HELBING • BURKART

chemical

MATTER

NUMBER

PROCESS

TABLES

for Laboratory and Industry

CHEMICAL TABLES
for
Laboratory and Industry

MATTER ● NUMBER ● PROCESS

WOLFGANG HELBING
Director of Studies, Karlsruhe

and

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WILEY EASTERN LIMITED
New Delhi Bangalore Bombay Calcutta

FOREWORD

Through a special way of describing and summarizing we have combined the information of the tabular work with that of a textbook. Colours have been used at certain places as methodical and didactical means. The use of technical words and comments has been made for a better understanding of the tabular and graphic matter. Therefore, this book also serves the purpose of a review course.

In the beginning of the first part 'Matter' (135 pages) an introduction of the chemical elements and their properties have been put together followed by an illustrative wave-mechanical model of the atom and a description of the chemical compounds. The synopses and tables of the inorganic compounds (matter) have been compiled in special ways based on the periodic classification of elements and according to their common properties. In the case of the organic compounds the syntheses provided the structural framework of the molecules and the kind of functional groups present as the principle of classification. Through the use of screens the tabular matter has been made easy to understand and the grouping of the various classes of matter made clear. The re-location of information through the group numbers on the respective pages has also been simplified. The inorganic chemistry part of the tables consists of information about 1300 types of matter and their properties. The organic portion has just as many compounds. The choice of the compounds included in the tabular part has been based on the matter included in the textbooks on inorganic and organic chemistry.

The second part 'Number' (45 pages) does not only contain the important values of chemical and physiochemical quantities and constants, but also the rules of calculation and principles which are of importance for the chemical reactions and methods. Of special significance is the gas reduction table. This part is supplemented by the log tables included as appendix (36 pages) which contain apart from the 5-digit logarithm tables about 10,000 so-called decadic supplements, i.e., the logarithms of the reciprocal values of the numbers. In calculations the logarithm numbers need only to be added up. Finally, the lists also contain a large number of useful numerical figures: reciprocal values, square numbers, square roots, circumferences and areas of the circle.

The third part 'Process' (66 pages) contains principal methods for research laboratories and industry, and the numerical values used there. Graphic description of the essential apparatus and other vivid symbols are of great help for understanding the text matter that has been presented in a concise form here. Apart from the general methods qualitative as well as quantitative inorganic and organic analytical methods have also been described. In connection with the analytical tables of numerical value short notes have been inserted at places which considerably enhance the purely mathematical value of the tables. A well-compiled list of technical words with about 5,000 such key-words simplify the location of the required information about the concepts, definitions, rules, laws or methods as well as of the matter and its characteristics.

We would also like to thank all those who in the publishing house extended to us all the facility in bringing out this book. The composing and printing of the chemical formulae put the publishers to a number of difficulties.

Karlsruhe, Spring 1969

Wolfgang Helbing
Adolf Burkart

First English Edition, 1979
Authorized translation of the edition published by
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Basic Materials or Elements.

Structure of basic materials

Basic materials or elements are substances which cannot be split into more other substances through chemical methods.

All fundamental matters are built up of atoms.
Atoms have spherical shape and consist of a nucleus and a sheath.

Diameter of the sheath	nearly 2 to	5.10^{-8} cm
Diameter of the nucleus	nearly 1 to	3.10^{-12} cm"
Mass of the atom	nearly 2 to	500.10^{-24} g

Atomic particles

Name and symbol	Mass in g	in me	in ME	Electrical charge in electrostatic units
Proton p	$1,6725.10^{-24}$	1836	1,0076	$+ 4,80.10^{-10}$
Neutron n	$1,6748.10^{-24}$	1838	1,0090	nil
Electron e^-	$9,1089.10^{-28}$	1	$5,5.10^{-4}$	$- 4,80.10^{-10}$

The atomic nucleus consists of neutrons and protons.
In conformity to law, the electrons are distributed in the atomic shell.

The number of electrons in the shell is equal to the number of protons in the nucleus and equals the atomic number of elements in the periodic system of elements.

The chemical properties of the elements depend on the structure of the shell.

A fundamental matter or an element is a substance in which all their shells have the structure and out of which atom is built.

Till now, we know 103 such elements.

The number of neutrons in the nucleus amounts to nearly 1.2 to 2.5 times the proton number and thus does not comprehend regularity.

Till now we know about 1,350 different atomic nuclei of which 324 occur in nature. The others are produced artificially and most undergo radioactive decay in short time.

Atoms whose nuclei have the same proton number but different neutron number, possess similarly built shells and have same atomic number, that is, they stand at the same place in the periodic system and are therefore called Isotopes (Greek, isos = equal, topos = place).

Isotopes have same chemical properties and distinguish themselves only in the mass, which by admission of a neutron, increases to about 1 ME.

A fundamental matter which possesses similarly built nucleus and shells, of which atom is built, is called pure element.

In nature 20 pure elements occur (see also pp. 14 and 15).

The percentage constituent of the isotope at the structure of a natural mixed element is (practically) constant (exception Pb, see pp. 16–19). Therefore, for the mixed element a constant atomic weight as weighed average value of isotopic weight results.

