

Reference Guide

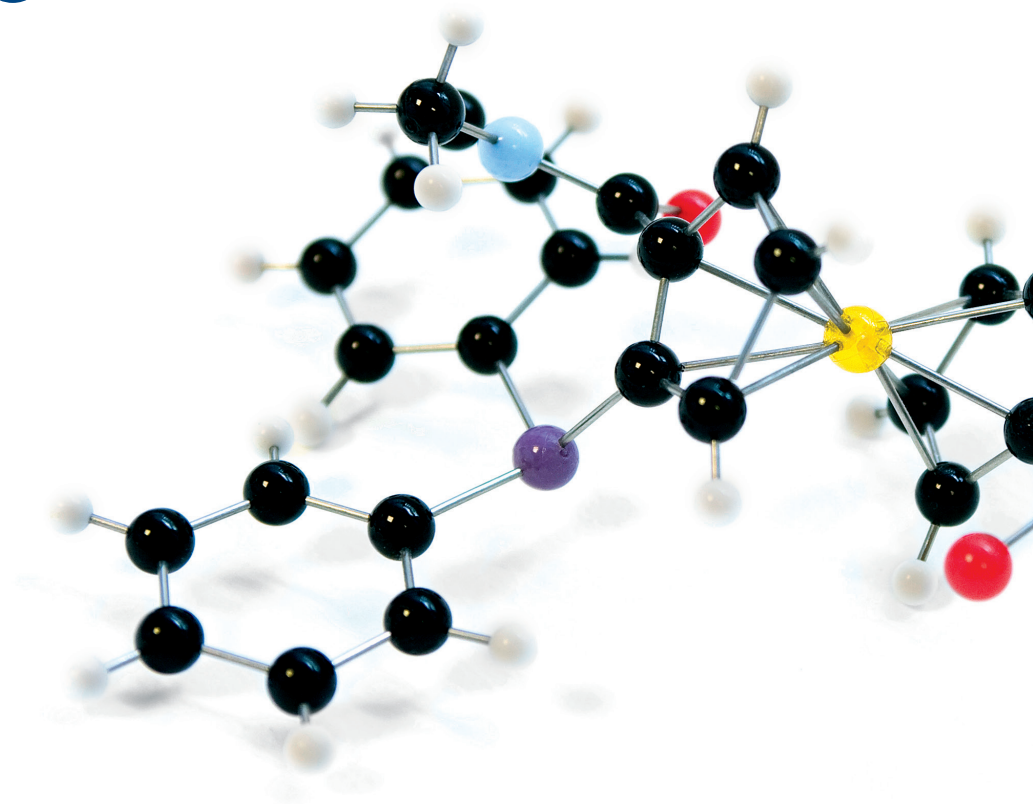
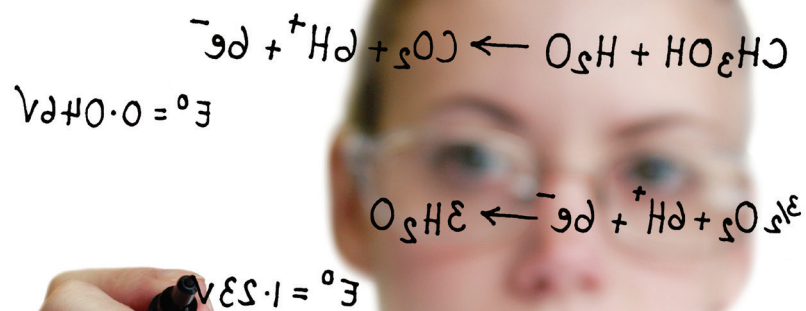


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About Alfa Aesar

Alfa Aesar is a leading manufacturer and supplier of research chemicals, metals and materials in a wide span of applications. For more than 50 years, scientists have relied on Alfa Aesar to supply high purity raw materials for a variety of research and development applications.

Today we offer over 46,000 products in stock, in sizes from gram-scale catalog items to semi-bulk and bulk production quantities. With custom manufacturing capabilities to supply many more specialized items, we are a one-stop source for research chemicals, metals and materials.

GLOBAL INVENTORY

The majority of our high purity metals and related products are available in research and development quantities from stock. We also supply most products from stock in semi-bulk or bulk quantities.

Many are in regular production and are available in bulk for next day shipment. Our experience in manufacturing, sourcing and handling a wide range of metals enables us to respond quickly and efficiently to your needs.

CUSTOM SYNTHESIS

We offer flexible custom manufacturing services with the assurance of quality and confidentiality. We can deliver the chemical you need in sizes for research, pilot-scale and full-scale production applications.

CUSTOMER SERVICE

Our dedicated scientific and commercial teams offer full service from production to delivery. Most products are stocked in catalog pack sizes and the majority are available from stock in semi-bulk and bulk quantities as well. All specialty and bulk products are shipped with a batch specific certificate of analysis and material safety data sheet. Because we understand that specific packaging is often important, we offer custom packaging and labeling to meet your requirements.

QUALITY CONTROL

We employ advanced quality control for both in-process and final product testing phases. The high standard of our modern quality control and assurance facilities is matched by the expertise of our experienced staff.

