Table 2–1 Elements commonly required by algae

element	examples of function/location in algal cells
N	amino acids, nucleotides, chlorophyll, phycobilins
P	ATP, DNA, phospholipids
Cl	oxygen-production in photosynthesis, trichloroethylene, perchloroethylene
S	some amino acids, nitrogenase, thylakoid lipids, CoA, carrageenan, agar, DMSP, biotin
Si	diatom frustules, silicoflagellate skeletons, synurophyte scales and stomatocyst walls, walls of the ulvophyte *Cladophora*
Na	nitrate reductase
Ca	alginates, calcium carbonate, calmodulin
Mg	chlorophyll
Fe	ferredoxin, cytochromes, nitrogenase, nitrate and nitrite reductase, catalase, glutamate synthetase
K	agar and carrageenan, osmotic regulation (ionic form), cofactor for many enzymes
Mo	nitrate reductase, nitrogenase
Mn	oxygen-evolving complex of photosystem II, wall-like lorica of some euglenoids and the chlorophyte *Dysmorphococcus*
Zn	carbonic anhydrase, Cu/Zn superoxide dismutase, alcohol dehydrogenase, glutamic dehydrogenase
Cu	plastocyanin, Cu/Zn superoxide dismutase, cytochrome oxidase
Co	vitamin B_{12}
V	bromoperoxidase, some nitrogenases
Br, I	halogenated compounds with antimicrobial, anti-herbivore, or allelopathic functions

CONCENTRATION OF INORGANIC NITROGEN (μg liter^{-1}) IN THE SURFACE WATERS OF VARIOUS LAKES AND RIVERS

Note the very wide range of total inorganic nitrogen (NO_3 + NH_4) available for plant growth. Values less than 100 μg liter^{-1} may limit growth, while levels above 400 would not. Both eutrophic and oligotrophic lakes may have very low or very high levels of total inorganic nitrogen.

Lake or river	Relative trophic state and mixing type	NO_3—N*		NH_4—N*		References†
		Summer	Winter	Summer	Winter	
Tahoe, Calif.	Oligotrophic, monomictic	4	μ–25	<2		1
Castle, Calif.	Mesotrophic, dimictic	<5	10–50	<5	10–50	2
Clear, Calif.	Eutrophic polymictic	μ–100	400–600	μ–300	μ–20	3
Superior	Oligotrophic monomictic	~230	~280	<10		4
Windermere	Mesotrophic monomictic	100–200	300–400	~10		5
Esthwaite Water	Eutrophic monomictic	μ–100	400–500	~30		6
George, Uganda	Eutrophic polymictic	μ		<10		7
Baikal, U.S.S.R.	Oligotrophic dimictic	0–20	45–80	μ		8
Titicaca, Andes	Mesotrophic monomictic	40–100	100–200	μ		9
Cayuga, N.Y.	Eutrophic monomictic	50–800	~800	100–300	~80	10
Uganda Rivers (annual mean)		530		24		11
Truckee River at km 3	—	20	—	<10		12
Hubbard Brook	—	440	2500	40		13

* μ = undetectable, generally < 10 μg liter^{-1}.
† References: (1, 2) Goldman, various sources; (3) Horne and Goldman, 1972; (4) Dobson et al., 1974; (5, 6) Heron, 1961; Horne and Fogg, 1970; (7) Viner, 1969; (8) Kozhov, 1963; (9) Richerson et al., 1977; (10) Oglesby, 1978; (11) Viner and Smith; (12) McLaren, 1977; (13) Likens et al., 1977.

TABLE 9-1

CONCENTRATIONS OF INORGANIC PHOSPHORUS (μg liter^{-1}) IN THE SURFACE WATERS OF VARIOUS LAKES AND RIVERS

Note the wide range of PO_4—P available for plant growth from limiting levels (< 2 to abundance, > 10). Also, note that eutrophic and oligotrophic lakes may have similar levels.

Lake or river	Relative trophic state and mixing type	Soluble PO_4—P		References*
		Summer	Winter	
Tahoe, Calif.	Oligotrophic monomictic	≈2		1
Castle, Calif.	Mesotrophic dimictic	≈2	—	2
Clear, Calif.	Eutrophic polymictic	≈20	≈10	3
Superior	Oligotrophic monomictic	0.5		4
Windermere	Mesotrophic monomictic	5	30	5
Esthwaite	Eutrophic monomictic	5	≈30	5
George, Uganda	Eutrophic polymictic	<2		6
Baikal, Siberia	Oligotrophic dimictic	≈2	6	7
Titicaca, Andes	Mesotrophic monomictic	≈15	≈15	8
Cayuga, NY	Eutrophic monomictic	>5	≈12	9
Uganda rivers	—	80–230		10
Truckee River at km 3	—	≈10	—	11
Hubbard Brook	—	3	2	12

Table 10-3 Concentration of Soluble Minor Nutrients (μg liter^{-1}) in the Surface Waters of Various Lakes and Rivers.

Although present in relatively low concentrations, most are not limiting or toxic to the biota. Both ionic and chelated metals are present in unknown proportions in the soluble, or filterable, fraction.