Trivial variations on account of local different mixtures of isotopes result in discrepancies in atomic weights of the following mixed elements.

H	1,00797 ± 0,000 01	O	15,999 4 ± 0,000 1*
B	10,811 ± 0,003	Si	28,086 ± 0,001
C	12,01115 ± 0,000 05	S	32,064 ± 0,003

*Since 1961, the fundamental unit 'atomic weight' or better the 'atom mass' 1 ME = 1/12 of mass of Carbon isotope $^{12}_{6}C$ has been chosen.
In case of accuracy of measurement the usual practical determination methods for molecular weights (molecular mass) have no significance in these discrepancies.

Wave mechanical model of atom

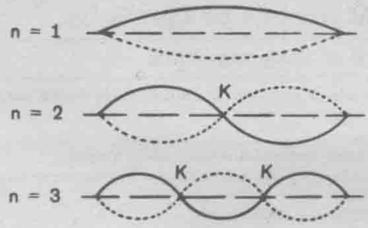
One dimensional oscillator, e.g., vibrating chord.

Basic oscillator (fundamental tone)

1. Over oscillation (overtone) at K originates a nodal point.

2. Over oscillation (overtone) at K originates a nodal points.

The whole can superimpose at which the oscillating chord is always the minima.



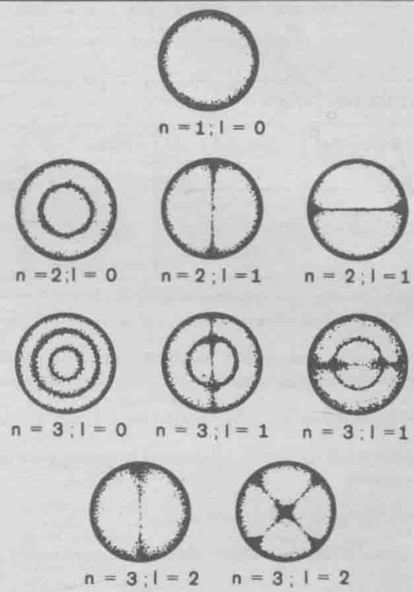
Two dimensional oscillator, e.g., drumhead basic oscillation (primary tone)

i. Over oscillation are three possible independent oscillations from one another. It results thereby a nodal line in the form of concentric circles or of diametrical nature.

ii. Over oscillations are five possible independent oscillations. The nodal lines are, thereby, in part, superimposed.

The fundamental and over oscillations can superimpose.

Through the nodal lines, the area in the region is so divided that either oscillations take place or they do not.



Such figures result when a vibrating drumhead is covered with powder.

Three dimensional Oscillator

(Wave mechanic model)

By these oscillations originate nodal planes in the form of concentric spheres and sectional plane (circular area) through the oscillating sphere.

Thus the sphere in spatial region is distributed which are designated as ORBITALS.

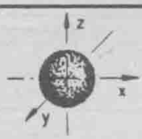
Number and Type of Nodal Planes in the Atomic Shells

Shell	n	l = No. of flat planes	n − l − 1 = No. of sphere shaped planes	Designation of electron orbitals
K	1	0	0	1s
L	2	0 1	1 0	2s 2p
M	3	0 1 2	2 1 0	3s 3p 3d
N	4	0 1 2 3	3 2 1 0	4s 4p 4d 4f

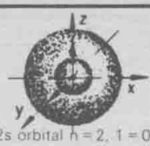
The limitation of shells comes as there are no further "walls" (planes) (see p. 7).

Atom Model

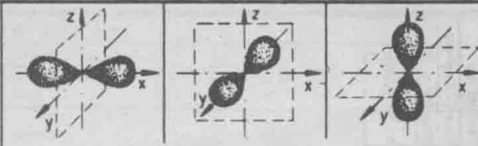
In every orbital two electrons can vibrate (see p. 8)



1s orbital $n = 1; l = 0$



2s orbital $n = 2, l = 0$
The inner sphere is a nodal plane



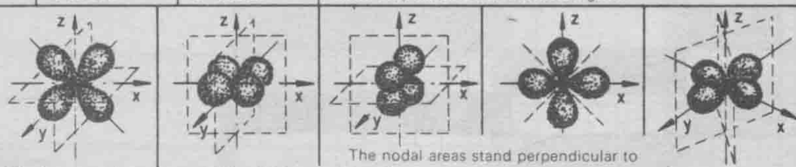
The three spatial positions of 2p orbitals $n = 2; l = 1$

NEON

Examples for the schematic or symbol-wise writing method

1s	2s 2p	3s 3p		
↑↓	↑↓ ↑↓ ↑↓ ↑↓		or $1s^2\ 2s^2\ 2p^6$	Neon
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑ ↑	or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$	Sulphur
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓	or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	Argon
K-	L-SHELL	M-SHELL	Read: one-s-two, two-s-two, three-p-six and so on; often only the outer electrons are given	

In the atomic shells, the oscillating orbitals are superimposed



The five spatial positions of 3d orbitals $n = 3, l = 2$

The nodal areas stand perpendicular to the marked plane

Krypton

1s	2s 2p	3s 3p 3d	4s 4p		
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓			Argon
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓	$4s^2$	Calcium
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑ ↑ ↑	↑↓	$3d^6\ 4s^2$	Iron
↑↓	↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓ ↑↓		Krypton
K-	L-SHELL	M-SHELL	N-SHELL		Further examples (see pp. 26–29)

Structure of Elements and the Chemical Formula

For writing various atoms, symbols are used, which are provided with indices.

