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Chemistry Examination Data Book (revised April 2026)

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Periodic table of the elements																	
H 1 1.0080																	He 2 4.0026
Li 3 6.94	Be 4 9.0122	symbol atomic number abridged standard atomic weight										B 5 10.81	C 6 12.011	N 7 14.007	O 8 15.999	F 9 18.998	Ne 10 20.180
Na 11 22.990	Mg 12 24.305											Al 13 26.982	Si 14 28.085	P 15 30.974	S 16 32.06	Cl 17 35.45	Ar 18 39.95
K 19 39.098	Ca 20 40.078	Sc 21 44.956	Ti 22 47.867	V 23 50.942	Cr 24 51.996	Mn 25 54.938	Fe 26 55.845	Co 27 58.933	Ni 28 58.693	Cu 29 63.546	Zn 30 65.38	Ga 31 69.723	Ge 32 72.630	As 33 74.922	Se 34 78.971	Br 35 79.904	Kr 36 83.798
Rb 37 85.468	Sr 38 87.62	Y 39 88.906	Zr 40 91.224	Nb 41 92.906	Mo 42 95.95	Tc 43 [97]	Ru 44 101.07	Rh 45 102.91	Pd 46 106.42	Ag 47 107.87	Cd 48 112.41	In 49 114.82	Sn 50 118.71	Sb 51 121.76	Te 52 127.60	I 53 126.90	Xe 54 131.29
Cs 55 132.91	Ba 56 137.33	La* 57 138.91	Hf 72 178.49	Ta 73 180.95	W 74 183.84	Re 75 186.21	Os 76 190.23	Ir 77 192.22	Pt 78 195.08	Au 79 196.97	Hg 80 200.59	Tl 81 204.38	Pb 82 207.2	Bi 83 208.98	Po 84 [209]	At 85 [210]	Rn 86 [222]
Fr 87 [223]	Ra 88 [226]	Ac† 89 [227]	Rf 104 [267]	Db 105 [268]	Sg 106 [269]	Bh 107 [270]	Hs 108 [269]	Mt 109 [277]	Ds 110 [281]	Rg 111 [282]	Cn 112 [285]	Nh 113 [286]	Fl 114 [290]	Mc 115 [290]	Lv 116 [293]	Ts 117 [294]	Og 118 [294]

*Lanthanides	Ce 58 140.12	Pr 59 140.91	Nd 60 144.24	Pm 61 [145]	Sm 62 150.36	Eu 63 151.96	Gd 64 157.25	Tb 65 158.93	Dy 66 162.50	Ho 67 164.93	Er 68 167.26	Tm 69 168.93	Yb 70 173.05	Lu 71 174.97
†Actinides	Th 90 232.04	Pa 91 231.04	U 92 238.03	Np 93 [237]	Pu 94 [244]	Am 95 [243]	Cm 96 [247]	Bk 97 [247]	Cf 98 [251]	Es 99 [252]	Fm 100 [257]	Md 101 [258]	No 102 [259]	Lr 103 [262]

Data from IUPAC Periodic Table of the Elements 2022 Edition https://iupac.org/wp-content/uploads/2022/05/IUPAC_Periodic_Table_150-04May22.jpg