Lake or river	Fe	Mn	Cu	Zn	Co	Mo	References*
Tahoe	< 10	2.6	Trace	<14	<0.6	0.5	1
Castle, Calif.	< 10	< 1	< 0.5	< 2	<1	< 0.5	2
Clear, Calif.	5–20	4.6	2–30	<14	<1.4	< 0.3	3
Windermere	...	...	...	8.0	>0.1	> 0.1	4
Cayuga, N.Y.	3–80	1–30	0.6	2.7	0.005	...	5
Biwa, Japan	40	5–17	> 2.5	5.30	0.03	...	6
Titicaca, Andes	...	...	2.5	28	...	...	7
Schöhsee, Germany	15	4.5	1.0	1.8	0.03	0.2	8
World ave.	≈ 40	35	10	10	0.9	0.8	9
Sacramento, Calif.	...	6.3	2.9	...	<1	0.4	9
Truckee, at km 10	110	9	4	5	2	>10	10

*References: (1,2) Goldman, various sources; (3) Goldman and Wetzel, 1963; Horne, 1975; (4) Macan, 1970; (5) Oglesby, 1978; (6) Itasaka and Koyama, 1980; (7) Richer[illegible], et al., 1977; (8) Groth, 1971; (9) Livingstone, 1963; (10) McLaren, 1977.

Table 18-1 How Eutrophic Lakes Can Be Distinguished from Oligotrophic Ones

Most of the very productive lakes in the world are shallow and unstratified, while most of the very unproductive ones are very deep. The terms oligotrophic and eutrophic are best applied to lakes within one lake district or climatic region. WL ratio = ratio of watershed area to lake area.

Factor	Oligotrophic (unproductive)	Eutrophic	
		Productive	Less productive
Nutrients	Low levels and low supply rates of at least one major nutrient (e.g., nitrogen, phosphorus, silica)	High supply rates and often high winter levels of all major and minor nutrients	Often high levels of nutrients year-round
O_2	Does not vary much from saturation in epilimnion or hypolimnion (100 ± 10%)	Great variation from saturation: Depression in hypolimnion (0–100%) and mostly supersaturation in epilimnion (80–250%)	Similar to oligotrophic.
Biota	Low densities and yields of phytoplankton and zooplankton, zoobenthos and fish	High densities and yields of phytoplankton and zooplankton, zoobenthos and fish	Similar to oligotrophic.
Light	Transparent water, deep light penetration, often to below thermocline. Secchi depth 8–40 m	Water not very transparent, light penetration relatively low, often not reaching thermocline or lake bed. Secchi depth 0.1–2 m	a. Water often cloudy; low light penetration due to peat fragments or humic acids (*dystrophic* lake) or to suspended sediments. b. Water clear but acid, pH < 4 (*acidotrophic* lake).
Basin shape and watershed	Lakes deep and steep-sided. Undisturbed, rocky, or unproductive watershed. WL ratio low (e.g., 1:1).	Lakes shallow with gently sloping sides. Often unstratified. Cultivated, disturbed, or naturally fertile watershed. WL ratio high (e.g., 100:1).	Lakes usually small and shallow. Watershed with peat wetlands, coniferous forest or easily eroded soils. Acid volcanic springs, acid rain or muddy inflows. WL ratio variable.

Cultural Eutrophication

The phenomenon of eutrophication is used in limnology to describe the normal processes that occur in lakes and lead to their eventual extinction. In most natural environments, the aging of lakes is a very slow process taking decades to cause perceptible change. Cultural eutrophication is the accelerated fertilization of lakes, reservoirs, streams, and estuaries arising from pollution associated with population growth, industrial development, and intensified agriculture. The response of aquatic ecosystems to increased input of nutrients is greater productivity to the detriment of water quality.

Effects of Eutrophication

The process of eutrophication is directly related to the aquatic food chain (Figure 5-4). Algae use carbon dioxide, inorganic nitrogen, orthophosphate, and trace nutrients for growth and reproduction. These plants serve as food for microscopic animals (zooplankton). Small fishes feed on zooplankton, and large fishes consume small ones. Productivity of the aquatic food chain is keyed to the availability of nitrogen and phosphorus, often in short supply in natural waters. The amount of plant growth and normal balance of the food chain are controlled by the limitation of plant nutrients. Abundant nutrients unbalance the normal succession and promote blooms of blue-green algae that are not easily utilized as food by zooplankton. Thus, the water becomes turbid and under extreme conditions takes on the appearance of "pea soup." Floating masses of algae are windblown to the shore, where they decompose producing malodors. Decaying algae also settle to the bottom, reducing dissolved oxygen. Shorelines and shallow bays become

Figure 5-4 The aquatic food chain unbalanced by eutrophication compared with normal succession.