Abbreviation of names of the elements are employed as 'symbols'. The abbreviation has not more than two letters and is employed internationally. A portion of the abbreviation has been derived not only from German names but also from Latin or Greek. (See pp. 11–12)

The **Symbol** stands for	Examples: Fe
1. The substance as such	1. Ferrum (Iron)
2. **An atom** of the substance	2. Iron atom
3. One gram atom of the substance	3. 55.85 g

Mixed Elements

In case of naturally occurring mixed elements the symbol is mostly given.

Pure Elements

In case of pure elements, through rounding off the isotope weight, it is made integral to the mass number and often the atomic number is attached as index to the symbol.

Mass Number / Atomic Number **Symbol**	Example $^{235}_{92}U$ or U 235

Atomic Ions

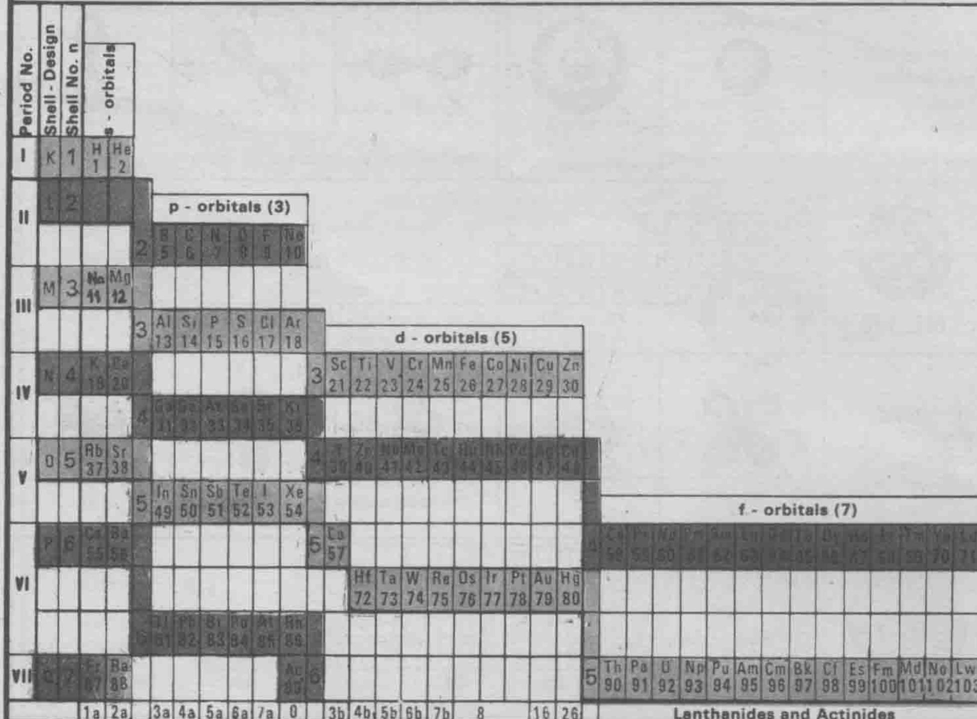
To write different atomic ions the element symbols are used and the charge is written on the top right hand side as index.

To indicate single charge of atomic ion often the sign + or − is used. However, multiple charge of atomic ion is indicated by number written before the sign + or −

In case of ions in aqueous solution (solvated ions) often the signs ˙ and ′ are employed instead of + and − respectively.

Examples are: H^+, O^{2-} or O″; Fe^{3+} or Fe

Structure and Arrangement of Atomic Shells



Orbital sub-groups of equal (or nearly equal) energy are arranged in equal height.
The energy increases stepwise—in these representations from above to below. First of all, the orbitals of equal energy grades, i.e., first singlet, then doublet, are filled. Subsequently, the structure passes on to the next grade.

Fundamental Rules for the Structure and the Arrangement of Atomic Covers

The total number of electrons in an Atomic Cover is equal to the atomic number.	Z = A.N.
The atomic sheath is classified as shells. Instead of "Numbers" symbols are also used frequently.	n = 1, 2, 3, ... K, L, M, ...
The total number (maximum) of possible orbitals in a shell is:	$z_{max} = 2n^2$
The total number of possible orbitals in a shell is:	$z_n = n^2$
The orbitals in orbital sub-groups are compounded. Instead of "numbers" symbols are also used.	l = 0, 1, 2, ... s, p, d, ...
The "numbers" of orbital sub-groups are equal to:	l = n − 1
The number of orbital sub-group is equal to:	z = 21 + 1
Each orbital can take up two electrons, the spins of which must be (opposite) coupled.	Pauli-principle

Values of the first 4 Shells in an atomic cover

Designation of Shell	Designation of Sub-groups	Number of Shells	Number of Sub-groups	Maximum number of Electrons	Number of Orbitals in the Shell	Number of Orbitals in the Orbital Sub-groups
K	s	1	1	0	1	= 1
L	s, p	2	0, 1	8	4	= 1 + 3
M	s, p, d	3	0, 1, 2	18	9	= 1 + 3 + 5
N	s, p, d, f	4	0, 1, 2, 3	32	16	= 1 + 3 + 5 + 7

The fifth Shell (O) contains these shell groups like the fourth Shell.
The sixth Shell (P) contains only s- and p-orbitals as well as a d-Orbital.
The seventh Shell (Q) contains only an s-Orbital.