Constants			SI prefixes					
Name	Symbol and definition	Value (Uncertainty)	Name	Symbol	Factor	Name	Symbol	Factor
	π	3.14159265358979...	deca	da	10^1	deci	d	10^{-1}
	e	2.718281828459...	hecto	h	10^2	centi	c	10^{-2}
	$\ln 10 = 1/\log_{10} e$	2.302585092994...	kilo	k	10^3	milli	m	10^{-3}
Speed of light	c	$2.99792458 \times 10^8 \text{ m s}^{-1}$	mega	M	10^6	micro	μ	10^{-6}
Planck constant	h	$6.62607015 \times 10^{-34} \text{ J s}$	giga	G	10^9	nano	n	10^{-9}
Reduced Planck constant	$\hbar = h/2\pi$	$1.054571817 \dots \times 10^{-34} \text{ J s}$	tera	T	10^{12}	pico	p	10^{-12}
Avogadro constant	N_A	$6.02214076 \times 10^{23} \text{ mol}^{-1}$	peta	P	10^{15}	femto	f	10^{-15}
Elementary charge	e	$1.602176634 \times 10^{-19} \text{ C}$	exa	E	10^{18}	atto	a	10^{-18}
Electron mass	m_e	$9.1093837139(28) \times 10^{-31} \text{ kg}$	zetta	Z	10^{21}	zepto	z	10^{-21}
Atomic mass unit	u	$1.66053906892(52) \times 10^{-27} \text{ kg}$	yotta	Y	10^{24}	yocto	y	10^{-24}
Proton mass	m_p	$1.67262192595(52) \times 10^{-27} \text{ kg}$	Other conversion factors					
Neutron mass	m_n	$1.67492750056(85) \times 10^{-27} \text{ kg}$	Length		$\text{\AA}$			10^{-10} m
Faraday constant	$F = N_A e$	$9.648533212 \dots \times 10^4 \text{ C mol}^{-1}$	Energy		cal			4.184 J
Boltzmann constant	k_B	$1.380649 \times 10^{-23} \text{ J K}^{-1}$	Pressure		1 atm = 760 Torr			101 325 Pa
Molar gas constant	$R = N_A k_B$	$8.314462618 \text{ J mol}^{-1} \text{ K}^{-1}$			1 Torr = 1 mmHg			133.3224 Pa
Vacuum magnetic permeability	μ_0	$1.25663706127(20) \times 10^{-6} \text{ N A}^{-2}$			1 bar			10^5 Pa
Vacuum electric permittivity	$\varepsilon_0 = 1/(\mu_0 c^2)$	$8.8541878188(14) \times 10^{-12} \text{ F m}^{-1}$	Radioactivity		becquerel, Bq			1 s^{-1}
Bohr magneton	$\mu_B = e\hbar/2m_e$	$9.2740100657(29) \times 10^{-24} \text{ J T}^{-1}$			curie, Ci			$3.7 \times 10^{10} \text{ Bq}$
Nuclear magneton	$\mu_N = e\hbar/2m_p$	$5.0507837393(16) \times 10^{-27} \text{ J T}^{-1}$	Charge		esu			$3.33564 \times 10^{-10} \text{ C}$
Stefan–Boltzmann constant	$\sigma = 2\pi^5 k^4/15h^3 c^2$	$5.670374419 \dots \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	Dipole moment		debye			10^{-18} esu cm
Bohr radius	$a_0 = 4\pi\varepsilon_0 \hbar^2/m_e e^2$	$5.29177210544(82) \times 10^{-11} \text{ m}$			debye			$3.33564 \times 10^{-30} \text{ C m}$
Hartree energy	$E_h = e^2/4\pi\varepsilon_0 a_0$	$4.3597447222060(48) \times 10^{-18} \text{ J}$			a.u. = ea_0			$8.4783536198(13) \times 10^{-30} \text{ C m}$
Fine-structure constant	$\alpha = e^2/4\pi\varepsilon_0 \hbar c$	$7.2973525643(11) \times 10^{-3}$	Temperature		$^\circ\text{C}$			$t/^\circ\text{C} = T/\text{K} - 273.15$
	α^{-1}	137.035999177(21)	Parts per million	ppm				1×10^{-6}
Rydberg constant	$R_\infty = m_e e^4/8\varepsilon_0^2 \hbar^3 c$	$1.0973731568157(12) \times 10^7 \text{ m}^{-1}$	Parts per billion	ppb				1×10^{-9}
Rydberg energy	$hcR_\infty = m_e e^4/8\varepsilon_0^2 \hbar^2$	$2.1798723611030(24) \times 10^{-18} \text{ J}$						
Newtonian constant of gravitation	G	$6.67430(15) \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$						
Electron g factor	g_{e-}	$-2.00231930436092(36)$						

CODATA recommended values, 2022 <https://physics.nist.gov/cuu/Constants/index.html>
The estimated standard uncertainty, in parentheses after the value, applies to the least significant digits of the value.

Energy conversion factors

	J	kJ mol ⁻¹	cm ⁻¹	K
1 J	1	6.0221×10^{20}	5.0341×10^{22}	7.2430×10^{22}
1 E_h	4.35974×10^{-18}	2625.5	219 475	315 775
1 eV	1.60218×10^{-19}	96.485	8065.54	11 605
1 kJ mol ⁻¹	1.66054×10^{-21}	1	83.5935	120.27
1 cm ⁻¹	1.98645×10^{-23}	0.011963	1	1.4388
1 K	1.38065×10^{-23}	8.3145×10^{-3}	0.69503	1
1 Hz	6.62607×10^{-34}	3.9903×10^{-13}	3.3356×10^{-11}	4.7992×10^{-11}

Note: the energy of a photon with reciprocal wavelength (wavenumber) $1/\lambda$ and frequency ν is $hc/\lambda = h\nu$. The energy corresponding to a temperature T is $k_B T$.