Periodic Table of the Elements

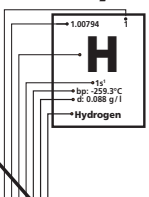
Alfa Aesar

Periodic Table of Elements

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1 IA										18 VIIIA																																											
1.00794 1 H [He] 1s¹ bp: -252.87°C d: 0.089 g/l Hydrogen										4.002602 2 He [He] 1s² bp: -268.9°C d: 0.179 g/l Helium																																											
2 IIA																		13 IIIA		14 IVA		15 VA		16 VIA		17 VIIA																											
6.941 3 Li [He] 2s¹ mp: 180.5°C d: 0.53 g/cc Lithium		9.012182 4 Be [He] 2s² mp: 1287°C d: 1.848 g/cc Beryllium																		10.811 5 B [He] 2s² 2p¹ mp: 2076°C d: 2.46 g/cc Boron		12.0107 6 C [He] 2s² 2p² mp: 3527°C d: 2.26 g/cc Carbon		14.0067 7 N [He] 2s² 2p³ mp: 195.8°C d: 1.25 g/l Nitrogen		15.9994 8 O [He] 2s² 2p⁴ bp: -183.9°C d: 1.43 g/l Oxygen		18.9984032 9 F [He] 2s² 2p⁵ bp: -188.1°C d: 1.696 g/l Fluorine		20.1797 10 Ne [He] 2s² 2p⁶ bp: -246.1°C d: 0.8999 g/l Neon																							
22.989769 11 Na [Ne] 3s¹ mp: 97.72°C d: 0.968 g/cc Sodium		24.3050 12 Mg [Ne] 3s² mp: 1287°C d: 1.738 g/cc Magnesium																		26.981539 13 Al [Ne] 3s² 3p¹ mp: 900.3°C d: 2.70 g/cc Aluminum		28.0855 14 Si [Ne] 3s² 3p² mp: 1414°C d: 2.33 g/cc Silicon		30.973762 15 P [Ne] 3s² 3p³ mp: 44.2°C d: 1.82 g/cc Phosphorus		32.065 16 S [Ne] 3s² 3p⁴ mp: 115.21°C d: 2.07 g/cc Sulfur		35.453 17 Cl [Ne] 3s² 3p⁵ bp: -34.0°C d: 3.12 g/l Chlorine		39.948 18 Ar [Ne] 3s² 3p⁶ bp: -185.8°C d: 1.784 g/l Argon																							
39.0983 19 K [Ar] 4s¹ mp: 63.4°C d: 0.856 g/cc Potassium			40.078 20 Ca [Ar] 4s² mp: 1541°C d: 1.55 g/cc Calcium			44.955912 21 Sc [Ar] 3d¹ 4s² mp: 1541°C d: 2.985 g/cc Scandium			47.867 22 Ti [Ar] 3d² 4s² mp: 1668°C d: 4.507 g/cc Titanium			50.9415 23 V [Ar] 3d³ 4s² mp: 1910°C d: 6.11 g/cc Vanadium			51.9961 24 Cr [Ar] 3d⁵ 4s¹ mp: 1907°C d: 7.17 g/cc Chromium			54.938045 25 Mn [Ar] 3d⁵ 4s² mp: 1246°C d: 7.47 g/cc Manganese			55.845 26 Fe [Ar] 3d⁶ 4s² mp: 1538°C d: 7.87 g/cc Iron			58.933195 27 Co [Ar] 3d⁷ 4s² mp: 1495°C d: 8.90 g/cc Cobalt			58.9334 28 Ni [Ar] 3d⁸ 4s² mp: 1455°C d: 8.90 g/cc Nickel			63.546 29 Cu [Ar] 3d¹⁰ 4s¹ mp: 1085°C d: 8.93 g/cc Copper			65.38 30 Zn [Ar] 3d¹⁰ 4s² mp: 419.5°C d: 7.14 g/cc Zinc			69.723 31 Ga [Ar] 3d¹⁰ 4s² 4p¹ mp: 29.76°C d: 5.90 g/cc Gallium			72.64 32 Ge [Ar] 3d¹⁰ 4s² 4p² mp: 938.3°C d: 5.32 g/cc Germanium			74.92160 33 As [Ar] 3d¹⁰ 4s² 4p³ mp: 817°C subl. d: 5.73 g/cc Arsenic			78.96 34 Se [Ar] 3d¹⁰ 4s² 4p⁴ mp: 221°C d: 4.82 g/cc Selenium			79.904 35 Br [Ar] 3d¹⁰ 4s² 4p⁵ bp: 59.47°C d: 3.12 g/l Bromine			83.798 36 Kr [Ar] 3d¹⁰ 4s² 4p⁶ bp: -153.3°C d: 3.73 g/l Krypton		
85.4678 37 Rb [Kr] 5s¹ mp: 39.3°C d: 1.532 g/cc Rubidium		87.62 38 Sr [Kr] 5s² mp: 777°C d: 2.64 g/cc Strontium		88.90585 39 Y [Kr] 4d¹ 5s² mp: 1526°C d: 4.47 g/cc Yttrium		91.224 40 Zr [Kr] 4d² 5s² mp: 1853°C d: 6.51 g/cc Zirconium		92.90638 41 Nb [Kr] 4d⁴ 5s¹ mp: 2477°C d: 8.48 g/cc Niobium		95.96 42 Mo [Kr] 4d⁵ 5s¹ mp: 2623°C d: 10.28 g/cc Molybdenum		98 43 Tc [Kr] 4d⁵ 5s² mp: 2177°C d: 12.37 g/cc Technetium		101.07 44 Ru [Kr] 4d⁷ 5s¹ mp: 2334°C d: 12.37 g/cc Ruthenium		102.9055 45 Rh [Kr] 4d⁸ 5s¹ mp: 1964°C d: 12.41 g/cc Rhodium		106.42 46 Pd [Kr] 4d¹⁰ mp: 1554°C d: 12.02 g/cc Palladium		107.8682 47 Ag [Kr] 4d¹⁰ 5s¹ mp: 961.8°C d: 10.49 g/cc Silver		112.41 48 Cd [Kr] 4d¹⁰ 5s² mp: 321.1°C d: 8.65 g/cc Cadmium		114.818 49 In [Kr] 4d¹⁰ 5s² 5p¹ mp: 156.6°C d: 7.31 g/cc Indium		118.710 50 Sn [Kr] 4d¹⁰ 5s² 5p² mp: 231.9°C d: 7.31 g/cc Tin		121.760 51 Sb [Kr] 4d¹⁰ 5s² 5p³ mp: 630.6°C d: 5.83 g/cc Antimony		127.60 52 Te [Kr] 4d¹⁰ 5s² 5p⁴ mp: 448.5°C d: 5.83 g/cc Tellurium		126.90447 53 I [Kr] 4d¹⁰ 5s² 5p⁵ mp: 113.7°C d: 4.94 g/cc Iodine		131.293 54 Xe [Kr] 4d¹⁰ 5s² 5p⁶ mp: -108°C d: 5.83 g/l Xenon																			
132.905452 55 Cs [Xe] 6s¹ mp: 28.4°C d: 1.88 g/cc Cesium		137.327 56 Ba [Xe] 6s² mp: 727°C d: 3.51 g/cc Barium		57-71 La-Lu [Xe] 4f¹⁴ 5d¹ 6s² mp: 2333°C d: 13.31 g/cc Lanthanum		178.49 72 Hf [Xe] 4f¹⁴ 5d² 6s² mp: 2233°C d: 13.31 g/cc Hafnium		180.94788 73 Ta [Xe] 4f¹⁴ 5d³ 6s² mp: 3017°C d: 16.45 g/cc Tantalum		183.84 74 W [Xe] 4f¹⁴ 5d⁴ 6s² mp: 3422°C d: 19.25 g/cc Tungsten		186.207 75 Re [Xe] 4f¹⁴ 5d⁵ 6s² mp: 3180°C d: 21.02 g/cc Rhenium		190.23 76 Os [Xe] 4f¹⁴ 5d⁶ 6s² mp: 3033°C d: 22.51 g/cc Osmium		192.227 77 Ir [Xe] 4f¹⁴ 5d⁷ 6s² mp: 2446°C d: 22.56 g/cc Iridium		195.084 78 Pt [Xe] 4f¹⁴ 5d⁹ 6s¹ mp: 1768.4°C d: 21.09 g/cc Platinum		196.966569 79 Au [Xe] 4f¹⁴ 5d¹⁰ 6s¹ mp: 1063.0°C d: 19.30 g/cc Gold		200.59 80 Hg [Xe] 4f¹⁴ 5d¹⁰ 6s² bp: 356.73°C d: 13.534 g/cc Mercury		204.3833 81 Tl [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p¹ mp: 304°C d: 11.85 g/cc Thallium		207.2 82 Pb [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p² mp: 327.5°C d: 11.34 g/cc Lead		208.98040 83 Bi [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p³ mp: 271.3°C d: 9.78 g/cc Bismuth		[209] 84 Po [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁴ mp: 254°C d: 9.78 g/cc Polonium		[210] 85 At [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁵ mp: none d: none Astatine		[222] 86 Rn [Xe] 4f¹⁴ 5d¹⁰ 6s² 6p⁶ bp: -61.7°C d: 9.73 g/cc Radon																			
[223] 87 Fr [Rn] 7s¹ mp: 27°C d: 2.23 g/cc Francium		[226] 88 Ra [Rn] 7s² mp: 700°C d: 5.00 g/cc Radium		89-103 Ac-Lr [Rn] 5f¹⁴ 6d¹ 7s² mp: none d: none Actinium		[261] 104 Rf [Rn] 5f¹⁴ 6d² 7s² mp: none d: none Rutherfordium		[262] 105 Db [Rn] 5f¹⁴ 6d³ 7s² mp: none d: none Dubnium		[266] 106 Sg [Rn] 5f¹⁴ 6d⁴ 7s² mp: none d: none Seaborgium		[264] 107 Bh [Rn] 5f¹⁴ 6d⁵ 7s² mp: none d: none Bohrium		[277] 108 Hs [Rn] 5f¹⁴ 6d⁶ 7s² mp: none d: none Hassium		[268] 109 Mt [Rn] 5f¹⁴ 6d⁷ 7s² mp: none d: none Meitnerium		[271] 110 Ds [Rn] 5f¹⁴ 6d⁸ 7s¹ mp: none d: none Darmstadtium		[272] 111 Rg [Rn] 5f¹⁴ 6d⁹ 7s¹ mp: none d: none Roentgenium		[285] 112 Cn [Rn] 5f¹⁴ 6d¹⁰ 7s² mp: none d: none Copernicium		[284] 113 Uut [Rn] 5f¹⁴ 6d¹⁰ 7s² 7p¹ mp: none d: none Ununtrium		[289] 114 Fl [Rn] 5f¹⁴ 6d¹⁰ 7s² 7p² mp: none d: none Flerovium		[288] 115 Uup [Rn] 5f¹⁴ 6d¹⁰ 7s² 7p³ mp: none d: none Ununpentium		[293] 116 Lv [Rn] 5f¹⁴ 6d¹⁰ 7s² 7p⁴ mp: none d: none Livermorium		ISO 9001:2008 ISO 14001:2004 BS OHSAS 18001:2007 Certified																					
138.90547 57 La [Xe] 5d¹ 6s² mp: 320°C d: 6.15 g/cc Lanthanum		140.116 58 Ce [Xe] 4f¹ 5d¹ 6s² mp: 320°C d: 6.69 g/cc Cerium		140.90765 59 Pr [Xe] 4f³ 6s² mp: 320°C d: 6.69 g/cc Praseodymium		144.242 60 Nd [Xe] 4f⁴ 6s² mp: 1290°C d: 7.26 g/cc Neodymium		[145] 61 Pm [Xe] 4f⁵ 6s² mp: 1100°C d: 7.26 g/cc Promethium		150.36 62 Sm [Xe] 4f⁶ 6s² mp: 1300°C d: 7.35 g/cc Samarium		151.964 63 Eu [Xe] 4f⁷ 6s² mp: 820°C d: 7.35 g/cc Europium		157.25 64 Gd [Xe] 4f⁷ 5d¹ 6s² mp: 1313°C d: 7.90 g/cc Gadolinium		158.92535 65 Tb [Xe] 4f⁹ 6s² mp: 1356°C d: 8.22 g/cc Terbium		162.500 66 Dy [Xe] 4f¹⁰ 6s² mp: 1407°C d: 8.55 g/cc Dysprosium		164.93032 67 Ho [Xe] 4f¹¹ 6s² mp: 1469°C d: 8.79 g/cc Holmium		167.259 68 Er [Xe] 4f¹² 6s² mp: 1529°C d: 9.07 g/cc Erbium		168.93421 69 Tm [Xe] 4f¹³ 6s² mp: 1545°C d: 9.32 g/cc Thulium		173.054 70 Yb [Xe] 4f¹⁴ 6s² mp: 824°C d: 8.57 g/cc Ytterbium		174.9668 71 Lu [Xe] 4f¹⁴ 5d¹ 6s² mp: 1652°C d: 9.84 g/cc Lutetium																									
[227] 89 Ac [Rn] 6d¹ 7s² mp: 1050°C d: 10.07 g/cc Actinium		232.03806 90 Th [Rn] 6d² 7s² mp: 1848°C d: 11.72 g/cc Thorium		231.03588 91 Pa [Rn] 5f¹⁴ 6d¹ 7s² mp: 1600°C d: 15.37 g/cc Protactinium		238.02891 92 U [Rn] 5f³ 6d¹ 7s² mp: 1132°C d: 19.05 g/cc Uranium		[237] 93 Np [Rn] 5f⁶ 6d¹ 7s² mp: 630.4°C d: 20.45 g/cc Neptunium		[244] 94 Pu [Rn] 5f⁷ 7s² mp: 1327°C d: 19.81 g/cc Plutonium		[243] 95 Am [Rn] 5f⁷ 7s² mp: 1327°C d: 13.51 g/cc Americium		[247] 96 Cm [Rn] 5f⁷ 7s² mp: 1340°C d: 13.51 g/cc Curium		[247] 97 Bk [Rn] 5f⁷ 7s² mp: 900°C d: 14.78 g/cc Berkelium		[251] 98 Cf [Rn] 5f⁹ 7s² mp: 900°C d: 15.10 g/cc Californium		[252] 99 Es [Rn] 5f⁹ 7s² mp: 860°C d: 8.84 g/cc Einsteinium		[257] 100 Fm [Rn] 5f⁹ 7s² mp: 1527°C d: none Fermium		[258] 101 Md [Rn] 5f⁹ 7s² mp: 827°C d: none Mendelevium		[259] 102 No [Rn] 5f⁹ 7s² mp: 827°C d: none Nobelium		[262] 103 Lr [Rn] 5f¹⁴ 6d¹ 7s² mp: 1652°C d: none Lawrencium																									

Key



- Element
- Density
- Boiling or Melting Point in °C
- Electron Configuration
- Symbol
- Atomic Weight
- Atomic Number

Abbreviations and Codes

Å	Angstrom	μ	Micro	Reagent	Reagent grade
AAS	Atomic absorption spectrometry	μg	Microgram	REM	Rare earth metal
ACS	Chemicals meeting the specifications outlined by the American Chemical Society	μm	Micrometer (micron)	(REO)	Rare earth oxide base - content of specific rare earth element in comparison to total rare earths present
AES	Atomic emission spectrometry	m	Meter	S.A.	Surface area
APS	Average particle size	M	Molarity of solution	soln.	Solution
anhy	Anhydrous	max	Maximum	Sp.Gr.	Specific gravity
approx.	Approximately	meq	Milliequivalent	Sp.Rot.	Specific rotation
aq.	Aqueous	Merck	The Merck Index	stab.	Stabilized
Atm	Atmospheres	mg	Milligram	subl.	Sublimes
b.p.	Boiling point in °C at 760mm pressure, unless otherwise specified	micron	Micrometer	Tc	Critical temperature
(c)	Contained weight of active material	min.	Minimum	tech.	Technical grade
°C	Celsius	ml	Milliliter	TLC	Thin-layer chromatography
ca	Circa	mm	Millimeter	TSCA	Toxic Substance Control Act
cc	Cubic centimeter	mmol	Millimole	UN	Hazardous material transportation identification number
cm	Centimeter	Mn	Number averaged molecular weight	λ	Wavelength in nanometers
cont.	Contained	mol	Mole	wt	Weight
cP	Centipoise	m.p.	Melting point	w/w	Weight/weight
cS	Centistoke	M.W.	Molecular weight	w/v	Weight/volume
d.	Density	Mw	Weighted averaged molecular weight	XRD	X-ray diffraction
dec.	Decomposes	Mw/Mn	Monodispersity value	△	Air sensitive
dia.	Diameter	(N)	Nematic phase of a liquid crystal	▣	Moisture sensitive
ea.	Each	N	Normality of solution	■	Hygroscopic
ee	Enantiomeric excess	n _D ²⁰	Refractive index for the sodium D line at 20 °C (or temperature indicated)	▲	Light sensitive
eV	Electron volt	nm	Nanometer	≈	Approximately
°F	Fahrenheit	NEW!	New product	>	Greater than
f.p.	Flash point	NMR	Nuclear magnetic resonance	≥	Greater than or equal to
FSSS	Fisher sub-sieve sizer	OD	Outer diameter	<	Less than
F.W.	Formula weight	oz	Ounce	≤	Less than or equal to
g	Gram	optical gr.	Suitable for optical applications	[]	Numbers in brackets after the chemical description indicate the Chemical Abstract Service Registry Number
g/l	Grams per liter (gas density)	pc(s)	Piece(s)	- mesh #	90% particles pass through screen having a given mesh size
GC	Gas chromatography	pH	Value taken to represent the acidity or alkalinity of an aqueous solution	+ mesh #	90% particles are retained by a screen having a given mesh size
GLC	Suitable for use in gas liquid chromatography	POR	Price on request	†	Denotes substance is listed in Toxic Substance Control Act (TSCA) inventory
HPLC	High-performance liquid chromatography	ppb	Parts per billion		
ICP	Inductively Coupled Plasma	ppm	Parts per million		
ID	Inner diameter	prec.	Precipitated		
in	Inch	Primary	Analytical reagent of exceptional purity, for standardizing volumetric solutions and preparing reference standards		
incl	Includes	Standard			
IR	Infrared	P.T.	Passes test		
J/mol.K	Joule(s) per mole Kelvin	PTFE	Poly(tetrafluoroethylene)		
kg	Kilogram	Purified	A grade of higher quality than technical, often used where there are no official standards		
kU	Kilounit	P.V.	Pore volume		
L or l	Liter				
lb	Pound				

Glossary of Elemental Forms

The various forms of an element appear in the order below. Special items specific to particular elements are noted before powders. For example, in the Gold (Au) listing, Bright Brushing Gold is listed before the powders.