Arrangement of Elements

Principle of Arrangement in the Periodic System of Elements

1. Successive increase in nuclear charge number or electron number gives the atomic number	IA.N. 1 ... 103
2. Arrangement according to the possible shells in the atomic cover gives the horizontal periods from:	I ... VII
3. Arrangement according to the number of valency electrons in the outer most shell gives the vertical group from:	0 ... 8
The Splitting of groups into main and sub-groups as well as the insertion of Lanthanides and Actinides is a result of alternately installing the electrons in the orbital sub-groups of the shell (see pp. 26–31)	1a, 1b, ... Lanthanides Actinides

Periodic system of Elements

I	1 H	2 He																															2 He
II*)	3 Li	4 Be																										5 B	6 C	7 N	8 O	9 F	10 Ne
III	11 Na	12 Mg																										13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
IV	19 K	20 Ca	21 Sc															22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
V	37 Rb	38 Sr	39 Y															40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
VI	55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
VII	87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw															
	1a	2a	3b	Lanthanides and Actinides														4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	8
	s-		d-	f- Orbitals														d- Orbitals									p- Orbitals					

Except rare gases, all atoms are qualified to either take electrons in their shell or give them out of their shell. These electrons are called **valence electrons.**
Out of a shell 1 to 8 valence electrons can be given up. Thus ionic atoms which carry 1 to 8 positive charges are formed.
Those possessing an ionic valency of +1 to +8 are called cations. (see p. 23)
In an atomic cover 1 to 4 valence electrons can be taken up. Thus ionic atoms which carry 1 to 4 negative charges are formed.
Those possessing an ionic valency of −1 to −4 are called anions. (see p. 23)
(An inert gas structure mostly results by giving up or receiving of electrons.)

Atoms, in particular of non-metallic elements, can build with the other elements to form a common structure. Besides electrons in pair always go together.
The number of possible electron pairs is equal to their cohesiveness.
In the I period upto 1 electron pair equals to 1 cohesiveness.
In the II period upto 4 electron pairs equal to 4 cohesiveness.
From the III period upto 8 electron pairs equal to 8 cohesiveness.
(Formation of a common cover also results in inert gas structure.) (see pp. 22, 26–30)

Metals are substances which can form only positive ionic atoms.
Non-metals are substances which preferably form negative ionic atoms.

A stable and permanent atomic structure can result:

1. with 2, 8, 18 or 32 electrons in the outermost shell:
   That in the above state rare gas is existing; it is designated as inert gas configuration (configuration = arrangement).
2. those which do not have completely filled shells with 18 outer most electrons.
   Examples of this state are atoms of Ni, Pd and Pt.
3. those outside the completely filled 8- or 18-shell possessing a completely filled s-orbital ($4s^2$, $5s^2$).
   Examples of this state are Sn^{+2} and other ions. (see pp. 26–29)