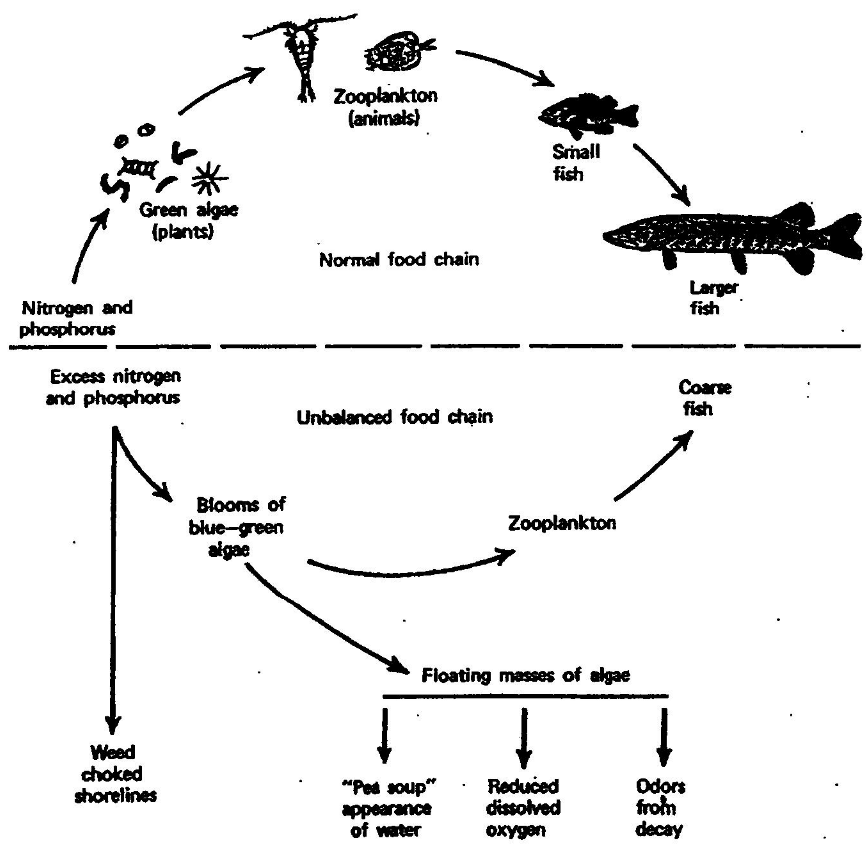

Table 10-1 Concentrations (mg liter^{-1}) of Soluble Major Nutrients (Other than Nitrogen and Phosphorus) in the Surface Waters of Various Lakes and Rivers.

The very dilute lakes, such as Tahoe or the Experimental Lakes Area (ELA) lakes in Ontario, contrast with terminal lakes such as Mono, where the conservative elements accumulate. Note how conservative elements increase downstream in rivers, indicating that dilute lakes need small watersheds to remain low in conservative elements.

Lake or river	Conductivity, μmho cm^{-1}	SiO_2	Ca	Mg	Na	K	SO_4	Cl	HCO_3	References*
Tahoe	92	···	9.4	2.5	6.1	1.7	2.5	1.9	···	1
Castle, Calif.	30	1.3	1.6	2.6	1.1	0.2	0.2	0.1	···	2
Clear, Calif.	250	14	23	15	10	2.0	9	6	145	3
English Lake District, ave.	···	···	4.5	1.0	3.9	0.5	6.3	7.1	7.8	4
South Basin, Windemere	···	···	6.2	0.7	3.8	0.6	7.6	6.7	11	4
Erie	6	0.3	38	8.5	7.2		22	15	118	5
Superior	79	2	12.4	2.8	1.1	0.6	3.2	1.9	28.1	5
ELA lakes, ave.	19	≈1	1.6	0.9	0.9	0.4	3.0	1.4	3.8	6
Cayuga, N.Y.	56	···	44	10	51	2.6	36	81	122	7
Mono, Calif.	···	···	···	60	28,000	1400	9000	17,500	18,800	8
George, Uganda	223	20	17.2	7.4	20	4.2	14.6	8.4	99	9
Biwa, Japan	···	≈1	≈10	≈2	≈5	≈2	≈6.8	≈7	···	10
Titicaca, Andes	···	0.07–1.1	66	34	176	14	282	260	···	11
Tanganyika	···	0.3	11	39	63	33	6.3	26	···	12
Baikal, Siberia	···	≈3	15	4.2	6.1		4.9	1.8	≈60	13
World ave. lakes and rivers	···	12	15	4.1	6.3	2.3	11.2	7.8	58.6	14
• North American rivers, ave.	···	9	21	5	9	1.4	20	8	68	14
• European rivers, ave.	···	7.5	31	5.6	5.4	1.7	24	7	95	14
• Nile, Khartoum	···	26	17.4	5.2	30.7	11.8	0.44	8	149	14
• Rhine, Netherlands	···	5.7	42	6.1	10.1	6.4	19.5	11.3	113	14
• Amazon (Narrow Santarem)	···	11.1	12.5	1.5	1.1	1.4	4.3	2.3	41	14
Truckee at km 10	···	···	8.5	4.3	6.1	1.7	2.9	≈3	···	15
Truckee at km 15	···	16	9.5	4.8	12.4	1.8	3.5	5.9	48	14,15
• Lower Congo River, Kinshasa	105	7.5	10.8	3.9	14.2	···	7.8	6.1	···	16
Hubbard Brook, N.H.	≈25	4.5	1.7	0.38	9.1	0.21	6.3	5.4	<1	17

*References: (1,2) Goldman, various sources; (3) Horne, 1975; Lallatin, 1972; (4) Macan, 1970; (5) Schelske and Roth, 1973; Dobson et al., 1974; Ragotzkie, 1974; Bennett, 1978; (6) Armstrong and Schindler, 1971; (7) Oglesby, 1978; (8) Mason, 1967; Livingstone, 1963; (9) Viner, 1973; Ganf and Viner, 1973; (10) Itasaka and Koyama, 1980; (11) Richerson et al., 1977; (12) Hecky et al., 1978; (13) Livingstone, 1963; Kozhov, 1963; (14) Livingstone, 1963; (15) McLaren, 1977; (16) Visser and Villeneuve, 1975; (17) Likens et al., 1970.