Bar	a rectangular or cylindrical piece of material
Cubes	uniform sized, cubic shaped pieces of material
Disc	a cylindrical piece of material with a diameter much larger than the thickness
Felt	compressed, porous, nonwoven fabric
Fiber	a pure monofilament form of solid material having an extremely high length to diameter ratio
Flake	powder with a flat, irregular shape
Foil	a thin sheet of pure material, 0.025mm
Gauze	a wire cloth material consisting of wires of a pure material woven into a grid having consistent
Granules	uniform, amorphous pieces of material
Ingot	a cast, usually rectangular piece of material
Lump	a solid piece of amorphous material, larger than a granule
Microleaf	an extremely thin layer of pure material on a temporary support ≤ 1 micron thick
Mossy	pieces formed by dropping molten metal into water
Needles	uniform, elongated pieces of material
Pellets	somewhat regular shaped pieces of material
Pieces	solid pieces of material, larger than a granule
Plate	a sheet of fabricated pure material >2 mm thick
Powder	solid material with a very small particle size
Ribbon	a thin width of foil, offered in rolls of varying length
Rod	a uniform strand of a pure material having a diameter ≥ 2.0 mm
Shot	spherical to semi
Slugs	short cylindrical pieces of material of varying lengths and diameters
Spheres	uniform sized, spherical pieces of material
Splatter	pieces formed by dropping molten metal onto a cooling surface
Sputtering target	a disc of high purity material used as an atomic sputtering source for ion bombardment
Sponge	pieces with a high surface area resulting from complex surface morphology
Sticks	rectangular pieces of a nonmetallic material
Thin foil	a very thin sheet of unsupported pure material 1.1
Tubing	a uniform strand of a pure material having a hollowed core
Turnings	small concentric shavings machined from a larger form
Ultrathin foil	an extremely thin sheet of pure material, supported or unsupported ≤ 1 micron thick
Wire	a uniform strand of a pure material having a diameter ≤ 2.0 mm
Yarn	a parallel collection of a definite number of fiber strands, usually three to several hundred

Bond Strengths

Average bond energies, ΔH° at 25°

Diatomic Molecules			Polyatomic Molecules		
	kcal/mol	kJ/mol		kcal/mol	kJ/mol
H—H	104.2	436	C—H	99	414
F—F	37.5	157	C—C	83	347
Cl—Cl	58.0	243	C=C	146	610
Br—Br	46.3	194	C≡C	200	836
I—I	36.5	153	C—O	86	359
H—F	135.9	568	C=O ¹	192	803
H—Cl	103.1	432	C=O ²	166	694
H—Br	87.4	366	C=O ³	176	736
H—I	71.4	299	C=O ⁴	179	748
O=O	119.1	498	C—N	73	305
N≡N	225.9	945	C=N	147	615
			C≡N	213	890
			C—F	116	485
			C—Cl	81	339
			C—Br	68	284
			C—I	51	213
			O—H	111	464
			O—O	35	146
			O—Cl	52	217
			O—Br	48	201
			N—H	93	389
			N—N	39	163
			N—O	53	221
			N=N	100	418
			N=O	145	606
			S—H	83	339
			S—S	54	226

Typical Bond Lengths

Typical Bond Lengths (in Å)

C — H Bonds		C — C Bonds		Other Bonds	
$\text{H}_3\text{C} - \text{H}$	1.091	$\text{H}_3\text{C} - \text{CH}_3$	1.541	$\text{C} - \text{N}$	1.47
$\begin{array}{c} \\ \text{H}_2\text{C} - \text{H} \end{array}$	1.101	$\text{H}_2\text{C} = \text{CH}_2$	1.337	$\text{C} = \text{N}$	1.30
$\begin{array}{c} \\ \text{HC} - \text{H} \\ \end{array}$	1.073	$\text{HC} \equiv \text{CH}$	1.204	$\text{C} \equiv \text{N}$	1.16
$\begin{array}{c} \\ -\text{C} - \text{H} \\ \end{array}$	1.070			$\text{C} - \text{O}$	1.43
$\begin{array}{c} \\ =\text{C} - \text{H} \end{array}$	1.07			$\text{C} = \text{O}$	1.23
$\equiv \text{C} - \text{H}$	1.056			$\text{C} - \text{Cl}$	1.77
				$\text{C} - \text{Br}$	1.94
				$\text{C} - \text{I}$	2.13
				$\text{N} - \text{H}$	1.04
				$\text{O} - \text{H}$	0.97

Atomic Weights

Based on the Atomic Mass $^{12}\text{C} = 1247.90$

Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight
Actinium	Ac	227.0278	Gadolinium	Gd	157.25	Oxygen	O	15.9994	Tin	Sn	118.69
Aluminum	Al	26.9815	Gallium	Ga	69.72	Palladium	Pd	106.4	Titanium	Ti	47.90
Americium	Am	(243)	Germanium	Ge	72.59	Phosphorus	P	30.9738	Tungsten	W	183.85
Antimony	Sb	121.75	Gold	Au	196.967	Platinum	Pt	195.09	Uranium	U	238.03
Argon	Ar	39.948	Hafnium	Hf	178.49	Plutonium	Pu	(244)	Vanadium	V	50.942
Arsenic	As	74.9216	Helium	He	4.0026	Polonium	Po	(209)	Xenon	Xe	131.30
Astatine	At	(210)	Holmium	Ho	164.930	Potassium	K	39.1	Ytterbium	Yb	173.04
Barium	Ba	137.34	Hydrogen	H	1.0079	Praseodymium	Pr	140.907	Yttrium	Y	88.906
Berkelium	Bk	(247)	Indium	In	114.82	Promethium	Pm	(145)	Zinc	Zn	65.37
Beryllium	Be	9.0122	Iodine	I	126.904	Protactinium	Pa	231.0359	Zirconium	Zr	91.22
Bismuth	Bi	208.980	Iridium	Ir	192.2	Radium	Ra	226.0254			
Boron	B	10.81	Iron	Fe	55.847	Radon	Rn	(222)			
Bromine	Br	79.904	Krypton	Kr	83.80	Rhenium	Re	186.2			
Cadmium	Cd	112.41	Lanthanum	La	138.91	Rhodium	Rh	102.905			
Calcium	Ca	40.08	Lawrencium	Lr	(260)	Rubidium	Rb	85.47			
Californium	Cf	(251)	Lead	Pb	207.19	Ruthenium	Ru	101.07			
Carbon	C	12.01115	Lithium	Li	6.939	Samarium	Sm	150.35			
Cerium	Ce	140.12	Lutetium	Lu	174.97	Scandium	Sc	44.956			
Cesium	Cs	132.905	Magnesium	Mg	24.31	Selenium	Se	78.96			
Chlorine	Cl	35.453	Manganese	Mn	54.9380	Silicon	Si	28.086			
Chromium	Cr	51.996	Mendelevium	Md	(258)	Silver	Ag	107.870			
Cobalt	Co	58.9332	Mercury	Hg	200.59	Sodium	Na	22.9898			
Copper	Cu	63.54	Molybdenum	Mo	95.94	Strontium	Sr	87.62			
Curium	Cm	(247)	Neodymium	Nd	144.24	Sulfur	S	32.064			
Dysprosium	Dy	162.50	Neon	Ne	20.18	Tantalum	Ta	180.948			
Einsteinium	Es	(254)	Neptunium	Np	237.0482	Technetium	Tc	(98)			
Erbium	Er	167.26	Nickel	Ni	58.71	Tellurium	Te	127.60			
Europium	Eu	151.96	Niobium	Nb	92.906	Terbium	Tb	158.924			
Fermium	Fm	(257)	Nitrogen	N	14.0067	Thallium	Tl	204.37			
Fluorine	F	18.9984	Nobelium	No	(259)	Thorium	Th	232.038			
Francium	Fr	(223)	Osmium	Os	190.2	Thulium	Tm	168.934			

A value in parentheses represents the atomic mass number of the radioisotope of longest known half-life.

Multiples of Element Weights

C	12.01	C ₃₅	420.35	H ₃₄	34.27	O ₃	48.00	(OCH ₃) ₂	62.07
C ₂	24.02	H	1.008	H ₃₅	35.28	O ₄	64.00	(OCH ₃) ₃	93.10
C ₃	36.03	H ₂	2.016	H ₃₆	36.29	O ₅	80.00	(OCH ₃) ₄	124.14
C ₄	48.04	H ₃	3.024	H ₃₇	37.30	O ₆	96.00	(OCH ₃) ₅	155.17
C ₅	60.05	H ₄	4.032	H ₃₈	38.30	O ₇	112.00	(OCH ₃) ₆	186.20
C ₆	72.06	H ₅	5.040	H ₃₉	39.31	O ₈	128.00	(OCH ₃) ₇	217.24
C ₇	84.07	H ₆	6.048	H ₄₀	40.32	O ₉	144.00	(OCH ₃) ₈	248.27
C ₈	96.08	H ₇	7.056	H ₄₁	41.33	O ₁₀	160.00	OC ₂ H ₅	45.06
C ₉	108.09	H ₈	8.064	H ₄₂	42.34	N	14.01	(OC ₂ H ₅) ₂	90.12
C ₁₀	120.10	H ₉	9.072	H ₄₃	43.34	N ₂	28.02	(OC ₂ H ₅) ₃	135.18
C ₁₁	132.11	H ₁₀	10.08	H ₄₄	44.35	N ₃	42.03	(OC ₂ H ₅) ₄	180.24
C ₁₂	144.12	H ₁₁	11.09	H ₄₅	45.36	N ₄	56.04	(OC ₂ H ₅) ₅	225.30
C ₁₃	156.13	H ₁₂	12.10	H ₄₆	46.37	N ₅	70.05	OCOCH ₃	59.04
C ₁₄	168.14	H ₁₃	13.10	H ₄₇	47.38	N ₆	84.06	(OCOCH ₃) ₂	118.09
C ₁₅	180.15	H ₁₄	14.11	H ₄₈	48.38	S	32.06	(OCOCH ₃) ₃	177.13
C ₁₆	192.16	H ₁₅	15.12	H ₄₉	49.39	S ₂	64.12	(OCOCH ₃) ₄	236.18
C ₁₇	204.17	H ₁₆	16.13	H ₅₀	50.40	S ₃	96.18	(OCOCH ₃) ₅	295.22
C ₁₈	216.18	H ₁₇	17.14	H ₅₁	51.41	S ₄	128.24	(OCOCH ₃) ₆	354.26
C ₁₉	228.19	H ₁₈	18.14	H ₅₂	52.42	F	19.00	(OCOCH ₃) ₇	413.31
C ₂₀	240.20	H ₁₉	19.15	H ₅₃	53.42	F ₂	38.00	(OCOCH ₃) ₈	472.35
C ₂₁	252.21	H ₂₀	20.16	H ₅₄	54.43	F ₃	57.00	(OCOCH ₃) ₉	531.40
C ₂₂	264.22	H ₂₁	21.17	H ₅₅	55.44	Cl	35.45	(OCOCH ₃) ₁₀	590.44
C ₂₃	276.23	H ₂₂	22.18	H ₅₆	56.45	Cl ₂	70.91	(H ₂ O) _{0.5}	9.01
C ₂₄	288.24	H ₂₃	23.18	H ₅₇	57.46	Cl ₃	106.37	H ₂ O	18.02
C ₂₅	300.25	H ₂₄	24.19	H ₅₈	58.46	Cl ₄	141.81	(H ₂ O) _{1.5}	27.02
C ₂₆	312.26	H ₂₅	25.20	H ₅₉	59.47	Cl ₅	177.27	(H ₂ O) ₂	36.03
C ₂₇	324.27	H ₂₆	26.21	H ₆₀	60.48	Br	79.90	(H ₂ O) ₃	54.05
C ₂₈	336.28	H ₂₇	27.22	H ₆₁	61.49	Br ₂	159.81	(H ₂ O) ₄	72.06
C ₂₉	348.29	H ₂₈	28.22	H ₆₂	62.50	Br ₃	239.71	(H ₂ O) ₅	90.08
C ₃₀	360.30	H ₂₉	29.23	H ₆₃	63.50	Br ₄	319.62	(H ₂ O) ₆	108.10
C ₃₁	372.31	H ₃₀	30.24	H ₆₄	64.51	I	126.90		
C ₃₂	384.32	H ₃₁	31.25	H ₆₅	65.52	I ₂	253.80		
C ₃₃	396.33	H ₃₂	32.26	O	16.00	I ₃	380.70		
C ₃₄	408.34	H ₃₃	33.26	O ₂	32.00	OCH ₃	31.03		