Properties of Elements

Group	Symbol	Name	A.N	Atomic mass	log AM	DE log	MP	BP	D/DD	$\Omega^{-1} \cdot cm^{-1}$	cal/g
0 Inert gas	He	Helium	2	4,0026	60239	39761	-270,7	-268,94	0,17848	–	
	Ne	Neon	10	20,183	30499	69501	-248,60	-245,98	0,9004	–	
	Ar	Argon	18	39,948	60108	39892	-189,3	-186,0	1,7839	–	
	Kr	Krypton	36	83,80	92324	07676	-157,2	-152,9	3,74	–	
	Xe	Xenon	54	131,30	11826	88174	-111,9	-108,1	5,851	–	
	Rn	Radon	86	222	34635	65365	-71	-61,9	9.730	–	
	H	Hydrogen**	1	1,00797*	00346	99654	-259,14	-252,78	0,08987	–	
1a Alkali-metals	Li	Lithium	3	6,939	84136	15864	186	1330	0,534	$1,2 \cdot 10^5$	0.79
	Na	Sodium	11	22,9898	36156	63844	97,7	883	0,971	$2,3 \cdot 10^5$	0,295
	K	Potassium	19	39,102	59218	40782	62,3	760	0,851	$1,6 \cdot 10^5$	0,192
	Rb	Rubidium	37	8,547	93186	06814	39,0	700	1,532	$8,6 \cdot 10^4$	0,080
	Cs	Casium	55	132,905	12355	87645	28,5	670	1,90	$4,5 \cdot 10^4$	0,052
	Fr	Frankium	87	(223)	34830	65170				–	–
2a Alkali-earthmetals	Be	Beryllium	4	9,0122	95521	04479	1280	2967	α = 1,86 β = 1,91	$1,5 \cdot 10^5$	0,425
	Mg	Magnesium	12	14,312	38596	61404	650	1107	1,74	$2,2 \cdot 10^5$	0,246
	Ca	Calcium	20	40,08	60293	39707	850	1240	1,55	$2,2 \cdot 10^5$	0,145
	Sr	Strontium	38	87,62	94265	05735	757	1150	2,60	$2,3 \cdot 10^5$	0,068
	Ba	Barium	56	137,34	13786	86214	850	1140	3,61	$3,3 \cdot 10^4$	0,066
	Ra	Radium	88	226,05	35421	64579	700	1140	~ 6	–	–
3a Earth-metals	B	Boron	5	10,811*	03423	96577	2300	~ 2550	Cryst: 2.33 amorph. 1,73	$1 \cdot 10^{-12}$	0,307
	Al	Aluminium	13	26,9815	43104	56896	660,1	2057	2,70	$3,8 \cdot 10^5$	0,214
	Ga	Gallium	31	69,72	84336	15664	29,78	1983	5,92	$1,9 \cdot 10^4$	0,079
	In	Indium	49	114,82	06002	93998	156,17	2000 ± 10	7,31	$1,2 \cdot 10^5$	0,057
	Tl	Thallium	81	204,37	31046	68954	302	1457	11,84	$5,7 \cdot 10^4$	0,0326
4a Carbon group	C	Carbon	6	12,01115*	0,7954	92046	> 3550	4200	Graphite Diamond 3.51	$4,7 \cdot 10^3$ $3 \cdot 10^{-14}$	0,147 0,109
	Si	Silicon	14	28,086*	44855	55145	1420	2355	2,33	$8,3 \cdot 10^{-8}$	0,181
	Ge	Germanium	32	72,59	86094	13906	958,5	2700	5,35	$1,1 \cdot 10^{-5}$	0,074
	Sn	Stannum	50	118,69	07445	92555	231,9	2270	α = 5,75 β = 7,28	$8,7 \cdot 10^4$	α 0.515 β 0.0542
	Pb	Plumbum	82	207,19	31641	68359	327,4	1620	11,344	$4,5 \cdot 10^4$	0,0306
5a Nitrogen group	N	Nitrogen	7	14,0067	14638	85362	-210	-195,8	1,2505	–	
	P	Phosphorus	15	30,9738	49101	50899	white: 44.1 red: 59b violet: 593	280	w: 1,84 violet: 2,36 red: 220 black: 2,70	$5 \cdot 10^{-6}$	0,190
	As	Arsenic	33	74,9216	87454	12546	817 b. 36at.	subl.610	2,0 - 5,73	$2,9 \cdot 10^4$	0,08
	Sb	Stibum	51	121,75	08550	91450	630,5	1380	6,684	$2,4 \cdot 10^4$	0,05
	Bi	Bismuth	83	208,980	32015	67985	271,3	~ 1560	9,845	$8,4 \cdot 10^3$	0,294
6a Oreforming	O	Oxygen	8	15,9994	20412	79588	-218,7	-182,97	1,42897	–	
	S	Sulphur	16	32,064*	50604	49396	α = 112,8 β = 119 γ = 120	= 444,6 = 444,6 = 444,6	= 2,07 = 1,96 = 1,92	$5,3 \cdot 10^{-18}$	0,176
	Se	Selenium	34	78,96	89741	10259	144,220	688	α = 4,47 β = 4,40 γ = 4,82	$1,3 \cdot 10^{-13}$ $1,3 \cdot 10^{-7}$	0.181
	Te	Tellurium	52	127,60	10588	89412	452	1390	6,24	$5 \cdot 10^3$	0,0483
	Po	Polonium	84	(210)	32222	67778			9,32	–	–
7a Saltforming or Halogens	F	Fluorine	9	18,9984	27875	72125	-218/-223	-188,3	1,695	–	
	Cl	Chlorine	17	35,453	54970	45030	-101	-34,1	1.557b -34° 3,214	fl. $1 \cdot 10^{-16}$	
	Br	Bromine	35	79,909	90263	09737	- 7,3	58,8	fl 3,14	fl $1,3 \cdot 10^{-15}$	0,107
	I	Iodine	53	126,9044	10349	89651	113,7	184,35	11,72 Ré	$1,3 \cdot 10^{-11}$	0,0523
	At	Astatine	85	(211)	32428	67572				–	–
1b	Cu	Cupprum	29	63,54	80305	19695	1083	2336	8,929	$5,8 \cdot 10^5$	0,0921
	Ag	Argentine	47	107,870	03294	96706	960,5	1950	10,50	$6,1 \cdot 10^5$	0,0558
	Au	Aurum	79	196,967	29447	70553	1063	2600	19,3	$4,1 \cdot 10^5$	0,0312
2b	Zn	Zinc	30	65,37	81544	18456	419,4	907	7,14	$1,7 \cdot 10^5$	0,0925
	Cd	Cadmium	48	112,40	05080	94920	320,9	765	8,642	$1,3 \cdot 10^5$	0,0552
	Hg	Hydrargyrum	80	200,59	30235	69765	- 38,87	356,58	13,546 b.20°	$1,1 \cdot 10^4$	0,03325
3b	Sc	Scandium	21	44,956	65283	34717	1400	2400	3,02	–	–
	Y	Yttrium	39	88,905	94900	05100	1490	2500	4,47	–	–
	La	Lanthan	57	138,91	14276	85724	920	4500/4230	6,15	–	0,0448
	Ac	Actinium	89	(227)	35603	64397	(1600)			–	–
4b	Ti	Titanium	22	47,90	68034	31966	1800	> 3000	4,50	$3,3 \cdot 10^5$	0,1125
	Zr	Zirconium	40	91,22	96009	03991	1857	> 2900	6,52	$2,5 \cdot 10^4$	0,068
	Hf	Hafnium	72	178,58	25183	74817	2230	> 3200	13,3	$3,0 \cdot 10^4$	0,033
5b	V	Ranadium	23	50,942	70714	29286	1710	3000	6,07	$5,0 \cdot 10^4$	0,1153
	Nb	Niobium	41	92,906	96806	03194	2415	3700	8,56	$7,7 \cdot 10^4$	0,065
	Ta	Tantalum	73	180,948	25756	74244	~ 3000	~ 4100	16,6	$7,2 \cdot 10^4$	0,033