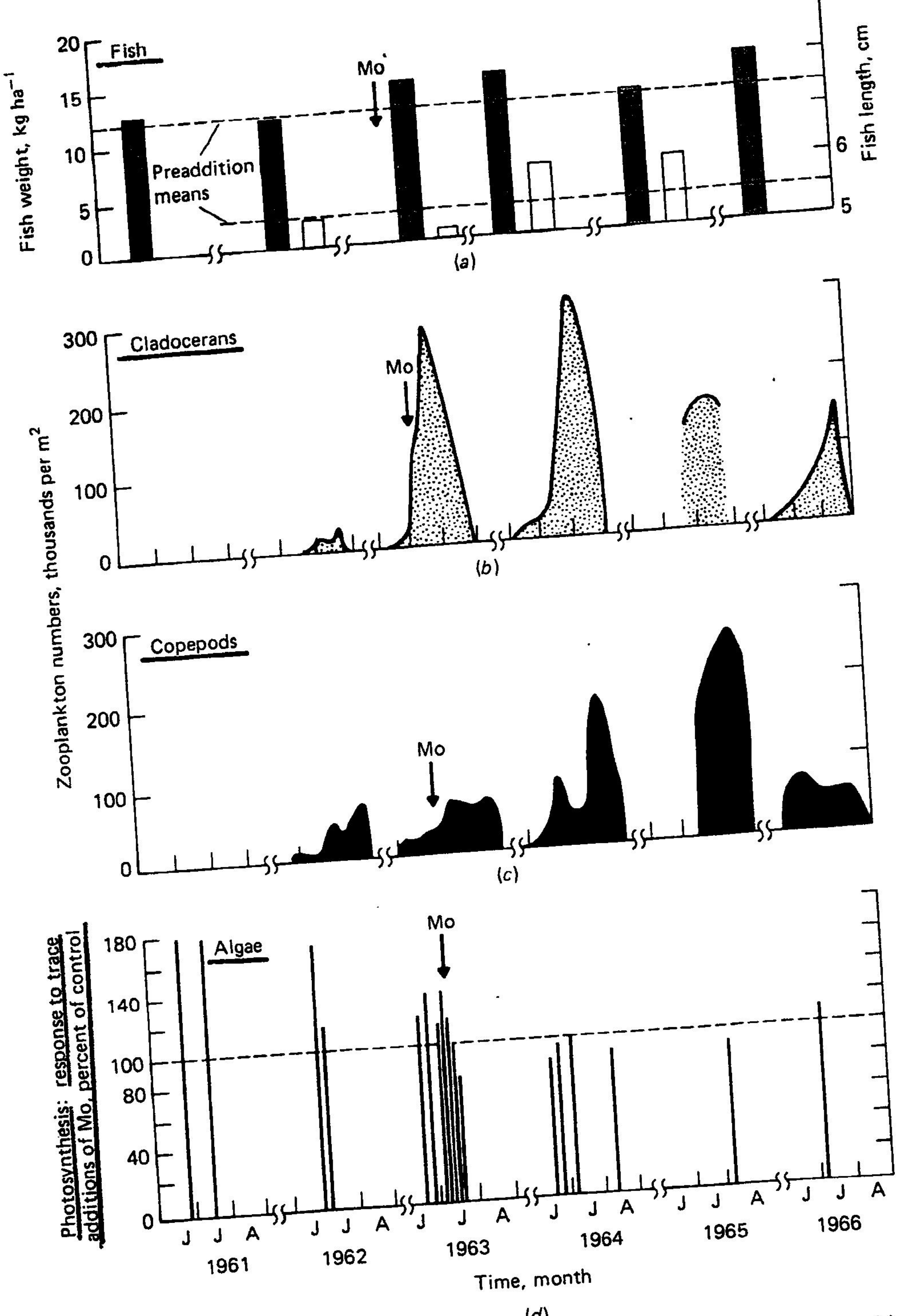

Figure 10-13 Changes in phytoplankton, zooplankton, and trout produced by addition of small quantities of a limiting trace metal, molybdenum, to Castle Lake, California. (*d*) Note immediate cessation of stimulation of photosynthesis by further additions of molybdenum in bottle assays (*c*) delayed increase in populations of the longer-lived copepod zooplankton, but (*b*) almost immediate response for the rapidly reproducing cladoceran zooplankton which were mostly *Daphnia rosea*. Despite natural year-to-year variations in cladoceran numbers, the prolonged increase over 4 years after molybdenum addition was probably due to the addition. (*a*) Note rapid response in fish catches or yield and increase in average fish length in years following molybdenum addition. This response by fish is similar to that found in fish ponds fertilized with nitrogen and phosphorus where effects usually occur in the first year after addition and last for 3 to 4 years. Arrow indicates date of molybdenum addition to the epilimnion on July 1963. Lake epilimnion concentrations rose from less than 0.2 to 15 μg liter^{-1}, while hypolimnion levels remained at less than 0.2 μg liter^{-1}. Phytoplankton numbers and primary production (not shown) rose less dramatically in the years after molybdenum addition, presumably due to rapid grazing of the algae by