Properties of Selected Elements

Element	Symbol	Atomic Weight	Density		Melting Point		Boiling Point		Thermal *Conductivity	Elec.Cnd. %IACS
			g/cc	lbs./cu.in.	°F	°C	°F	°C		
Aluminum	Al	26.98	2.70	0.0975	1220	660	4521	2494	0.480	64.94
Antimony	Sb	121.75	6.70	0.2420	1168	631	2889	1587	0.045	—
Arsenic	As	74.92	5.78	0.2087	1501	816	1139	615	0.115	4.9
Beryllium	Be	9.01	1.85	0.0668	2354	1290	5018	2770	0.40	—
Bismuth	Bi	208.98	9.80	0.3538	520	271	2847	1564	0.02	—
Boron	B	10.81	2.34	0.0845	4172	2300	4712	2600	0.063	—
Cadmium	Cd	112.41	8.64	0.3119	610	321	1412	767	0.22	25.00
Calcium	Ca	40.08	1.55	0.0560	1542	839	2703	1484	0.30	49.6
Chromium	Cr	52.00	7.19	0.2596	3407	1875	4856	2680	0.16	13.0
Cobalt	Co	58.93	8.90	0.3213	2723	1495	5198	2870	0.165	27.6
Copper	Cu	63.55	8.93	0.3223	1985	1085	4653	2567	0.94	103.06
Gallium	Ga	69.72	5.91	0.2133	86	30	4357	2403	0.08	—
Germanium	Ge	72.59	5.32	0.1920	1719	937	5133	2834	0.15	—
Gold	Au	196.97	19.30	0.6967	1947	1064	5175	2857	0.71	73.4
Indium	In	114.82	7.30	0.2635	315	157	3763	2073	0.057	—
Iron	Fe	55.85	7.87	0.2841	2800	1538	5198	2870	0.20	17.59
Lead	Pb	207.19	11.35	0.4097	621	327	3182	1750	0.083	8.3
Lithium	Li	6.94	0.53	0.0191	358	181	2448	1342	0.17	—
Magnesium	Mg	24.31	1.74	0.0628	1202	650	2025	1107	0.37	38.6
Manganese	Mn	54.94	7.47	0.2697	2271	1244	3803	2095	0.18	0.9
Mercury	Hg	200.59	13.55	0.4891	-38	-39	675	357	0.022	—
Molybdenum	Mo	95.94	10.22	0.3689	4730	2610	10040	5560	0.34	34.0
Nickel	Ni	58.70	8.90	0.3213	2647	1453	4946	2730	0.22	25.2
Niobium	Nb	92.91	8.57	0.3094	4474	2468	8901	4927	0.125	13.2
Selenium	Se	78.96	4.81	0.1736	423	217	1265	685	0.001	—
Silicon	Si	28.08	2.33	0.0841	2570	1410	5936	3280	0.20	—
Silver	Ag	107.87	10.50	0.3790	1764	962	3551	1955	1.0	105.0
Tellurium	Te	127.60	6.24	0.2253	842	450	1810	988	0.014	—
Tin	Sn	118.69	7.30	0.2635	450	232	5018	2770	0.155	15.6
Titanium	Ti	47.88	4.51	0.1628	3034	1668	5949	3287	0.43	—
Tungsten	W	183.85	19.25	0.6949	6170	3410	10292	5700	0.40	—
Vanadium	V	50.94	6.10	0.2202	3452	1900	6116	3380	0.074	—
Zinc	Zn	65.38	7.14	0.2577	788	420	1663	906	0.27	28.27
Zirconium	Zr	91.22	6.50	0.2346	3366	1852	6692	3700	0.052	4.1

*cal./sq. cm/cm/sec/°c

Physical Properties of the Platinum Group Metals¹

Property	Units	Ru	Rh	Pd	Os	Ir	Pt
Atomic Number	—	44	45	46	76	77	78
Atomic Weight	—	101.07	102.9055	106.4	190.2	192.22	195.09
Crystal Structure ^a	—	HCP	FCC	FCC	HCP	FCC	FCC
Lattice Constants	a c	0.27058 0.42819	0.38031	0.38898	0.27341 0.43197	0.38394	0.39231
Atomic Radius	nm	0.133	0.134	0.138	0.134	0.136	0.139
Density at 25°C	g·cm ⁻³	12.45	12.41	12.02	22.61	22.65	21.45
Density at Melting Point	g·cm ⁻³	10.9	11.1	10.5	20.1	20.0	19.8
Melting Point	°C	2310	1960	1554	3050	2443	1769
Boiling Point	°C	3900	3730	3125	5500	4500	3825
Ionization Potentials - 1st	ev	7.36	7.46	8.33	8.7	9.6	9.0
2nd	ev	16.8	18.07	19.42	17	—	18.56
3rd	ev	28.46	31.05	32.92	—	—	28.5
4th	ev	—	—	48.8	—	—	41.1
Vapor Pressure at 3000°C (est)	nm	4.1	5.17	—	0.0195	0.541	—
Specific heat at 0°C	J/K/mole	24.095	24.941	25.929	—	25.121	25.958
Thermal Conductivity 0-100°C	Watt/m/°C	105	150	76	87	148	73
Linear Coefficient of Thermal Expansion	°C ⁻¹	—	8X10 ^{-6b}	11.67x10 ^{-6c}	5x10 ^{-6b}	—	8.9x10 ^{-6c}
Electrical Resistivity	μΩ · cm	6.80	4.33	9.33	8.12	4.71	9.85
Temperature Coefficient of Resistance (0-100°C)	Ω · °C ⁻¹	0.0042	0.0046	0.0033	0.0042	0.0043	0.003
Hardness (Annealed - Vicker Hardness Number)	—	220	101	41	>250	220	41
Tensile Strength	ton·in ⁻²	36	45	11	—	71	9

^aHCP = hexagonal close packed; FCC = face centered cubic

^bat 0°C

^cat 25°C

1. *Chemistry of the Platinum Group Metals*, ed. Frank R. Hartley (Oxford: Elsevier, 1991) 21-22.

Mesh Size Conversion Table

A "+" before the mesh size indicates the particles are retained on and are larger than the sieve. A "-" before the mesh size indicates the particles pass through and are smaller than the sieve. For example, -325 mesh indicates the particles pass through and are smaller than the openings of a 325 mesh (44 micron) sieve. Typically 90% or more of the particles will fall within the specified mesh.

Mesh Size	Approximate Micron Size	Approximate Millimeters	Inches
4	4760	4.76	0.185
6	336	3.36	0.131
8	2380	2.38	0.093
12	1680	1.68	0.065
16	1190	1.19	0.046
20	840	0.84	0.0328
30	590	0.59	0.0232
40	420	0.42	0.0164
50	297	0.29	0.0116
60	250	0.25	0.0097
70	210	0.21	0.0082
80	177	0.17	0.0069
100	149	0.14	0.0058
140	105	0.10	0.0041
200	74	0.07	0.0029
230	62	0.06	0.0024
270	53	0.05	0.0021
325	44	0.04	0.0017
400	37	0.03	0.0015
625	20	0.02	0.0008
1250	10	0.01	0.0004
2500	5	0.005	0.0002

MOHS Scale of Hardness

1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Wire Gauge Dimension Conversion Charts

AWG; B&S	
Gauge No.	Inches
0000000
000000	0.580000
00000	0.516500
0000	0.460000
000	0.409642
00	0.364796
0	0.324861
1	0.289297
2	0.257627
3	0.229423
4	0.204307
5	0.181940
6	0.162023
7	0.144285
8	0.128490
9	0.114423
10	0.101897
11	0.090742
12	0.080808
13	0.071962
14	0.064084
15	0.057068
16	0.050821
17	0.045257
18	0.040303
19	0.035890
20	0.031961
21	0.028462
22	0.025346
23	0.022572
24	0.020101
25	0.017900
26	0.015941
27	0.014195
28	0.012641
29	0.011257

Inches	Millimeters
0.00001	0.000254
0.00005	0.00127
0.0001	0.00254
0.0005	0.0127
0.001	0.0254
0.002	0.0506
0.003	0.0762
0.004	0.1016
0.005	0.1270
0.006	0.1524
0.007	0.1778
0.008	0.2032
0.009	0.2286
0.010	0.2540
0.015	0.3810
0.020	0.5080
0.025	0.6350
0.030	0.7620
0.035	0.8890
0.040	1.016
0.045	1.143
0.050	1.270
0.060	1.524
0.070	1.778
0.080	2.032
0.090	2.286
0.100	2.540
0.125	3.175
0.150	3.810
0.20	5.080
0.25	6.350
0.30	7.620
0.40	10.160
0.50	12.700
0.75	19.050
1.0	25.40

AWG; B&S	
Gauge No.	Inches
30	0.010025
31	0.008928
32	0.007950
33	0.007080
34	0.006305
35	0.005615
36	0.005000
37	0.004453
38	0.003965
39	0.003531
40	0.003144

Inches	Millimeters
2	50.80
3	76.20
4	101.60
5	127.00
6	152.40
7	177.80
8	203.20
9	228.60
10	254.00
11	279.40
12	304.80

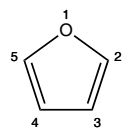
Crystal Structure and Atomic Radius (nm)

	Crystal Structure	Atomic Radius(nm)
H		0.046
Li	bodycentered cubic	0.157
Na	bodycentered cubic	0.192
K	bodycentered cubic	0.238
Rb	bodycentered cubic	0.251
Cs	bodycentered cubic	0.27
Fr		0.27
Be	close-packedstructure	0.113
Mg	close-packedstructure	0.16
Ca	face-centered cubic	0.197
Sr	face-centered cubic	0.215
Ba	bodycentered cubic	0.2224
Ra		0.223
Sc	close-packedstructure	0.16
Y	close-packedstructure	0.181
Ti	close-packedstructure	0.147
Zr	close-packedstructure	0.16
Hf	close-packedstructure	0.159
Rf		
V	bodycentered cubic	0.136
Nb	bodycentered cubic	0.147
Ta	bodycentered cubic	0.147
Cr	bodycentered cubic	0.128
Mo	bodycentered cubic	0.14
W	bodycentered cubic	0.141
Db		
Mn	bodycentered cubic	0.112
Tc		0.135
Re	close-packedstructure	0.138
Sg		
Fe	bodycentered cubic	0.128

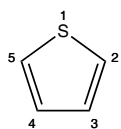
	Crystal Structure	Atomic Radius(nm)
Ru	close-packedstructure	0.134
Os	close-packedstructure	0.135
Bh		
Co	close-packedstructure	0.125
Rh	face-centered cubic	0.134
Ir	face-centered cubic	0.135
Hs		
Ni	face-centered cubic	0.125
Pd	face-centered cubic	0.137
Pt	face-centered cubic	0.138
Mt		
Ag	face-centered cubic	0.144
Au	face-centered cubic	0.144
Ds		
Cu	face-centered cubic	0.128
Cd	close-packedstructure	0.152
Hg	rhombohedral crystal	0.155
Rg		
B	Tetragonal System	0.097
Al	face-centered cubic	0.143
Zn	close-packedstructure	0.137
In	face-centered cubic	0.157
Tl	close-packedstructure	0.171
Cp		
C	hexagonal crystal/carbite	0.077
Si	carbide	0.117
Ga	Tetragonal System	0.135
Sn	Tetragonal System	0.158
Pb	face-centered cubic	0.175
N		0.071
P		0.109

	Crystal Structure	Atomic Radius(nm)
Ge	carbide	0.139
Sb	rhombohedral crystal	0.161
Bi	rhombohedral crystal	0.182
O		0.06
S		0.104
As	rhombohedral crystal	0.125
Te	hexagonal crystal	0.143
Po		0.14
F		0.071
Cl		0.107
Se	hexagonal crystal	0.116
I		0.138
At		
He		0.128
Ne		0.158
Ar		0.191
Br		0.119
Xe		0.218
Rn		0.132
La	close-packedstructure/ face-centered cubic	0.187
Ce	face-centered cubic	0.182
Pr	close-packedstructure	0.183
Nd	close-packedstructure	0.182