Properties of elements

Behaviour towards					Further properties	Isotopes**			Nomenclature	Symbol
H_2O	HCl	H_2SO_4	HNO_3	OH		a	b	c		
0.009	–	–	–	–	t_k -267.9 p_k 2.26at D_k 0.0693g/cm³	4	2	–	gr. Helias = sun	He
0.012	–	–	–	–	,, -228.7 ,, 25.9 ,, 0.484 ,,	7	3	–	gr. Neas = new	Ne
0.056	–	–	–	–	,, -122 ,, 48 ,, 0.531 ,,	8	3	–	gr. Argos = inert	Ar
0.06	–	–	–	–	,, - 63 ,, 54 ,, 0.78 ,,	25	6	–	gr. Kryptos = hidden	Kr
0.119	–	–	–	–	,, - 16.6 ,, 58.2 ,, 1.155 ,,	29	9	–	gr. Xenon = strange	Xe
0.224	–	–	–	–	,, -104 ,, 62 ,, – ,,	16	–	3	from sodium	Rn
0.018	–	–	–	–	,, -239.9 ,, 12.8 ,, 0.0310 ,,	3	2	–	gr. Hydrogenium = water forming	H
d	+	+	+	o	w H_2O → LiOH; w.alk. → alcoholate	5	2	–	gr. lithos = brick	Li
d	+	+	+	o	w H_2O → NaOH; w.alk. → alcoholate	8	1	–	Natron (saltpeter)	Na
d	+	+	+	o	w H_2O → KOH; w.alk. → alcoholate	10	2	1	Arabic alkali = soda	K
d	+	+	+	o	with H_2O → RbOH;	20	1	1	L. Rubidus = red	Rb
d	+	+	+	o	with H_2O → CsoH;	22	1	–	L. Caesium = skyblue	Cs
o	o	o	o	o	properties like above	8	–	1	from France	Fr
–	+	+	+	+	corrosion resistant (oxide film)	4	1	–	from Beryl (crystal)	Be
–	+	+	+	–	corrosion resistant (oxidefilm)	3	3	–	Magnesia city	Mg
d	+	+	+	o	w H_2O → $Ca(OH)_2$	12	6		L. calx = chalk	Ca
d	+	+	+	o	w H_2O → $Sr(OH)_2$	18	4	–	Stranton city	Sr
d	+	+	+	o	w H_2O → $Ba(OH)_2$	22	7		gr. Brayo = hard	Ba
d	+	+	+	o	w H_2O → $Ra(OH)_2$; Radioact.	13	–	4	L. Radius ray	Ra
–	–	+	+	–	crystal hardness ~ 10; semiconductor	4	2	–		B
–	+	+	–	+	corrosion resistant (oxide film)	7	1	–	from Alum (salt)	Al
–	+	+	+	+	Thermometer packing	11	2	–	L. Gallien = France	Ga
–	+	+	+	o	soft like wax	28	1	1	Indigo (blue spectral line)	In
–	(+)	+	+	o	similarity with lead	22	2	4	gr. Thallos = branch	Tl
–	–	–	–	–	Hardness of diamond = 10 Brittle n = 2·4173	7	2	–	L. carbo = coal	C
–	–	–	–	+	I in HF/HNO_3; see crystal hardness	7	3	–	L. silex = silica, sand	Si
–	–	h+	–	–	"semiconductor"; I in HCl/HNO_3	16	5	–	L. Germania = Germany	Ge
–	+	+	k v+ ox	h+	grey decom α 13.2° β 161° γ brittle d	29	10	–	L. Stannum = tin	Sn
–	–	h+k	+	–	very soft and malleable	27	3	5	L. Plumbum = lead	Pb
0.015	–	–	–	–	t_k -118.8° p_k 49.7 at D_k 0.430g/cm³	6	2	–	gr. Nitrogen = $NaNO_3$ forming	N
–	–	–	–	+	☠ white P at 250-300° to red P Ignition temperature ~ 50°	7	1	–	gr. Phosphorus = light carrier	P
–	–	–	+	–	brittle crystal	14	1	–		As
–	–	h+k	–	–	brittle crystal; I HCl/HNO_3	29	2	–	L. Stibium	Sb
–	–	h+	+	–	brittle crystal; I HCl/HNO_3	22	–	6	white mass	Bi
0.031	–	–	–	–	t_k -118.8° p_k 47.7atm; D_k 0.430g/cm³	3	3	–	gr. Oxygenium = acid forming	O
–	–	–	–	–	α or rhomb 95.6 β monocli.yellow, s. CS_2	8	4	–	L. Sulphur	S
–	–	+	+	–	"Semi conductor"; photoelectric	22	6	–	gr. Selene = moon goddess	Se
–	–	+	+	+	little hardness, brittle	27	8	–	h. tellus = earth	Te
o	o	o	o	o	"strong and noble like silver"	22	–	7	from Poland	Po