Greek alphabet

A	α	alpha	H	η	eta	N	ν	nu	T	τ	tau
B	β	beta	Θ	θ, ϑ	theta	Ξ	ξ	xi	Υ	υ	upsilon
Γ	γ	gamma	I	ι	iota	O	o	omicron	Φ	ϕ, φ	phi
Δ	δ	delta	K	κ	kappa	Π	π	pi	X	χ	chi
E	ε, ϵ	epsilon	Λ	λ	lambda	P	ρ	rho	Ψ	ψ	psi
Z	ζ	zeta	M	μ	mu	Σ	σ, ς	sigma	Ω	ω	omega

Series

Arithmetic progression

$$S_n = a + (a + d) + (a + 2d) + \cdots + (a + [n - 1]d) = \frac{n(2a + [n - 1]d)}{2}.$$

Geometric progression

$$S_n = a + az + az^2 + \cdots + az^{n-1} = a \frac{1 - z^n}{1 - z}. \quad S_\infty = \frac{a}{1 - z} \quad \text{when } |z| < 1.$$

Power series

$$f(x) = f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \dots$$

$$e^z = 1 + z + \frac{z^2}{2!} + \frac{z^3}{3!} + \dots$$

$$\cos z = \frac{e^{iz} + e^{-iz}}{2} = 1 - \frac{z^2}{2!} + \frac{z^4}{4!} - \frac{z^6}{6!} + \dots$$

$$\sin z = \frac{e^{iz} - e^{-iz}}{2i} = z - \frac{z^3}{3!} + \frac{z^5}{5!} - \frac{z^7}{7!} + \dots$$

$$\cosh z = \frac{e^z + e^{-z}}{2} = 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \frac{z^6}{6!} + \dots$$

$$\sinh z = \frac{e^z - e^{-z}}{2} = z + \frac{z^3}{3!} + \frac{z^5}{5!} + \frac{z^7}{7!} + \dots$$

$$(1+z)^p = 1 + pz + \frac{p(p-1)}{2!}z^2 + \frac{p(p-1)(p-2)}{3!}z^3 + \dots, \quad |z| < 1$$

$$\ln(1+z) = z - \frac{z^2}{2} + \frac{z^3}{3} - \dots, \quad |z| < 1$$

Stirling's formula

$$\ln n! \approx n \ln n - n \quad \text{for large } n$$

Determinants

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc$$

In general,

$$\det(\mathbf{A}) = \sum_j A_{ij} M_{ij} (-1)^{i+j} \quad (i \text{ fixed at any value}),$$

where M_{ij} is the determinant of the matrix obtained by deleting the i th row and the j th column of $\mathbf{A}$. For example,

$$\begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix} = a_{11} \begin{vmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \end{vmatrix} - a_{12} \begin{vmatrix} a_{21} & a_{23} \\ a_{31} & a_{33} \end{vmatrix} + a_{13} \begin{vmatrix} a_{21} & a_{22} \\ a_{31} & a_{32} \end{vmatrix} \\ = a_{11}a_{22}a_{33} - a_{11}a_{23}a_{32} + a_{12}a_{23}a_{31} - a_{12}a_{21}a_{33} + a_{13}a_{21}a_{32} - a_{13}a_{22}a_{31}.$$

Multinomial examples

Binomial theorem

$$(x + y)^n = \sum_{k=0}^n \binom{n}{k} x^{n-k} y^k,$$

where the binomial coefficients are given by

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}.$$

Trinomial theorem

$$(x_1 + x_2 + x_3)^n = \sum_{k=0}^n \sum_{l=0}^{n-k} \frac{n!}{k!l!(n-k-l)!} x_1^k x_2^l x_3^{n-k-l}$$

Double factorial

The double factorial of n is the product of all positive integers up to n that have the same parity.

$$n!! = \begin{cases} 1 \times 3 \times 5 \times \dots \times n & \text{odd } n \\ 2 \times 4 \times 6 \times \dots \times n & \text{even } n \end{cases}.$$