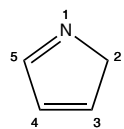
Heterocycle Ring Numbering



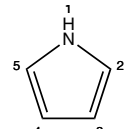
Furan



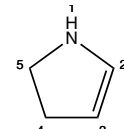
Thiophene



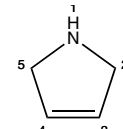
2H-Pyrrole



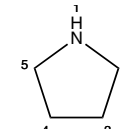
Pyrrole



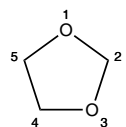
2-Pyrroline



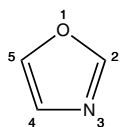
3-Pyrroline



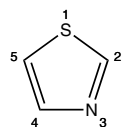
Pyrrolidine



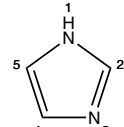
1,3-Dioxolane



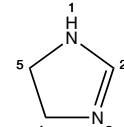
Oxazole



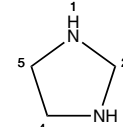
Thiazole



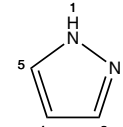
Imidazole



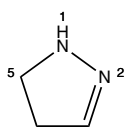
2-Imidazoline



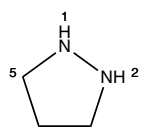
Imidazolidine



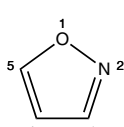
Pyrazole



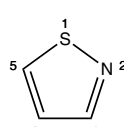
2-Pyrazoline



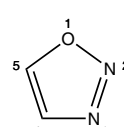
Pyrazolidine



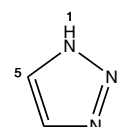
Isoxazole



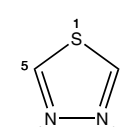
Isothiazole



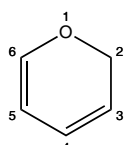
1,2,3-Oxadiazole



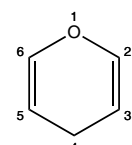
1,2,3-Triazole



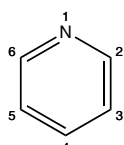
1,3,4-Thiadiazole



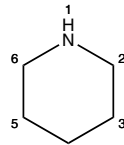
2H-Pyran



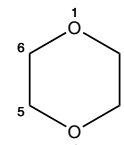
4H-Pyran



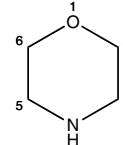
Pyridine



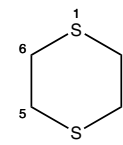
Piperidine



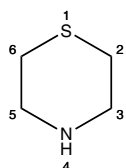
1,4-Dioxane



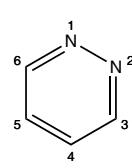
Morpholine



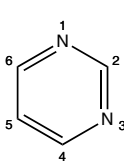
1,4-Dithiane



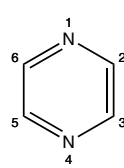
Thiomorpholine



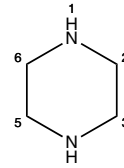
Pyridazine



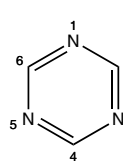
Pyrimidine



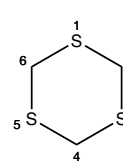
Pyrazine



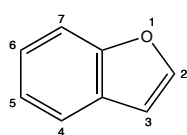
Piperazine



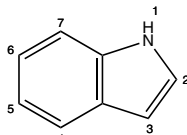
1,3,5-Triazine



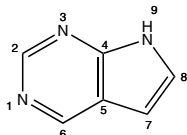
1,3,5-Trithiane



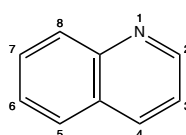
Benzofuran



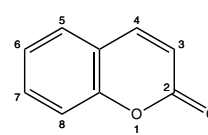
Indole



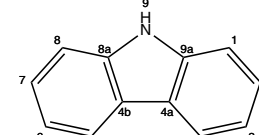
Purine



Quinoline



Coumarin



Carbazole

Numerical Prefixes

Numerical Prefixes Used in Chemical Names

Numeral	Prefix
1/2	hemi-
1	mono-
1-1/2	sesqui-
2	di-, bi-
2-1/2	hemipenta-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	ennea-, nona-
10	deca-
11	hendeca-, undeca-
12	dodeca-
13	trideca-
14	tetradeca-
15	pentadeca-
16	hexadeca-
17	heptadeca-
18	octadeca-
19	nonadeca-
20	eicosa-

Numeral	Prefix
21	heneicosa-
22	docosa-
23	tricoso-
24	tetracoso-
25	pentacoso-
26	hexacoso-
27	heptacoso-
28	octacoso-
29	nonacoso-
30	triaconta-
40	tetraconta-
50	pentaconta-
60	hexaconta-
70	heptaconta-
80	octaconta-
90	nonaconta-
100	hecta-
101	henhecta-
102	dohecta-
110	decahecta-
120	eicosahecta-
200	dicta-

Metric Conversion Factors

To convert from	To	Multiply by	To convert from	To	Multiply by
angstrom	m	$1.0000 \cdot 10^{-10}(a)$	hp(e)	W	$7.4570 \cdot 10^2$
atm	Pa	1.0133×10^5	hp(f)	W	7.4600×10^2
Btu(b)	J	1.054×10^3	in.	m	2.5400×10^{-2}
Btu(b)/ft ² · h	W/m ²	3.1525	in. ²	m ²	6.4516×10^{-4}
Btu(b)/ft ² · h · °F	W/m ² · K	5.6745	in. ³	m ³	1.6387×10^{-5}
Btu(b) · ft/h · ft ² · °F	W/m · K	1.7296	in. of Hg(g)	Pa	3.3864×10^3
Btu(b)/ft ² · s	W/m ²	1.135×10^4	in. of water(c)	Pa	2.4908×10^2
Btu(b) · in/ft ² · h · °F	W/m · K	1.4413×10^{-1}	K	°C	$t_{°C} = t_K - 273.15$
Btu(b) · in/s · ft ² · °F	W/m · K	5.1887×10^2	kgf	N	9.80665(a)
Btu(b)/lbm · °F	J/kg · K	4.1840×10^3	kgf/mm ²	Pa	$9.80665 \times 10^6(a)$
cal(b)	J	4.1840(a)	ksi	MPa	6.8948
cal(b)/cm · s · °C	W/m · K	$4.1840 \times 10^2(a)$	ksi	Pa	6.8948×10^6
cal(b)/g	J/kg	$4.1840 \times 10^3(a)$	ksi√in.	MPa√m	1.089
cal(b)/g · °C	J/kg · K	$4.1840 \times 10^3(a)$	lb(h)	kg	4.5359×10^{-1}
circ mil	m ²	5.0671×10^{-10}	lb/in. ³	kg/m ³	2.7680×10^4
°C	K	$t_K = t_{°C} + 273.15$	lbf	N	4.4482
degree	rad	1.7453×10^{-2}	lbf · in.	N · m	1.1298×10^{-1}
dyne/cm ²	Pa	$1.0000 \times 10^{-1}(a)$	lbf · ft	N · m	1.3558
°F	°C	$t_{°C} = (t_{°F} + 32)/1.8$	MPa√m	MNm ^{-3/2}	1.0000(a)
°F	K	$t_K = t_{°F} + 459.67/1.8$	μin.	m	$2.5400 \times 10^8(a)$
ft	m	3.0480×10^{-1}	mil	m	$2.5400 \times 10^{-5}(a)$
ft ²	m ²	9.2903×10^{-2}	N/m ²	Pa	1.0000(a)
ft ³	m ³	2.8317×10^{-2}	oersted	A/m	79.578
ft of water(c)	Pa	2.9890×10^3	oz/ft ²	kg/m ²	3.0515×10^{-1}
ft ² /h (thermal diffusivity)	m ² /s	$2.58064 \times 10^{-5}(a)$	psi	Pa	6.8948×10^3
ft · lbf	J	1.3558	°R	K	$t_K = t_{°R}/1.8$
ft · lbf/s	W	1.3558	ton(j)	kg	9.0718×10^2
ft/s	m/s	3.0480×10^{-1}	ton(k)	kg	1.0160×10^3
gauss	T	$1.0000 \times 10^{-4}(a)$	ton/in. ²	Pa	1.3786×10^4
gallon(d)	m ³	3.7854×10^{-3}	tonne	kg	$1.0000 \times 10^3(a)$
g/cm ³	kg/m ³	$1.0000 \times 10^3(a)$	tonr	Pa	1.3332×10^2
g/cm ³	Mg/m ³	1.0000(a)	Ω/circ mil · ft	Ω · m	1.6624×10^{-9}

(a) Exactly. (b) Thermochemical. (c) At 4 °C (39.2 °F). (d) U.S. liquid. (e) Mechanical (1 hp = 550 ft·lbf/s). (f) Electrical. (g) At 0 °C (32 °F). (h) Avoirdupois. (j) Short; equal to 2000 lbm. (k) Long; 2240 lbm.

Common Conversion Factors

To convert from	To	Multiply by	To convert from	To	Multiply by
Atmospheres	cm of Hg at 0 °C	76	Inches	mils	1000
Atmospheres	gm/cm ²	1033.3	Inches of Hg at 32 °C	atmospheres	0.033421
Atmospheres	inches of Hg at 32 °F	29.921	Inches of Hg at 32 °C	feet of water at 39.1 °F	1.13299
Atmospheres	lb/in. ²	14.696	Inches of water at 39.2 °F	inches of Hg	0.073554
Btu	calories (gram)	252	Kilograms	ounces (avoir.)	35.274
Calories, gram	Btu	3.968 x 10 ⁻³	Kilograms	pounds (avoir.)	2.2046
Centimeters	angstrom units	1 x 10 ⁸	Liters	cubic feet	0.035316
Centimeters	feet	0.032808	Liters	gallons (U.S.)	0.2642
Cubic cm	cubic inches	0.061023	Liters	ounces (U.S. fluid)	33.81343
Cubic cm	gallons (U.S.)	2.6417 x 10 ⁻⁴	Liters	pints (U.S. fluid)	2.11336
Cubic cm	ounces (U.S. fluid)	0.033814	Liters	quarts (U.S. fluid)	1.05668
Cubic cm	pints (U.S. fluid)	0.0021134	Meters	angstrom units	1 x 10 ¹⁰
Cubic ft	cubic cm	28317	Meters	feet (U.S.)	3.28083
Cubic ft	cubic meters	0.02832	Meters	inches (U.S.)	39.3700
Cubic ft	gallons (U.S.)	7.481	Microns	angstrom units	1 x 10 ⁴
Cubic ft	liters	28.316	Microns	inches	3.937 x 10 ⁻⁵
Cubic in. (U.S.)	cubic cm	16.3872	Microns	millimeters	0.001
Cubic in. (U.S.)	liters	0.016387	Microns	mils	0.03937
Cubic yd (U.S.)	cubic meters	0.7646	Millimeters	inches (U.S.)	0.03937
Cubic yd of sand	pounds	2700	Millimeters	microns	1000
Feet (U.S.)	centimeters	30.48	Millimeters	mils	39.37
Feet (U.S.)	meters	0.3048	Ounces (avoir.)	grams	28.3495
Gallons (U.S.)	cubic centimeters	3785.4	Ounces (U.S. fluid)	cubic cm	29.5737
Gallons (U.S.)	cubic feet	0.13368	Ounces (U.S. fluid)	cubic in.	1.8047
Gallons (U.S.)	cubic inches	231	Ounces (U.S. fluid)	liters	0.02957
Gallons (U.S.)	liters	3.7854	Pints (U.S. liquid)	cubic cm	473.179
Grams	ounces (avoir.)	0.03527	Pints (U.S. liquid)	liters	0.473168
Grams	pounds (avoir.)	0.002205	Pounds (avoir.)	grams	453.5924
Horsepower	Btu (mean)/min	42.418	Square cm	square in.	0.1550
Horsepower	calories, log (mean)/min	10.688	Square in. (U.S.)	square cm	6.5416
Inches (U.S.)	angstrom units	2.5400 x 10 ⁸	Years (leap)	hours	8784