PERIODIC TABLE OF THE ELEMENTS

Table of Radioactive Isotopes

Ac 227(22y)β^-,α
Ag 110(24s)β^-,γ; 111(7.5d)β^-,γ
Am 241(470y)α,γ,e^-; 242(100y)β^-,K,α,γ; 243(8000y)α,γ
As 76(26.7h)β^-,γ; 77(39h)β^-,γ
At 210(8.3h)K,α,γ; 211(7.5h)K,α,γ
Au 198(2.69d)β^-,γ
Ba 131(12d)K,γ; 133(7.5y)K,γ,e^-
Bi 210(5d)β^-,α
Bk 245(4.9d)K,α,γ; 249(290d)β^-,α,SF
Br 82(36h)β^-,γ
C 14(5600y)β^-
Ca 41(1×10^{5}y)K; 45(160d)β^-; 47(4.7d)β^-,γ
Cd 115(43d)β^-,γ
Ce 141(32d)β^-,γ; 143(33h)β^-,γ; 144(285d)β^-,γ
Cf 246(35h)α,γ,SF; 249(500y)α,γ,SF; 251(700y)γ
Cl 36(3×10^{5}y)β^-
Cm 243(35y)α,γ; 245(11000y)α,γ; 247(1y)
Co 58(71d)K,β^+,γ; 60(5.27y)β^-,γ
Cr 51(27d)K,γ
Cs 134(2.2y)β^-,γ; 135(3×10^{6}y)β^-; 137(30y)β^-,γ
Cu 64(12.8h)K,β^-,β^+,γ
Es 253(20d)α,γ,SF; 254(1y)α,SF
Eu 154(16y)β^-,γ; 155(1.7y)β^-,γ
Fe 55(2.9y)K; 59(45d)β^-,γ
Fm 255(20h)α
Fr 223(22m)β^-,γ,α
Ga 72(14.1h)β^-,γ
Gd 153(236d)K,γ,e^-; 159(18h)β^-,γ
Ge 71(11d)K
H 3(12.3y)β^-
Hf 181(45d)β^-,γ,e^-
Hg 197(65h)K,γ,e^-; 203(47d)β^-,γ,e^-
Ho 166(27.3h)β^-,γ
I 129(10^{7}y)β^+,γ,e; 131(8.05d)β^-,γ
In 114(50d)γ
Ir 192(74.4d)β^-,γ
K 40(10^{9}y)β^+,K,γ; 42(12.4h),β^-,γ
La 140(40.2h)β^-,γ
Lu 176(10^{10}y)β^-,K,γ; 177(6.8d)β^-,γ
Md 256(30m)K,SF
Mo 99(67h)β^-,γ
Na 22(2.6y)β^+,K,γ; 24(15h)β^-,γ
Nd 147(11.1d)β^-,γ
Ni 63(125y)β^-; 59(8×10^{4}y),K
Np 237(2.2×10^{6}y)α,γ; 239(2.33d)β^-,γ
Os 191(15d)β^-,γ,e^-
P 32(14.2d)β^-
Pa 231(34000y)α,γ
Pb 210(19.4y)β^-,γ,e^-; 202(10^{5}y)L
Pd 103(17d)K,γ
Pm 147(2.6y)β^-; 145(25y)K,L,α
Po 210(138.4d)α,γ; 209(100y)α,K,γ
Pr 143(13.8d)β^-
Pt 197(18h)β^-,γ
Pu 242(3.8 × 10^{5}y)α,SF; 241(13y)β^-,α,γ; 239(24300y)α,γ,SF
Ra 226(1620y)α,γ
Rb 86(18.6h)β^-,γ
Re 188(16.7h)β^-,γ; 186(3.7d)β^-,γ
Rn 222(3.82d)α
Ru 103(40d)β^-,γ; 97(2.9d),K,γ,e^-
S 35(87d)β^-
Sb 122(2.8d)β^-,K,β^+,γ; 124(60d)β^-,γ
Sc 46(84d)β^-,γ
Se 75(121d)K,γ
Sm 153(47h)β^-,γ; 145(340d)K,γ
Sn 113(119d)K,L,γ,e^-
Sr 90(28y)β^-; 89(51d)β^-,γ; 85(64d)K,γ
Ta 182(115d)β^-,γ
Tb 160(73d)$\beta^-\gamma$
Tc 99(2×10^{5}y)β^-; 97(10^{5}y)K
Te 127(9.3h)β^-
Th 232(1.4×10^{10}y)α,γ,SF; 228(1.91y)β^-
Tl 204(3.56y)β^-,K
Tm 170(127d)β^-,γ,e^-
U 238(4.5×10^{9}y)α,γ,SF; 234(2.5×10^{5}y)α,γ,SF; 235(7.1×10^{8}y)α,γ,SF; 233(1.6×10^{5}y)α,γ
W 185(73d)β^-,γ
Y 90(64h)β^-,e^-
Yb 175(4.2d)β^-,γ; 169(31d)K,γ,e^-
Zn 65(245d)K,β^+,γ
Zr 95(65d)β^-,γ,e^-; 93(9×10^{5}y)β^-,γ