Integrals

$$\int_{-\infty}^{\infty} e^{-ax^2} dx = \sqrt{\pi/a}, \quad (a > 0)$$

$$\int_{-\infty}^{\infty} x^{2n} e^{-ax^2} dx = (2n-1)!! \frac{\sqrt{\pi/a}}{(2a)^n} \quad (n \geq 1; a > 0)$$

$$\int_0^{\infty} x^{2n-1} e^{-ax^2} dx = \frac{(n-1)!}{2a^n} \quad (n \geq 1; a > 0)$$

$$\int_0^{\infty} x^n e^{-ax} dx = \frac{n!}{a^{n+1}} \quad (n \geq 0; a > 0)$$

$$\int_0^{\pi/2} \sin^m \theta \cos^n \theta d\theta = \frac{(m-1)!!(n-1)!!}{(m+n)!!} \times C,$$

where $C = \pi/2$ if m and n are both *even*, and $C = 1$ otherwise, e.g.:

$$\int_0^{\pi/2} \sin \theta \cos^3 \theta d\theta = \frac{2}{4 \times 2} = \frac{1}{4}; \quad \int_0^{\pi/2} \sin^2 \theta \cos^2 \theta d\theta = \frac{1 \times 1}{4 \times 2} \frac{\pi}{2} = \frac{\pi}{16}.$$

Integration by parts

$$\int_a^b u \frac{dv}{dx} dx = [uv]_a^b - \int_a^b \frac{du}{dx} v dx$$

Trigonometrical formulae

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$2 \cos A \cos B = \cos(A+B) + \cos(A-B)$$

$$2 \sin A \sin B = \cos(A-B) - \cos(A+B)$$

$$2 \sin A \cos B = \sin(A+B) + \sin(A-B)$$

$$\sin 2A + \sin 2B = 2 \sin(A+B) \cos(A-B)$$

$$\sin 2A - \sin 2B = 2 \cos(A+B) \sin(A-B)$$

$$\cos 2A + \cos 2B = 2 \cos(A+B) \cos(A-B)$$

$$\cos 2A - \cos 2B = -2 \sin(A+B) \sin(A-B)$$

$$\operatorname{arsinh} A = \ln(A + \sqrt{A^2 + 1})$$

$$\operatorname{arcosh} A = \ln(A \pm \sqrt{A^2 - 1})$$

$$\operatorname{artanh} A = \frac{1}{2} \ln \frac{1+A}{1-A}$$

Cosine formula

$$a^2 = b^2 + c^2 - 2bc \cos A$$

Spherical polar coordinates

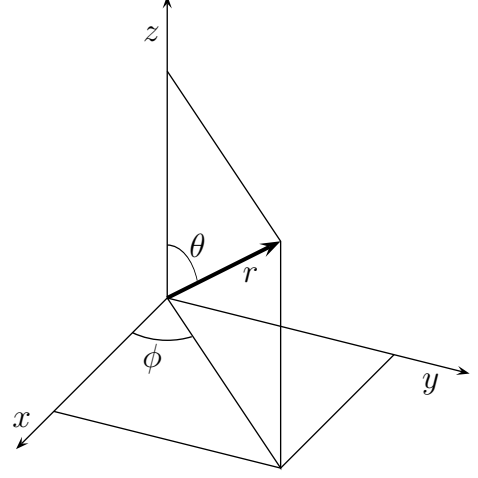
Relationship with Cartesian coordinates

$$\begin{aligned} x &= r \sin \theta \cos \phi & r &= \sqrt{x^2 + y^2 + z^2} \\ y &= r \sin \theta \sin \phi & \theta &= \arccos(z/r) \\ z &= r \cos \theta & \phi &= \arctan(y/x) \end{aligned}$$

These definitions do not take into account the quadrant of the position vector.

Integration

$$\int \dots dV = \int_{r=0}^{\infty} \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} \dots r^2 \sin \theta dr d\theta d\phi$$



Selected spherical harmonics, Y_{J,M_J}

$$\begin{aligned} Y_{0,0}(\theta, \phi) &= \frac{1}{2} \sqrt{\frac{1}{\pi}} \\ Y_{1,0}(\theta, \phi) &= \frac{1}{2} \sqrt{\frac{3}{\pi}} \cos \theta = \frac{1}{2} \sqrt{\frac{3}{\pi}} \frac{z}{r} \\ Y_{1,\pm 1}(\theta, \phi) &= \mp \frac{1}{2} \sqrt{\frac{3}{2\pi}} e^{\pm i\phi} \sin \theta = \mp \frac{1}{2} \sqrt{\frac{3}{2\pi}} \frac{x \pm iy}{r} \\ Y_{2,0}(\theta, \phi) &= \frac{1}{4} \sqrt{\frac{5}{\pi}} (3 \cos^2 \theta - 1) = \frac{1}{4} \sqrt{\frac{5}{\pi}} \frac{(3z^2 - r^2)}{r^2} \\ Y_{2,\pm 1}(\theta, \phi) &= \mp \frac{1}{2} \sqrt{\frac{15}{2\pi}} e^{\pm i\phi} \sin \theta \cos \theta = \mp \frac{1}{2} \sqrt{\frac{15}{2\pi}} \frac{(x \pm iy) z}{r^2} \\ Y_{2,\pm 2}(\theta, \phi) &= \frac{1}{4} \sqrt{\frac{15}{2\pi}} e^{\pm 2i\phi} \sin^2 \theta = \frac{1}{4} \sqrt{\frac{15}{2\pi}} \frac{(x \pm iy)^2}{r^2} \end{aligned}$$