Physical Constants

Name and symbol	Value and units
Velocity of light, c	2.997902×10^{10} cm/s
Planck constant, h	6.62377×10^{-27} erg s/molecule
Avogadro constant, N	6.02380×10^{23} molecule mol
Faraday constant, F	96.493.1 C/equivalent
Absolute temperature of ice point, T (0 °C)	273.15 K
Pressure-volume product for 1 mol of gas at 0 °C and zero pressure (PV) $P = 0$; $T = 0$ °C	2271.16 J/mol
Gas constant $P = 0$	8.31469 J/mol°
$R = \frac{(PV)_{T=0\text{ °C}}}{T(0\text{ °C})}$	1.98726 cal/mol°
Boltzmann constant $k = R/N$	1.38031×10^{16} erg/molecule° 11.96171 Jcm/mol
Constant relating wave number and energy $Z = Nhc$	2.858917 cal cm/mole
Standard atmosphere, atm	1,013,250 dynes/cm ²
Thermocalorical calorie	4.1840 J (exact)

Characteristic Proton NMR Chemical Shifts

Methyl		Methylene		Methyne		Others	
Group	δ ppm	Group	δ ppm	Group	δ ppm	Group	δ ppm
$\text{CH}_3-\text{C}-$	0.9	$-\text{CH}_2-\text{C}-$	1.2	$-\text{CH}-\text{C}-$	1.5	$\text{H}-\text{N}<$	1-3
$\text{CH}_3-\text{C}=\text{C}<$	1.6	$-\text{CH}_2-\text{C}=\text{C}<$	2.05	$-\text{CH}-\text{C}=\text{C}<$	2.6	$\text{H}-\text{OR}$	1-5
$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-$	2.1	$-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-$	2.4	$-\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-$	2.5	$\text{H}-\text{C}\equiv\text{C}-$	2.5
CH_3-NR_2	2.2	$-\text{CH}_2-\text{NR}_2$	2.4	$-\text{CH}-\text{NR}_2$	2.9	$\text{H}-\overset{\text{O}}{\parallel}{\text{C}}<$	5.5
CH_3-Ar	2.3	$-\text{CH}_2-\text{Ar}$	2.6	$-\text{CH}-\text{Ar}$	3.0	$\text{H}-\text{Ar}$	7.3
CH_3-Br	2.7	$-\text{CH}_2-\text{Br}$	3.4	$-\text{CH}-\text{Br}$	4.1	$\text{H}-\overset{\text{O}}{\parallel}{\text{C}}-$	10
CH_3-Cl	3.1	$-\text{CH}_2-\text{Cl}$	3.4	$-\text{CH}-\text{Cl}$	4.1	$\text{H}-\overset{\text{O}}{\parallel}{\text{OC}}-$	9-12
$\text{CH}_3-\text{O}-$	3.2	$-\text{CH}_2-\text{O}$	3.4	$-\text{CH}-\text{O}$	3.7		
$\text{CH}_3-\overset{+}{\text{N}}<$	2.9						

Concentrations of Commonly Used Laboratory Reagents

Reagent	Specific Gravity	Approx. % Acid or Base Present in Concentrated Reagent (by weight)	Weight of Acid of base (gms) in Solution per liter of Reagent (Ave.)	Molecular Weight	Normality of Concentrated Reagent
Hydrochloric Acid	1.18	37.0	442	36.46	11.6
Nitric Acid	1.42	70.0	989	63.02	16
Perchloric Acid	1.67	70.0	1169	100.46	11.6
Sulfuric Acid	1.84	96.0	1772	98.08	36
Phosphoric Acid	1.69	85.0	1436	98.00	44
Formic Acid	1.20	90.0	1084	46.03	24
Glacial Acetic Acid	1.05	99.5	1053	60.05	17.4
Ammonium Hydroxide	0.90	58 (NH ₄ OH) 29 (NH ₃)	535	35.05	15

Solvent Selection Guide

Solvent	ACS	HPLC	Spectro-photometric	Semi-conductor
Acetone	30698	22928	32451	19392
Acetonitrile	36423	22927	32470	—
Benzene	33290	39196	33291	—
1-Butanol	31068	22925	32443	—
2-Butanone (MEK)	39119	22924		—
n-Butylacetate	XX	39197	—	19395
Carbon disulfide	39785	38993	—	—
Carbon disulfide (low benzene)	XX		—	—
Chlorobenzene	36401	22922	22921	—
Chloroform	32614	22920	32442	—
Cyclohexane	22864	22919		—
Cyclohexanone	33309	—	—	—
1,2-Dichlorobenzene	XX	19385	32154	—
1,2-Dichloroethane	39121	22918	32462	—
Dichloromethane	39116	22917	32440	—
Dimethylacetamide	XX	22916		—
N,N-Dimethylformamide	39117	22915	13808	—
Dimethylsulfoxide	36480	22914	32434	—
p-Dioxane	39118	22913		—
Ethanol (anhydrous)	33361	22930	22931	—
Diethyl ether	33224	38990	40976	—
Ether, petroleum	42085	38985	—	—
Ethyl acetate	31344	22912	39177	—
Glycerol, ultrapure	36646	38988	32450	—

Solvent	ACS	HPLC	Spectro-photometric	Semi-conductor
Heptanes	XX	22911	32441	—
Hexanes	33321	39199	32454	—
Isobutanol	36643	22908	32433	—
Isopropanol	36644	22906	39194	—
Methanol, absolute low acetone	31721	—	—	19397
Methanol, ultrapure	XX	22909	32435	19393
2-Methoxyethanol	31733	—	32444	—
1-Methyl-2-pyrrolidinone	43894	38986	39176	—
Pentane	XX	22907	32449	—
1-Propanol	43848	22932	22933	—
2-Propanol	36644	22906	39194	19397
Pyridine	19378	22905	32436	—
Tetrachloroethylene	XX	—	32437	—
Tetrahydrofuran, UV	30760	22904	32468	—
Tetrahydrofuran, non UV	XX	38994	—	—
Toluene	31755	22903	19376	19399
1,1,1-Trichloroethane		—	—	
1,2,4-Trichlorobenzene	XX	—	19390	—
1,1,1-Trichloroethylene	19401	—	43487	39744
2,2,4-Trimethylpentane	31787	22901		—
Water	36645	22934	19391	—
o-Xylene	XX	22902	32471	
Xylenes	16371	—	—	19402

xx= No ACS specifications published per ACS Committee on analytical reagents

Solvents and Baths for Heating and Cooling

System	°C
p-Xylene/N ₂	13
p-Dioxane/N ₂	12
Cyclohexane/N ₂	6
Benzene/N ₂	5
Formamide/N ₂	2
Aniline/N ₂	-6
Cycloheptane/N ₂	-12
Benzonitrile/N ₂	-13
Ethylene glycol/CO ₂	-15
o-Dichlorobenzene/N ₂	-18
Tetrachloroethane/N ₂	-22
Carbon tetrachloride/N ₂	-23
Carbon tetrachloride/CO ₂	-23
m-Dichlorobenzene/N ₂	-25
Nitromethane/N ₂	-29
o-Xylene/N ₂	-29
Bromobenzene/N ₂	-30
Iodobenzene/N ₂	-31
Thiophene/N ₂	-38
3-Heptanone/CO ₂	-38
Acetonitrile/N ₂	-41
Pyridine/N ₂	-42
Acetonitrile/CO ₂	-42
Chlorobenzene/N ₂	-45
Cyclohexanone/CO ₂	-46
m-Xylene/N ₂	-47
n-Butyl amine/N ₂	-50
Diethyl carbitol/CO ₂	-52
n-Octane/N ₂	-56
Chloroform/CO ₂	-61 (-77)
Chloroform/N ₂	-63
Methyl iodide/N ₂	-66

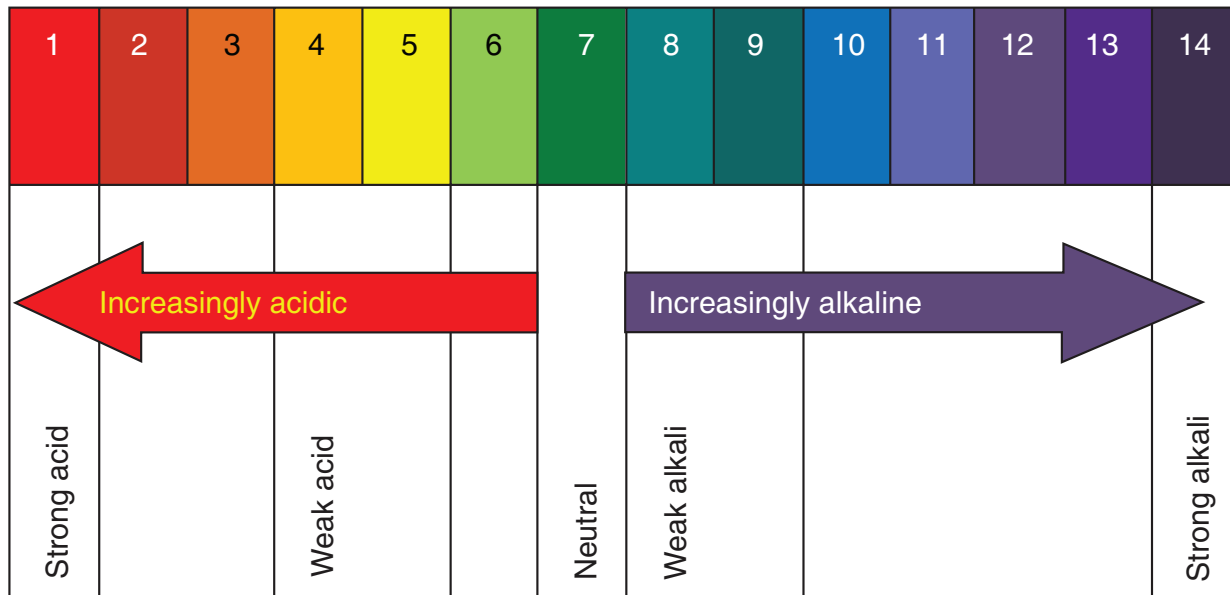
System	°C
Carbitol acetate/CO ₂	-67
t-Butyl amine/N ₂	-68
Ethanol/CO ₂	-72
Trichloroethylene/N ₂	-73
Butyl acetate/N ₂	-77
Isoamyl acetate/N ₂	-79
Acrylonitrile/N ₂	-82
Sulfur dioxide/CO ₂	-82
Ethyl acetate/N ₂	-84
Ethyl methyl ketone/N ₂	-86
Acrolein/N ₂	-88
Nitroethane/N ₂	-90
Heptane/N ₂	-91
Cyclopentane/N ₂	-93
Hexane/N ₂	-94
Toluene/N ₂	-95
Methanol/N ₂	-98
Diethyl ether/CO ₂	-100
n-Propyl iodide/N ₂	-101
n-Butyl iodide/N ₂	-103
Cyclohexene/N ₂	-104
Isooctane/N ₂	-107
Ethyl iodide/N ₂	-109
Carbon disulfide/N ₂	-110
Butyl bromide/N ₂	-112
Ethyl bromide/N ₂	-119
Acetaldehyde/N ₂	-124
Methyl cyclohexane/N ₂	-126
n-Pentane/N ₂	-131
1,5-Hexadiene/N ₂	-141
i-Pentane/N ₂	-160