Naturally occurring radioactive isotopes are indicated by a blue mass number. Half lives are in parentheses where s, m, h, d and y stand for seconds, minutes, hours, days and years respectively. The symbols describing the mode of decay and resulting radiation are defined as follows:

α	alpha particle	L	L-electron capture
β^-	beta particle	SF	spontaneous fission
β^+	positron	γ	gamma ray
K	K-electron capture	e^-	internal electron conversion

Elements

Period	Group	Atomic number	Symbol	Name	Atomic weight	Oxidation states	Boiling point, °C	Melting point, °C	Density	Electron structure
1	IA	1	H	Hydrogen	1.00797	1	−252.7	−259.2	0.071	s^{1}
1	Inert gases	2	He	Helium	4.0026	0	−268.9	−269.7	0.126	s^{2}
2	IA	3	Li	Lithium	6.939	1	1330	108.5	0.53	$s^{2}2s^{1}$
2	IIA	4	Be	Beryllium	9.0122	2	2770	1277	1.85	$s^{2}2s^{2}$
2	IIIA	5	B	Boron	10.811	3	—	(2030)	2.34	$s^{2}2s^{2}2p^{1}$
2	IVA	6	C	Carbon	12.0111	±4,2	4830	3727	2.26	$s^{2}2s^{2}2p^{2}$
2	VA	7	N	Nitrogen	14.0067	±3,5,4,2	−195.8	−210	0.81	$s^{2}2s^{2}2p^{3}$
2	VIA	8	O	Oxygen	15.9994	−2	−183	−218.8	1.14	$s^{2}2s^{2}2p^{4}$
2	VIIA	9	F	Fluorine	18.9984	−1	−188.2	−219.6	1.11	$s^{2}2s^{2}2p^{5}$
2	Inert gases	10	Ne	Neon	20.183	0	−246	−248.6	1.20	$s^{2}2s^{2}2p^{6}$
3	IA	11	Na	Sodium	22.9898	1	892	97.8	0.97	$[Ne]3s^{1}$
3	IIA	12	Mg	Magnesium	24.312	2	1107	650	1.74	$[Ne]3s^{2}$
3	IIIA	13	Al	Aluminum	26.9815	3	2450	660	2.70	$[Ne]3s^{2}3p^{1}$
3	IVA	14	Si	Silicon	28.086	4	2680	1410	2.33	$[Ne]3s^{2}3p^{2}$
3	VA	15	P	Phosphorus	30.9738	±3,5,4	280w	44.2w	1.82w	$[Ne]3s^{2}3p^{3}$
3	VIA	16	S	Sulfur	32.064	6,4,−2	444.6	119.0	2.07	$[Ne]3s^{2}3p^{4}$
3	VIIA	17	Cl	Chlorine	35.453	±1,4,5,6,7	−34.7	−101.0	1.56	$[Ne]3s^{2}3p^{5}$
3	Inert gases	18	Ar	Argon	39.948	0	−185.8	−189.4	1.40	$[Ne]3s^{2}3p^{6}$
4	IA	19	K	Potassium	39.102	1	760	63.7	0.86	$[Ar]4s^{1}$
4	IIA	20	Ca	Calcium	40.08	2	1440	838	1.55	$[Ar]4s^{2}$
4	IIIB	21	Sc	Scandium	44.956	3	2730	1539	3.0,	$[Ar]3d^{1}4s^{2}$
4	IVB	22	Ti	Titanium	47.90	4,3	3260	1668	4.51	$[Ar]3d^{2}4s^{2}$
4	VB	23	V	Vanadium	50.942	5,4,3,2,	3450	1900	6.1	$[Ar]3d^{3}4s^{2}$
4	VIB	24	Cr	Chromium	51.996	6,3,2	2665	1875	7.19	$[Ar]3d^{5}4s^{1}$
4	VIIB	25	Mn	Manganese	54.938	7,6,4,2,3	2150	1245	7.43	$[Ar]3d^{5}4s^{2}$
4	VIII	26	Fe	Iron	55.847	2,3	3000	1536	7.86	$[Ar]3d^{6}4s^{2}$
4	VIII	27	Co	Cobalt	58.933	2,3	2900	1495	8.9	$[Ar]3d^{7}4s^{2}$
4	VIII	28	Ni	Nickel	58.71	2,3	2730	1453	8.9	$[Ar]3d^{8}4s^{2}$
4	IB	29	Cu	Copper	63.54	2,1	2595	1083	8.96	$[Ar]3d^{10}4s^{1}$
4	IIB	30	Zn	Zinc	65.37	2	906	419.5	7.14	$[Ar]3d^{10}4s^{2}$
4	IIIA	31	Ga	Gallium	69.72	3	2237	29.8	5.91	$[Ar]3d^{10}4s^{2}4p^{1}$
4	IVA	32	Ge	Germanium	72.59	4	2830	937.4	5.32	$[Ar]3d^{10}4s^{2}4p^{2}$
4	VA	33	As	Arsenic	74.922	±3,5	613*	817	5.72	$[Ar]3d^{10}4s^{2}4p^{3}$
4	VIA	34	Se	Selenium	78.96	6,4,−2	685	217	4.79	$[Ar]3d^{10}4s^{2}4p^{4}$