d	–	–	–	–	☠ weakly yellowish gas	5	1	–	L. Fluo = bleed	F
3.1 (d)	–	–	–	+	☠ t_k 144°, p_k 76.1 atm D_k 0.573g/cm³ yellowish green gas	11	2	–	gr. Chloros = green	Cl
3.58^xi	–	–	–	+	☠ Brown liquid corrosive vapours	19	2	–	gr. Bromos = stench	Br
0.02^xi	–	–	–	+	s. in KI, HI and alcohol	23	1	–	gr. Iodos = violet (vapour)	I
o	o	o	o	o	marked metallic property	18	–	3	gr. Astos = unstable	At
–	(+)	h+	+	–	pale red malleable and ductile	12	2	–	L. Cuprium = copper	Cu
–	–	h+	+	–	s. KCN soln. "Noble metal"	24	2	–	L. Argentum = silver	Ag
–	–	(h+)	–	–	s. KCN soln., "Noble metal"	19	1	–	L. Aurum = gold	Au
–	+	+	+	+	corrosion resistant (hydroxide film)	15	5	–		Zn
–	+	h+	+	+	corrosion resistant	27	8	–	gr. Kadmia = earth	Cd
–	–	–	k+	–	silvery gloss liquid; ☠ vapours especially	23	7	–	gr. Hydrargyrum = active silver	Hg
d	+	+	–	+	hard and not easily accessible	13	1	–	from Scandinavia	Sc
d	+	+	–	+	"rare earths" very closely	19	1	–	Yttorby, city in Sweden	Y
d	+	+	–	+	related metals	14	1	1	gr. Lanthanos = secret	La
o	o	o	o	o	radioactive, β-radiations	10	–	2	gr. Actis = rays	Ac
–	v+	v+	v+	–	very corrosion resistant, "light metal"	9	5	–	Titanen	Ti
–	((+))	((+))	((+))	–	s. in HF and HCl/HNO_3 corrosion resistant	15	5	–	Arabic Zargon = golden	Zr
–	–	–	–	–	analogus to Zr, corrosion resistant	16	6	–	Hafnia = Copenhagen	Hf
–	–	+	+	–	very corrosion resistant, s. HF and HCl/HNO_3	10	1	1	Vanadis = Venus goddess	V
–	–	((h+))	–	–	corrosion resistant solids Insol. in HF and HCl/HNO_3	20	1	–	Niobe gr. goddess	Nb
–	–	–	–	(+)	steel like properties	15	1	1	Tantalos = Goddess father	Ta

*g in 100g H_2O **Isotopes: a total number; b stable and natural; c unstable and natural

PROPERTIES OF ELEMENTS

Group	Symbol	Name	AN	Atomic mass	log	DElog	MP	BP	D/DD	$\Omega^{-1} cm^{-1}$	cal/g
6b	Cr	Chromium	24	52.01	71609	28391	1890	2480	6.92	$7.7 \cdot 10^4$	0.11
	Mo	Molebdenum	42	95.95	98204	01796	2620	(4800)	10.21	$1.8 \cdot 10^5$	0.065
	W	Tungsten	74	183.86	26449	73551	3380	~6000	19.32	1.8·10	0.034
7b	Mn	Maganese	25	54.94	73989	26011	1260	1900	7.21-7.42	$2.0 \cdot 10^5$	0.1211
	Tc	Technitium	43	(99)	99564	00436				—	—
	Re	Rhenium	75	186.22	27003	72997	3170		21.0	$5.0 \cdot 10^4$	0.035
8	Fe	Ferrous	26	55.85	74702	25298	1535	3000	7.86	$1.0 \cdot 10^4$	0.107
	Co	Cobalt	27	58.94	77041	22959	1495	2900	$\alpha = 8.89$ $\beta = 8.64$	$1.0 \cdot 10^5$	0.1001
	Ni	Nickel	28	58.71	78671	23129	1454.8	2900	8.90	$1.5 \cdot 10^5$	0.105
	Ru	Ruthenium	44	101.1	00475	99525	2450	2700	12.43	$1.3 \cdot 10^5$	0.0611
	Rh	Rhodium	45	102.91	01246	98754	1966	>2500	12.5	$2.1 \cdot 10^5$	0.058
	Pd	Palladium	46	106.7	02816	97184	1549.4	2200	11.97	$9.1 \cdot 10^4$	0.0538
	Os	Osmium	76	190.2	27921	72079	2700	>5300	22.48	$1.7 \cdot 10^4$	0.0311
	Ir	Iridium	77	192.2	28375	71625	2454	4400	22.421	$1.6 \cdot 10^5$	0.0323
	Pt	Platin	78	195.09	29014	70986	1773.5	4300	21.45	$1.0 \cdot 10^4$	0.0324

