1789)	The planet Uranus
93	Neptunium, Np, (1940)	The planet Neptune
94	Plutonium, Pu, (1940)	The planet Pluto
95	Americium, Am, (1944)	English: America
96	Curium, Cm, (1944)	Pierre and Marie Curie
97	Berkelium, Bk, (1949)	English: Berkeley
98	Californium, Cf, (1950)	English: California
99	Einsteinium, Es, (1952)	Albert Einstein
100	Fermium, Fm, (1952)	Enrico Fermi
101	Mendelevium, Md, (1955)	Dmitri Mendeleyev
102	Nobelium, No, (1958)	Alfred Nobel
103	Lawrencium, Lr, (1961)	Ernest O. Lawrence
104	Rutherfordium, Rf, (1964)	Ernest Rutherford
105	Dubnium, Db, (1967)	The town of Dubna, home to a centre for nuclear research

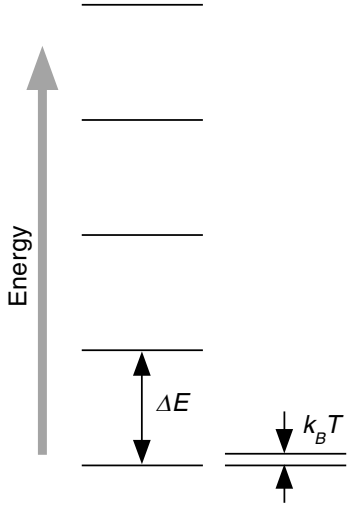
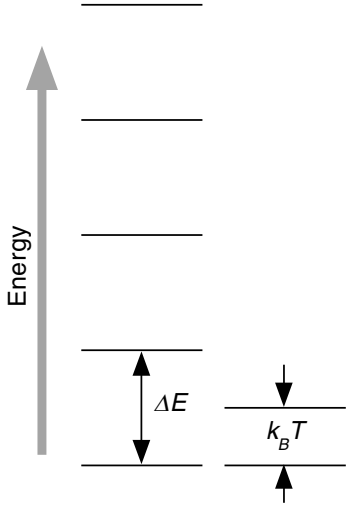
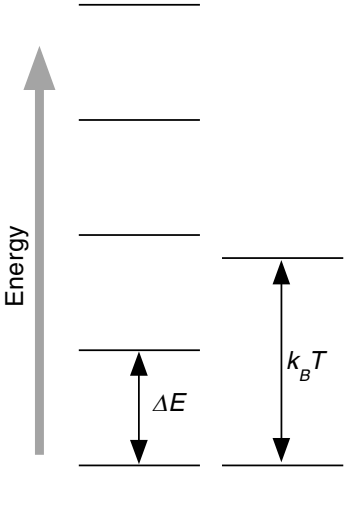
Table 2.3 Photon energies, frequencies, and wavelengths.

Frequency (Hz)	**Wavelength** (m)	**Energy** (eV)	**Comment**
10^{6}	3×10^{2}	4.14×10^{-9}	Radio broadcasts
10^{7}	3×10^{1}	4.14×10^{-8}	
10^{8}	3	4.14×10^{-7}	Television broadcasts
10^{9}	3×10^{-1}	4.14×10^{-6}	A gigahertz: microwave ovens and mobile phones
10^{10}	3×10^{-2}	4.14×10^{-5}	Infra-red
10^{11}	3×10^{-3}	4.14×10^{-4}	Infra-red
10^{12}	3×10^{-4}	4.14×10^{-3}	A terahertz: Infra-red: Typical frequency of atomic vibration
6.6×10^{12}	4.55×10^{-4}	2.5×10^{-2}	Infra-red: corresponds to processes occurring at around room temperature (290K)
10^{13}	3×10^{-5}	4.14×10^{-2}	Infra-red
4×10^{14}	7.5×10^{-7}	1.654	Red light: Corresponds to processes involving electrons in the outer (valence) shells of atoms
10^{15}	3×10^{-7}	4.14	Blue light: corresponds to processes involving electrons in the outer (valence) shells of atoms
10^{16}	3×10^{-8}	4.14×10^{1}	Ultra-violet light
10^{17}	3×10^{-9}	4.14×10^{2}	Ultra-violet light
10^{18}	3×10^{-10}	4.14×10^{3}	Ultra-violet light
10^{19}	3×10^{-11}	4.14×10^{4}	X-rays
10^{20}	3×10^{-12}	4.14×10^{5}	X-rays: corresponds to processes involving electrons in the inner shells of atoms
10^{21}	3×10^{-13}	4.14×10^{6}	X-rays
10^{22}	3×10^{-14}	4.14×10^{7}	X-rays
10^{23}	3×10^{-15}	4.14×10^{8}	Gamma rays: Corresponds to processes that occur within nuclei

Table 2.4 The first few energy levels for particles trapped in a box. The columns show in order (i) the quantum numbers of the states, (ii) the energy of the states with these quantum numbers, (iii) the number of quantum states with the same energy level (the degeneracy of the level), and (iv) the running total of the number of quantum states.

Quantum numbers (n_x, n_y, n_z)	Energy $\times \frac{h^2}{8mL^2}$	Number of quantum states with this energy	Cumulative total of quantum states
(1,1,1)	3	1	1
(1,1,2) (1,2,1) (2,1,1)	6	3	1 + 3 = 4
(1,2,2) (2,1,2) (2,2,1)	9	3	1 + 3 + 3 = 7
(1,1,3) (1,3,1) (3,1,1)	11	3	1 + 3 + 3 + 3 = 10
(2,2,2)	12	1	1 + 3 + 3 + 3 + 1 = 11

Table 2.5 Illustration of the use of the term *accessibility* of quantum states. Notice that increasing the temperature always increases the number of 'accessible' quantum states.

Inaccessible	**Marginal accessibility**	**Fully accessible**
		
$k_BT << \Delta E$	$k_BT \approx \Delta E$	$k_BT >> \Delta E$
e.g. $k_BT < 0.1\Delta E$	e.g. $0.1\ \Delta E < k_BT < 1.5\Delta E$	e.g. $k_BT > 1.5\Delta E$
In this case, only occasionally do molecules make transitions to higher quantum states. We can consider the degrees of freedom associated with these transitions to be inaccessible. In colloquial terms, the processes associated with transitions between quantum states occur so rarely that they may generally be ignored.	In this case, molecules make transitions to the higher quantum states. Detailed calculations are required to assess the extent to which the quantum state can be considered accessible.	In this case, molecules frequently make transitions to higher quantum states. We can consider the degrees of freedom associated with these transitions to be fully accessible. In colloquial terms, the processes associated with transitions between quantum states occur so frequently that the quantum nature of the states may generally be ignored.