4	VIIA	35	Br	Bromine	79.909	±1,4,5	58	−7.2	3.12	$[Ar]3d^{10}4s^{2}4p^{5}$
4	Inert gases	36	Kr	Krypton	83.80	0	−152	−157.3	2.6	$[Ar]3d^{10}4s^{2}4p^{6}$
5	IA	37	Rb	Rubidium	85.47	1	688	38.9	1.53	$[Kr]5s^{1}$
5	IIA	38	Sr	Strontium	87.62	2	1380	768	2.6	$[Kr]5s^{2}$
5	IIIB	39	Y	Yttrium	88.905	3	2927	1509	4.47	$[Kr]4d^{1}5s^{2}$
5	IVB	40	Zr	Zirconium	91.22	4	3580	1852	6.49	$[Kr]4d^{2}5s^{2}$
5	VB	41	Nb	Niobium	92.906	5,3	3300	2415	8.4	$[Kr]4d^{4}5s^{1}$
5	VIB	42	Mo	Molybdenum	95.94	6,5,4,3,2	5560	2610	10.2	$[Kr]4d^{5}5s^{1}$
5	VIIB	43	Tc	Technetium	(99)	7	—	2200	11.5	$[Kr]4d^{5}5s^{2}$
5	VIII	44	Ru	Ruthenium	101.07	2,3,4,6,8	4900	2500	12.2	$[Kr]4d^{7}5s^{1}$
5	VIII	45	Rh	Rhodium	102.905	2,3,4	4500	1966	12.4	$[Kr]4d^{8}5s^{1}$
5	VIII	46	Pd	Palladium	106.4	2,4	3980	1552	12.0	$[Kr]4d^{10}5s^{0}$
5	IB	47	Ag	Silver	107.870	1	2210	960.8	10.5	$[Kr]4d^{10}5s^{1}$
5	IIB	48	Cd	Cadmium	112.40	2	765	320.9	8.65	$[Kr]4d^{10}5s^{2}$
5	IIIA	49	In	Indium	114.82	3	2000	156.2	7.31	$[Kr]4d^{10}5s^{2}5p^{1}$
5	IVA	50	Sn	Tin	118.69	4,2	2270	231.9	7.30	$[Kr]4d^{10}5s^{2}5p^{2}$
5	VA	51	Sb	Antimony	121.75	±3,5	1380	630.5	6.62	$[Kr]4d^{10}5s^{2}5p^{3}$
5	VIA	52	Te	Tellurium	127.60	6,4,−2	989.8	449.5	6.24	$[Kr]4d^{10}5s^{2}5p^{4}$
5	VIIA	53	I	Iodine	126.904	±1,4,5,7	183	113.7	4.94	$[Kr]4d^{10}5s^{2}5p^{5}$
5	Inert gases	54	Xe	Xenon	131.30	0	−108.0	−111.9	3.06	$[Kr]4d^{10}5s^{2}5p^{6}$
6	IA	55	Cs	Cesium	132.905	1	690	28.7	1.90	$[Xe]6s^{1}$
6	IIA	56	Ba	Barium	137.34	2	1640	714	3.5	$[Xe]6s^{2}$
6	IIIB	57	La★	Lanthanum	138.91	3	3470	920	6.17	$[Xe]5d^{1}6s^{2}$
6	IVB	72	Hf	Hafnium	178.49	4	5400	2222	13.1	$[Xe]4f^{14}5d^{2}6s^{2}$
6	VB	73	Ta	Tantalum	180.948	5	5425	2996	16.6	$[Xe]4f^{14}5d^{3}6s^{2}$
6	VIB	74	W	Wolfram	183.85	6,5,4,3,2	5930	3410	19.3	$[Xe]4f^{14}5d^{4}6s^{2}$
6	VIIB	75	Re	Rhenium	186.2	7,6,4,2,−1	5900	3180	21.0	$[Xe]4f^{14}5d^{5}6s^{2}$
6	VIII	76	Os	Osmium	190.2	2,3,4,6,8	5500	2700	22.6	$[Xe]4f^{14}5d^{6}s^{2}$
6	VIII	77	Ir	Iridium	192.2	2,3,4,6	5300	2454	22.5	$[Xe]4f^{14}5d^{7}6s^{2}$
6	VIII	78	Pt	Platinum	195.09	2,4	4530	1769	21.4	$[Xe]4f^{14}5d^{10}6s^{0}$
6	IB	79	Au	Gold	196.967	3,1	2970	1063	19.3	$[Xe]4f^{14}5d^{10}6s^{1}$
6	IIB	80	Hg	Mercury	200.59	2,1	357	−38.4	13.6	$[Xe]4f^{14}5d^{10}6s^{2}$
6	IIIA	81	Tl	Thallium	204.37	3,1	1457	303	11.85	$[Xe]4f^{14}5d^{10}6s^{2}6p^{1}$
6	IVA	82	Pb	Lead	207.19	4,2	1725	327.4	11.4	$[Xe]4f^{14}5d^{10}6s^{2}6p^{2}$
6	VA	83	Bi	Bismuth	208.980	3,5	1560	271.3	9.8	$[Xe]4f^{14}5d^{10}6s^{2}6p^{3}$
6	VIA	84	Po	Polonium	(210)	4,2	—	254	(9.2)	$[Xe]4f^{14}5d^{10}6s^{2}6p^{4}$
6	VIIA	85	At	Astatine	(210)	—	—	(302)	—	$[Xe]4f^{14}5d^{10}6s^{2}6p^{5}$
6	Inert gases	86	Rn	Radon	(222)	0	(−61.8)	(−71)	—	$[Xe]4f^{14}5d^{10}6s^{2}6p^{6}$
7	IA	87	Fr	Francium	(223)	1	—	(27)	—	$[Rn]7s^{1}$
7	IIA	88	Ra	Radium	(226)	2	—	700	5.0	$[Rn]7s^{2}$
7	IIIB	89	Ac★★	Actinium	(227)	3	—	1050	—	$[Rn]6d^{1}7s^{2}$