Group	Symbol	Name	An	Atomic mass	log	DElog	MP	BP	D	Nomenclature
	Ce	Cerium	58	140.13	14653	85347	1077	3200	6.768	Plenetoid ceres
	Pr	Praesedium	59	140.92	14897	85103	1208	3290	6.769	gr. Prasimos = green gr. dydimos = twin
	Nd	Neodynium	60	£44.27	15918	84082	1297	3450	7.007	gr. neos = new gr. dydimos = twin
	Pm	Promethium	61	(145)	16137	83863	1570	3000	·······	gr. God Prometheus
	Sm	Samarium	62	150.35	17711	82289	1325	1900	7.540	Samarski, Russian city
	Eu	Europium	63	152.0	18184	81816	~1200	1700	5.166	from Europe
	Gd	Gadolinium	64	157.26	19662	80338	~1520	3000	7.868	Gadolina a chemist
	Tb	Terbium	65	158.93	20120	79880	1638	2800	8.253	Ytterby a city in Sweden
	Dy	Dysprosium	66	162.51	21088	78912	~1670	2600	8.556	Gadolin, Finish chemist
	Ho	Holmium	67	164.94	21723	78268	~1770	2600	8.700	Holmia = Stockholm
	Er	Erbium	68	167.27	22342	77658	~1800	2900	9.058	Ytterby a city in Sweden
	Tm	Thulium	69	168.94	22773	77227	~1900	2400	9.318	Thule = island
	Yb	Ytterbium	70	173.04	23815	76185	1097	1800	6.959	Ytterby = a city in Sweden
	Lu	Lutetium	71	174.09	24302	75698	~2000	2200	9.849	Lutetia = Paris

Group	Symbol	Name	AN	Atomic mass	MP	BP	D	Half-life	period	Decay	Nomenclature
	Th	Thorium	90	232.05	1845	4500	11.2	$1.4 \cdot 10^{10}$	years	α	German god
	Pa	Protactinium	91	231	—	—	—	$3.4 \cdot 10^4$	years	α	gr. protos = first
	U	Uranium	92	238.07	~1133	—	18.7	$4.5 \cdot 10^9$	years	α	Uranus = 7th planet
	Np	Neptiunium	93	237	640	—	20.5	$2.2 \cdot 10^6$	years	α	Neptune = 8th planet
	Pu	Plutonium	94	242	640	—	19.7	$2.4 \cdot 10^4$	years	α	Pluto = 9th planet
	Am	Americium	95	243	827	610	11.7	$8.3 \cdot 10^3$	years	α	from America
	Cm	Curium	96	248	—	—	~7	$4.0 \cdot 10^5$	years	α	Curie discoverer
	Bk	Berkelium	97	249	—	—	—	$7.0 \cdot 10^3$	years	α	Berkeley (city in USA)
	Cf	Californium	98	251	—	—	—	$7.0 \cdot 10^2$	years	α	California
	Es	Einsteinium	99	254	—	—	—	38.5	hours	β	from Einstein
	Fm	Fermium	100	253	—	—	—	3	days	K	Fermi, math.
	Md	Mendelevium	101	256	—	—	—	1.5	hours	K	Mandeleef
	Nb	Nobelium	102	253	—	—	—	10	min.	α	Nobel (of Nob Pr.)
	Lw	Lawrentium	103	257	—	—	—	8	see.	α	discoverer's name

CLASSIFICATION OF METALS ACCORDING TO DENSITY

Light metals				Heavy metals										
Mg.	Be	Al	Ti	Ge	V	Cr	Zn	Sn	Fe	Cu	Ag	Pb	Au	Os
1.74	1.90	2.70	4.50	5.35	6.07	6.92	7.14	7.28	7.86	8.93	10.5	11.4	19.3	22.5

Classification of Metals from the viewpoint of their industrial applications

Ferrous metals F-Metals					Non-ferrous metals					Noble metals				
Fe	Mn	Cr	Ni	V	Cu	Zn	Sn	Pb	Cd	Au	Ag	Pt	Jr	Pd
and few others with which Fe is used in allowing.					and few others which together with copper and among themselves form alloy.					and other platinum metals with which Pt is alloyed.				