Standard Selection Guide

Element, matrix	AAS Standard 1000 ppm	Plasma Standard 10 ppm	Plasma Standard 1000 ppm	Plasma Standard 10,000 ppm
Aluminum, HCl	33557	-	13856	14405
Aluminum, HNO ₃	-	-	38727	38721
Antimony, HCl	33558	-	13818	14387
Antimony, H ₂ O/tartaric acid/tr. HNO ₃	-	-	41682	41683
Arsenic, HNO ₃	33559	45246	13836	14369
Barium, HNO ₃	88052	45247	13876	14423
Beryllium, HNO ₃	88053	45248	13848	14406
Bismuth, HNO ₃	88054	45249	13822	14388
Boron, NH ₄ OH	-	-	13859	14370
Boron, H ₂ O	88055	-	39147	-
Cadmium, HNO ₃	88056	45250	13813	14424
Calcium, HNO ₃	88057	-	13852	14407
Carbon, H ₂ O	-	-	13844	14389
Cerium, HNO ₃	30520	-	13815	14371
Cesium, HNO ₃	88058	-	13825	14425
Chromium, HCl	88059	-	13864	14408
Chromium, HNO ₃	-	45251	38728	38722
Cobalt, HNO ₃	88060	45252	13828	14390
Copper, HNO ₃	88061	45253	13867	14372
Dysprosium, HNO ₃	88062	-	13838	14426
Erbium, HNO ₃	88063	-	13877	14409
Europium, HNO ₃	88064	-	35753	35761
Gadolinium, HNO ₃	88065	-	13829	14373
Gallium, HNO ₃ /tr. HCl	88066	-	13869	14427
Germanium, HNO ₃ /tr. HF	88067	45254	13841	14410
Germanium, H ₂ O/tr. F-	-	-	42242	-
Gold, HCl	88068	-	13881	14392
Hafnium, HCl	88069	-	13843	14374
Holmium, HNO ₃	88070	45255	35756	35762
Indium, HNO ₃	88071	45256	13846	14411
Iridium, HCl	88072	-	35751	35752
Iron, HNO ₃	88073	-	13830	14375
Lanthanum, HNO ₃	88074	-	13870	14429
Lead, HNO ₃	88075	45257	13853	14412
Lithium, HNO ₃	88076	-	13821	14394
Lutetium, HNO ₃	89886	-	35765	35757
Magnesium, HNO ₃	88077	-	13861	14430
Manganese, HNO ₃	88078	45258	13826	14413
Mercury, HNO ₃	88079	45259	13865	14395
Molybdenum, HNO ₃ /tr. HF	35764	45260	35758	35766
Molybdenum, NH ₄ OH			38719	38726

Element, matrix	AAS Standard 1000 ppm	Plasma Standard 10 ppm	Plasma Standard 1000 ppm	Plasma Standard 10,000 ppm
Neodymium, HNO	88081	45281	13882	14431
Nickel, HNO ₃	88082	45261	13839	14414
Niobium, HF	88083	-	13831	14396
Niobium, H ₂ O/tr. F-	-	-	42244	42245
Osmium, HCl	42239	-	13871	-
Palladium, HCl	88085	-	13833	14432
Palladium, HNO ₃		-	44631	-
Palladium, H ₂ O			-	-
Phosphorus, HNO	89887	-	45270	45271
Platinum, HCl	88086	-	13827	14397
Potassium, HNO ₃	88087	-	13866	14379
Praseodymium, HNO	88088	-	13812	14433
Rhenium, HNO ₃	88089	-	13817	14416
Rhodium, HCl	88090	45320	35754	35763
Rubidium, HNO ₃	88091	-	13872	14380
Ruthenium, HCl	89117	-	35767	35773
Samarium, HNO ₃	88092	-	13854	14417
Scandium, HNO ₃	88093		35769	35755
Selenium, HNO ₃	88094	45263	13845	14381
Silicon, HNO ₃ /tr. HF	88095	-	13814	14435
Silicon, H ₂ O/tr. F-	-	-	38717	38723
Silver, HNO ₃	88096	45264	13849	14418
Sodium, HNO ₃	88097	-	13832	14400
Strontium, HNO ₃	88098	-	13874	14382
Sulfur, H ₂ O	22958	-	13842	14436
Tantalum, HF	89888	-	13840	14419
Tantalum, H ₂ O/tr. F-	-	-		
Tellurium, HCl	88099	-	13879	14401
Tellurium, HNO ₃	-	45265	44632	-
Terbium, HNO ₃	88110	45266	13860	14383
Thallium, HNO ₃	88111	-	13851	14437
Thulium, HNO ₃	89889	-	13824	14402
Tin, HCl	88112	-	13863	14384
Titanium, HNO ₃ /tr.	35771	45267	35768	35759
Titanium, H ₂ O/tr. F-	-	-	38720	38725
Tungsten, HNO ₃ /tr.	35760	-	35770	35772
Tungsten, H ₂ O	-	-	42248	42249
Vanadium, HNO ₃	88116	-	13850	14385
Ytterbium, HNO ₃	89890	-	13819	14439
Yttrium, HNO ₃	88117	45268	13855	14422
Zinc, HNO ₃	88118	45269	13835	14404
Zirconium, HCl	88119	-	13875	14386

pH Indicator



Molecular Sieve Selection Guide

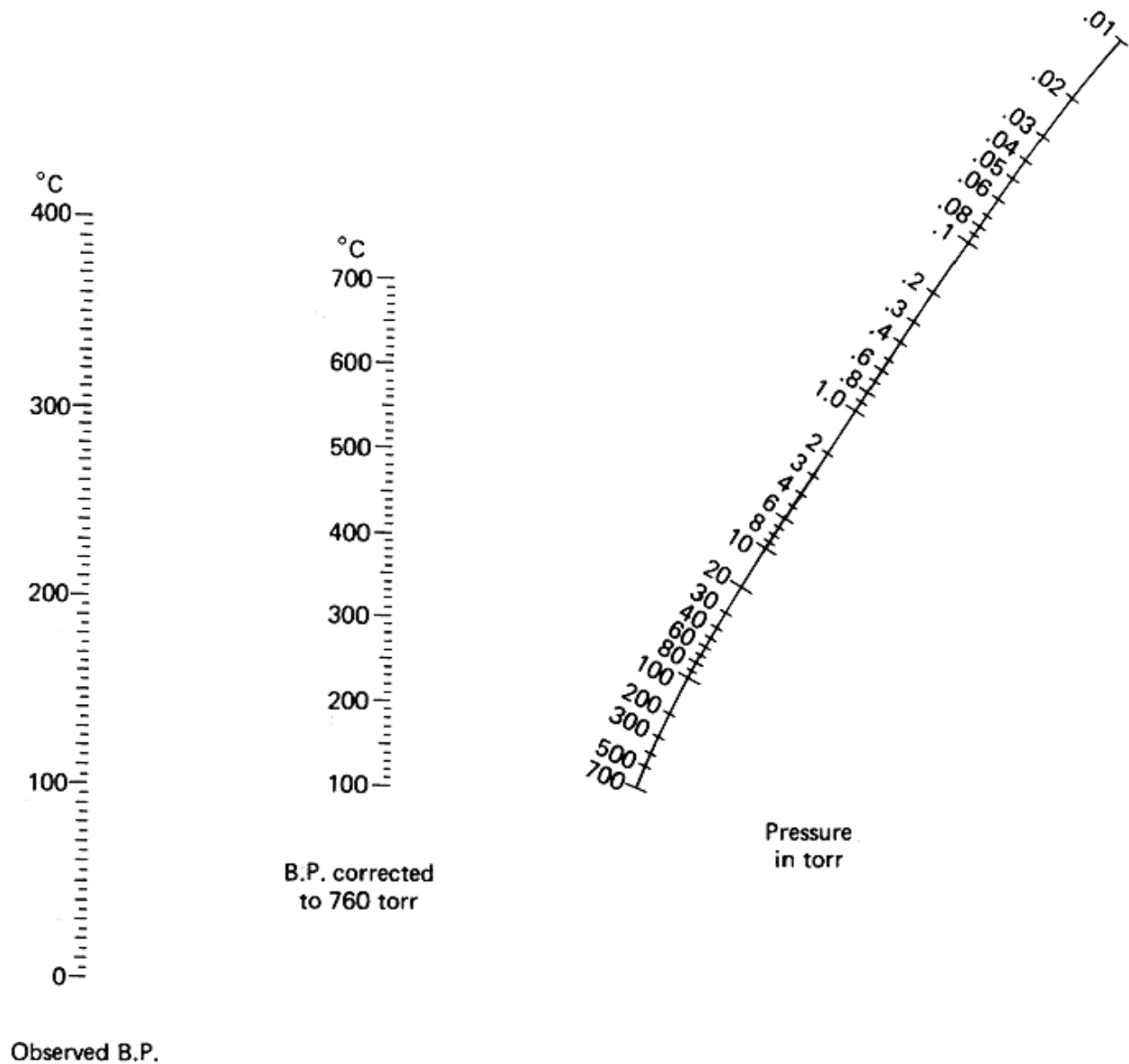
Basic Type	Nominal Pore - Diameter in Ångstroms	Form	Alfa Aesar Item Number	Bulk Density in g/ml	Equilibrium Water Adsorption Capacity % wt*	Equilibrium CO ₂ Adsorption Capacity % wt†	Crush Strength (N)	Heat of Adsorption (max) kJ/kg H ₂ O	Molecules Adsorbed‡	Molecules Excluded	Applications
3A	3	Powder	B21165	0.48	23			4200	Molecules with an effective diameter <3 Ångstroms, including water and ammonia	Molecules with an effective diameter >3 Ångstroms, e.g. ethane and methanol	The preferred adsorbent for the dehydration of unsaturated hydrocarbon streams such as cracked gas, propylene, butadiene and acetylene. Also used for drying polar liquids such as methanol and ethanol.
		0.4-0.8mm (0.02-0.03in) beads	L05383	0.71	20	1.5					
		1-2mm (0.04-0.08in) beads	L05335	0.71	20	1.5	31				
		3-5mm (0.12-0.20in) beads	L05359	0.71	20	1.5	80				
		1-2mm (0.04-0.08in) dia. pellets	87957	0.71	20	1.5	44				
		3-4mm (0.12-0.16in) dia. pellets	33530	0.71	20	1.5	88				
4A	4	Powder	A11535	0.48	26			4200	Molecules with an effective diameter <4 Ångstroms, including H ₂ S, CO ₂ , SO ₂ , ethanol, ethylene, ethane, and propylene	Molecules with an effective diameter >4 Ångstroms, e.g. n-propane	The preferred adsorbent for static dehydration in a closed gas or liquid system. Used as a static desiccant in household refrigeration systems; in packaging of drugs, electronic components and perishable chemicals; as a water scavenger in paint and plastic systems. In drying saturated hydrocarbon streams.
		0.4-0.8mm (0.02-0.03in) beads	L05512	0.75	21	1.5					
		1-2mm (0.04-0.08in) beads	L05454	0.75	21	1.5	31				
		3-5mm (0.12-0.20in) beads	L05466	0.72	21	1.5	80				
		1-2mm (0.04-0.08in) dia. pellets	87956	0.72	21	1.5	44				
				3-4mm (0.12-0.16in) dia. pellets	88120	0.72	21				
		-8+12 (ca 2mm) beads, with indicator	32256	0.72	21	1.5	31				
AW-500	5	3-4mm (0.12-0.16in) dia. pellets	47024	0.72	20	16	80	3400	Molecules with an effective diameter <5 Ångstroms, including n-butanol, n-butane, and n-propane up to n-docosane	Molecules with an effective diameter >5 Ångstroms, e.g. iso compounds and rings greater than C4	Used commercially to dry and purify process streams containing strong acid contaminants.
5A	5	3-5mm (0.12-0.20in) beads	L05722	0.72	22	16	35	4200	Molecules with an effective diameter <5 Ångstroms, including n-butanol, n-butane, and n-propane up to n-docosane	Molecules with an effective diameter >5 Ångstroms, e.g. iso compounds and rings greater than C4	Separates normal paraffins from branched-chain and cyclic hydrocarbons through a selective adsorption process
		1-2mm (0.04-0.08in) dia. pellets	87955	0.72	22	16	27				
		3-4mm (0.12-0.16in) dia. pellets	33551	0.72	22	16	53				
13X	10	Powder	A10378	0.60	33	25		4200	Molecules with an effective diameter <10 Ångstroms, including benzene, toluene, and di-n-butylamine	Molecules with an effective diameter >10 Ångstroms, e.g. tri-n-butylamine	Used for general gas drying, air plant feed purification (simultaneous removal of water and CO ₂) and liquid hydrocarbon and natural gas sweetening (H ₂ S mercaptan removal).
		1.6-2.5mm (0.063-0.098in) beads	B21109	0.64	26	13	36				
		3-5mm (0.12-0.20in) beads	L06085	0.64	26	13	80				
		1-2mm (0.04-0.08in) dia. pellets	87954	0.62	26	19	31				
				3-4mm (0.12-0.16in) dia. Pellets	33550	0.62	26				

*water:adsorbant; 1:100 wt%, 2.3 kPa at 25°C using activated adsorbent

†CO₂:adsorbant; 1:100 wt%, 33.3 kPa at 25°C using activated adsorbent

‡Each type adsorbs listed molecules plus those of preceding types.