★ (6) Lanthanides

Atomic number	Symbol	Name	Atomic weight	Oxidation states	Boiling point, °C	Melting point, °C	Density	Electron structure
58	Ce	Cerium	140.12	3,4	3468	795	6.67	$[Xe]4f^{2}5d^{0}6s^{2}$
59	Pr	Praseodymium	140.907	3,4	3127	935	6.77	$[Xe]4f^{3}5d^{0}6s^{2}$
60	Nd	Neodymium	144.24	3	3027	1024	7.00	$[Xe]4f^{4}5d^{0}6s^{2}$
61	Pm	Promethium	(147)	3	—	(1027)	—	$[Xe]4f^{5}5d^{0}6s^{2}$
62	Sm	Samarium	150.35	3,2	1900	1072	7.54	$[Xe]4f^{6}5d^{0}6s^{2}$
63	Eu	Europium	151.96	3,2	1439	826	5.26	$[Xe]4f^{7}5d^{0}6s^{2}$
64	Gd	Gadolinium	157.25	3	3000	1312	7.89	$[Xe]4f^{7}5d^{1}6s^{2}$
65	Tb	Terbium	158.924	3,4	2800	1356	8.27	$[Xe]4f^{9}5d^{0}6s^{2}$
66	Dy	Dysprosium	162.50	3	2600	1407	8.54	$[Xe]4f^{10}5d^{0}s^{2}$
67	Ho	Holmium	164.930	3	2600	1461	8.80	$[Xe]4f^{11}5d^{0}6s^{2}$
68	Er	Erbium	167.26	3	2900	1497	9.05	$[Xe]4f^{12}5d^{0}6s^{2}$
69	Tm	Thulium	168.934	3,2	1727	1545	9.33	$[Xe]4f^{13}5d^{0}6s^{2}$
70	Yb	Ytterbium	173.04	3,2	1427	824	6.98	$[Xe]4f^{14}5d^{0}6s^{2}$
71	Lu	Lutetium	174.97	3	3327	1652	9.84	$[Xe]4f^{14}5d^{1}6^{2}$

★★ (7) Actinides

Atomic number	Symbol	Name	Atomic weight	Oxidation states	Boiling point, °C	Melting point, °C	Density	Electron structure
90	Th	Thorium	232.038	4	3850	1750	11.7	$[Rn]6d^{2}7s^{2}$
91	Pa	Protactinium	(231)	5,4	—	(1230)	15.4	$[Rn]5f^{2}6d^{1}7s^{2}$
92	U	Uranium	238.04	6,5,4,3	3818	1132	19.07	$[Rn]5f^{3}6d^{1}7s^{2}$
93	Np	Neptunium	(237)	6,5,4,3	—	637	19.5	$[Rn]5f^{5}6d^{0}7s^{2}$
94	Pu	Plutonium	(242)	6,5,4,3	3235	640	—	$[Rn]5f^{6}6d^{0}7s^{2}$
95	Am	Americium	(243)	6,5,4,3	—	—	11.7	$[Rn]5f^{7}6d^{0}7s^{2}$
96	Cm	Curium	(247)	3	—	—	—	$[Rn]5f^{7}6d^{1}7s^{2}$
97	Bk	Berkelium	(247)	4,3	—	—	—	$[Rn]5f^{7}6d^{2}7s^{2}$
98	Cf	Californium	(251)	3	—	—	—	$[Rn]5f^{9}6d^{1}7s^{2}$
99	Es	Einsteinium	(254)	—	—	—	—	
100	Fm	Fermium	(253)	—	—	—	—	
101	Md	Mendelevium	(256)	—	—	—	—	
102	No	Nobelium	(254)	—	—	—	—	
103	(Lw)	(Lawrencium) See note 3	(257)	—	—	—	—	

KEY

30 Zn Zinc — ATOMIC NUMBER: 30; ATOMIC WEIGHT (2): 65.37; OXIDATION STATES (Bold most stable): 2; BOILING POINT, °C: 906; MELTING POINT, °C: 419.5; DENSITY (g/ml) (4): 7.14; SYMBOL (1): Zn; ELECTRON STRUCTURE: $[Ar]3d^{10}4s^{2}$; NAME: Zinc

NOTES:

(1) Black — solid.
Red — gas.
Blue — liquid.
Outline — synthetically prepared.

(2) Based upon carbon – 12. ( ) indicates most stable or best known isotope.

(3) Proposed; not officially accepted

(4) Values for gaseous elements are for liquids at the boiling point.