Pressure-Temperature Nomograph



Glassy Carbon Specifications

Characteristic properties	Units	Type 1	Type 2
Bulk density	g/cm ³	1.54	1.42
Ash values acc. to DIN 51903	ppm	<100	<100
Maximum service temperature ¹ (under argon)	°C	1000	3000
Open porosity	%	0	0
Permeability coefficient (He gas)	cm ² /s	10 ⁻¹¹	10 ⁻⁹
Vickers hardness	HV1	340	230
Flexural strength ²	N/mm ²	210	260
Compressive strength ³	N/mm ²	580	480
Young's modulus ²	kN/mm ²	35	35
Coefficient of thermal expansion (20-200°C)	1/K	3.5 x 10 ⁻⁶	2.6 x 10 ⁻⁶
Thermal conductivity (30°C)	W/(Kxm)	4.6	6.3
¹ in air, rapid oxidation takes place above 500° ² 4-point bending test; geometry of specimen: circular rod, diameter 3mm, length 60mm ³ geometry of specimen: circular rod, diameter 7mm, length 10mm			

Typical Properties of High Purity Oxide Ceramics

Material	Units	Al-23	Al-24	Al-25	ZrO ₂ /Y ₂ O ₃	MgO
Principal Constituent		99.7% Al ₂ O ₃	99.7% Al ₂ O ₃	99.7% Al ₂ O ₃	90% *ZrO ₃	98%
Typical Minimum		99.5% Al ₂ O ₃	99.5% Al ₂ O ₃	99.5% Al ₂ O ₃	90%	98%
Apparent Density	g/cm ³	3.7-3.95	3.4-3.6	2.8-3.1	5.8	2.96
Main Grain Size	µm	10	40	70	20-30	-
Open Porosity	%	0	0-5	20-30	0	3-4
Average Pore Size	µm	-	5	5-20	-	-
Hardness (Knoop, 100g)	N/mm ² (MPa)	23000	-	-	-	-
Compressive Strength	N/mm ² (MPa)	3500	1000	300	2000	800
Bending Strength	N/mm ² (MPa)	300	150	70	250	40
Modulus of Elasticity	GPa	380	-	-	1.5	-
Resistance to Thermal Shock		good	very good	very good	-	-
Melting Point	°C	2030	2030	2030	-	-
Maximum Working Temperature	°C	1950	1950	1950	2000	2400
Specific Heat	J/kg K	900	-	-	550	-
Thermal Conductivity at 100°C	W/m K	30	-	-	2	50
Thermal Conductivity at 1000°C	W/m K	5	4	3	-	-
Coefficient of Linear Expansion between 0 and 1000°C	10 ⁻⁶ /K	8.5	8.5	8.5	10	16
Emissivity at 1000°C	%	21	-	-	-	-
Specific Electrical Resistance at: 20°C 500°C 1000°C 1500°C	Ohm-cm	>10 ¹⁴ 10 ¹⁰ 10 ⁷ 10 ⁴	- - - -	- - - -	- - - -	- - - -
Dielectric Constant at 10 MHz, 20°C		9.2	-	-	-	-
Dielectric Loss Factor at 10 MHz, 20°C		2x10 ⁻⁴	-	-	-	-
Electrical Breakdown Strength (dry-pressed and slip-cast parts)	kV eff/mm	22	-	-	-	-

* The balance is % Y₂O₃.

The details of these products and instruments and of their plants and processes are based on extensive research work and operational experience. These data are supplied verbally and in writing to the best of our knowledge and belief. This, however, does not exempt the user from verifying their own responsibility involved in their application. This also applies - particularly for shipments abroad - to safeguard third-party protective rights and applications, and methods of procedure not expressly specified by us in writing.

Our liability is thus limited in all cases to compensation in the same extent and scope as provided for quality deficiencies. In addition, our Technical Service is available for further advice and cooperation in the solving of manufacturing and application problems.

FEPA Grit Sizes

Millimeters	Microns*	Inches	100 % min Sieve	20% max Sieve	40% min Sieve	70% min Sieve	3% max Sieve	FEPA Grit
4.75	4750	0.189	5/16	3 1/2	4	4+5	6	F4
4	4000	0.159	0.265	4	5	5+6	7	F5
3.35	3350	0.133	3 1/2	5	6	6+7	8	F6
2.8	2800	0.111	4	6	7	7+8	10	F7
2.36	2360	0.094	5	7	8	8+10	12	F8
2	2000	0.079	6	8	10	10+12	14	F10
1.7	1700	0.068	7	10	12	12+14	16	F12
			100% min	20% Max	45% min	70% min	3% max thru	
1.4	1400	0.056	8	12	14	14+16	18	F14
1.18	1180	0.047	10	14	16	16+18	20	F16
1	1000	0.04	12	16	18	18+20	25	F20
0.85	850	0.034	14	18	20	20+25	30	F22
			100% min	25% Max	40% min	65% min	3% max thru	
0.71	710	0.028	16	20	25	25+30	35	F24
0.6	600	0.024	18	25	30	30+35	40	F30
0.5	500	0.02	20	30	35	35+40	45	F36
			100% min	30% max	40% min	65% min	3% max thru	
0.425	425	0.017	25	35	40	40+45	50	F40
0.355	355	0.014	30	40	45	45+50	60	F46
0.3	300	0.012	35	45	50	50+60	70	F54
0.25	250	0.01	40	50	60	60+70	80	F60
			100% min	25% max	40% min	65% min	3% max thru	
0.212	212	0.008	45	60	70	70+80	100	F70
0.18	180	0.007	50	70	80	80+100	120	F80
			100% min	20% max	40% min	65% min		
0.15	150	0.006	60	80	100	100+120	140	F90
0.125	125	0.005	70	100	120	120+140	200	F100
0.106	106	0.004	80	120	140	140+170	230	F120
			100% min	15% max	40% min	65% min	3% max thru	
0.075	75	0.003	100	140	200	200+230	325	F150
0.063	63	0.0025	120	170	200 + 230	200+230+270	-	F180
			100% min	15% max	40% min	60% min		
0.053	53	0.0021	140	200	230 + 270	230+270+325	-	F220

Metal Composition of Common Electroplating Salts

(estimates only)

Name	% Metal	Name	% Metal
Cobalt chloride	24.8	Palladium chloride	60.0
Cobalt sulfate	21.0	Palladium diaminodinitrite (P salt)	45.8
Copper(II) carbonate (basic)	57.5	Platinum chloride	45.7
Copper(II) chloride	24.8	Platinum diaminodinitrite (P salt)	60.8
Copper(I) cyanide	71.0	Potassium stannate	39.6
Copper(I) potassium cyanide	26.3	Rhodium chloride	39.1
Copper(I) sodium cyanide	26.3	Rhodium sulfate	20.8
Copper(II) sulfate	25.5	Silver chloride	75.2
Gold chloride	58.1	Silver cyanide	80.5
Gold cyanide	88.3	Silver nitrate	63.5
Gold potassium cyanide	68.3	Silver oxide	93.3
Gold sodium cyanide	72.5	Silver potassium cyanide	54.2
Iron(III) chloride (anhydrous)	34.5	Silver sodium cyanide	59.0
Iron(III) chloride	20.6	Silver sulfate	34.6
Iron(II) sulfate	20.1	Sodium stannate	44.5
Iron(II) chloride	28.1	Tin chloride	52.6
Iron(II) sulfate	20.1	Tin fluoborate	40.6
Lead carbonate (basic)	80.1	Tin sulfate	55.3
Lead acetate, trihydrate	54.6	Tungstic acid	73.6
Nickel acetate	33.2	Zinc carbonate	52.2
Nickel ammonium sulfate	14.9	Zinc chloride	48.0
Nickel carbonate (basic)	50.0	Zinc cyanide	55.7
Nickel chloride	24.7	Zinc fluoborate	27.3
Nickel cyanide	32.1	Zinc oxide	80.3
Nickel fluoborate	25.3	Zinc pyrophosphate	42.9
Nickel sulfamate	23.4	Zinc sulfate	22.7
Nickel sulfate	22.3	Zinc sulfate, anhydrous	40.4

Amino Acid Abbreviations

Amino Acid	3-Letter[108]	1-Letter[108]	Side-chain polarity[108]	Side-chain charge (pH 7.4)[108]	Hydropathy index[109]	Absorbance $\lambda_{\max}(\text{nm})$ [110]	ϵ at λ_{\max} ($\times 10^{-3}$ M $^{-1}$ cm $^{-1}$)[110]
Alanine	Ala	A	nonpolar	neutral	1.8		
Arginine	Arg	R	Basic polar	positive	-4.5		
Asparagine	Asn	N	polar	neutral	-3.5		
Aspartic acid	Asp	D	acidic polar	negative	-3.5		
Cysteine	Cys	C	nonpolar	neutral	2.5	250	0.3
Glutamic acid	Glu	E	acidic polar	negative	-3.5		
Glutamine	Gln	Q	polar	neutral	-3.5		
Glycine	Gly	G	nonpolar	neutral	-0.4		
Histidine	His	H	Basic polar	positive(10%) neutral(90%)	-3.2	211	5.9
Isoleucine	Ile	I	nonpolar	neutral	4.5		
Leucine	Leu	L	nonpolar	neutral	3.8		
Lysine	Lys	K	Basic polar	positive	-3.9		
Methionine	Met	M	nonpolar	neutral	1.9		
Phenylalanine	Phe	F	nonpolar	neutral	2.8	257, 206, 188	0.2, 9.3, 60.0
Proline	Pro	P	nonpolar	neutral	-1.6		
Serine	Ser	S	polar	neutral	-0.8		
Threonine	Thr	T	polar	neutral	-0.7		
Tryptophan	Trp	W	nonpolar	neutral	-0.9	280, 219	5.6, 47.0
Tyrosine	Tyr	Y	polar	neutral	-1.3	274, 222, 193	1.4, 8.0, 48.0
Valine	Val	V	nonpolar	neutral	4.2		

DNA Agarose Separation

Effective Range of Separation of DNA in Agarose Gels

<u>% Agarose (w/v)</u>	<u>Efficient Range of Separation of Linear DNA Molecules (kb)</u>
0.3	5-60
0.6	1-20
0.7	0.8-10
0.9	0.5-7
1.2	0.4-6
1.5	0.2-3
2	0.1-2

Nucleotide Properties

Nucleotide	Nucleotide triphosphate abbreviation	Molecular Weight (Free Acid)	λ_{max} (pH 7)	ϵ_{M} at λ_{max} (pH 7)
Adenosine	ATP	507.2	259	15,400
Cytidine	CTP	483.2	271	9,000
Guanosine	GTP	523.2	253	13,700
Uridine	UTP	484.2	262	10,000
Deoxyadenosine	dATP	491.2	260	15,100
Deoxycytidine	dCTP	467.2	270	9,100
Deoxyguanosine	dGTP	507.2	253	13,800*
Thymidine	dTTP	482.2	267	9,600

* ϵ_{M} value for deoxyguanosine monophosphate (dGMP)

The Genetic Code

Codon	Amino Acid	Codon	Amino Acid	Codon	Amino Acid	Codon	Amino Acid
UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys
UUC		UCC		UAC		UGC	
UUA	Leu	UCA		UAA	STOP	UGA	STOP
UUG		UCG		UAG		UGG	Trp
CUU	Leu	CCU	Pro	CAU	His	CGU	Arg
CUC		CCC		CAC		CGC	
CUA		CCA		CAA	Gln	CGA	
CUG		CCG		CAG		CGG	
AUU	Ile	ACU	Thr	AUU	Asn	AGU	Ser
AUC		ACC		AAC		AGC	
AUA		ACA		AAA	Lys	AGA	Arg
AUG	Met	ACG		AAG		AGG	
GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly
GUC		GCC		GAC		GGC	
GUA		GCA		GAA	Glu	GGA	
GUG		GCG		GAG		GGG	