Angular momentum ladder operators

$$\hat{J}_{\pm} \equiv \hat{J}_x \pm i\hat{J}_y; \quad \hat{J}_{\pm}|J, M\rangle = \sqrt{J(J+1) - M(M \pm 1)}|J, M \pm 1\rangle$$

Differentiation

Euler's cyclic chain rule

$$\left(\frac{\partial x}{\partial y} \right)_z \left(\frac{\partial y}{\partial z} \right)_x \left(\frac{\partial z}{\partial x} \right)_y = -1$$

l'Hôpital's rule

$$\lim_{x \rightarrow a} \frac{f(x)}{g(x)} = \lim_{x \rightarrow a} \frac{f'(x)}{g'(x)} \quad \text{if } \lim_{x \rightarrow a} f(x) = \lim_{x \rightarrow a} g(x) \in \{0, \pm\infty\}$$

Gradient

$$\begin{aligned} \nabla f &= \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right) \cdot (\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{z}}) \\ &= \left(\frac{\partial f}{\partial r}, \frac{1}{r} \frac{\partial f}{\partial \theta}, \frac{1}{r \sin \theta} \frac{\partial f}{\partial \phi} \right) \cdot (\hat{\mathbf{r}}, \hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\phi}}) \end{aligned}$$

Divergence

$$\begin{aligned} \nabla \cdot \mathbf{A} &= \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \\ &= \frac{1}{r^2} \frac{\partial}{\partial r} r^2 A_r + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} A_\theta \sin \theta + \frac{1}{r \sin \theta} \frac{\partial A_\phi}{\partial \phi} \end{aligned}$$

Curl

$$\begin{aligned} \nabla \times \mathbf{A} &= \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}, \frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}, \frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y} \right) \cdot (\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{z}}) \\ &= \left(\frac{1}{r \sin \theta} \left(\frac{\partial}{\partial \theta} A_\phi \sin \theta - \frac{\partial A_\theta}{\partial \phi} \right), \frac{1}{r} \left(\frac{1}{\sin \theta} \frac{\partial A_r}{\partial \phi} - \frac{\partial}{\partial r} r A_\phi \right), \frac{1}{r} \left(\frac{\partial}{\partial r} r A_\theta - \frac{\partial A_r}{\partial \theta} \right) \right) \\ &\quad \cdot (\hat{\mathbf{r}}, \hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\phi}}) \end{aligned}$$

Laplacian

$$\begin{aligned} \nabla^2 f &= \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2} \\ &= \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial f}{\partial r} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 f}{\partial \phi^2} \end{aligned}$$

Character tables for some important symmetry groups

C_i	E	i	
A_g	1	1	$R_x; R_y; R_z \quad x^2; y^2; z^2; xy; xz; yz$
A_u	1	-1	$x; y; z$

C_s	E	σ_h	
A'	1	1	$x; y \quad R_z \quad x^2; y^2; z^2; xy$
A''	1	-1	$z \quad R_x; R_y \quad xz; yz$

C_2	E	C_2^z	
A	1	1	$z \quad R_z \quad x^2; y^2; z^2; xy$
B	1	-1	$x; y \quad R_x; R_y \quad xz; yz$

C_{2v}	E	C_2^z	σ^{xz}	σ^{yz}	
A_1	1	1	1	1	$z \quad x^2; y^2; z^2$
A_2	1	1	-1	-1	$R_z \quad xy$
B_1	1	-1	1	-1	$x \quad R_y \quad xz$
B_2	1	-1	-1	1	$y \quad R_x \quad yz$

C_{2h}	E	C_2^z	i	σ^{xy}	
A_g	1	1	1	1	$R_z \quad x^2; y^2; z^2; xy$
B_g	1	-1	1	-1	$R_x; R_y \quad xz; yz$
A_u	1	1	-1	-1	z
B_u	1	-1	-1	1	$x; y$

D_2	E	C_2^z	C_2^y	C_2^x	
A	1	1	1	1	$x^2; y^2; z^2$
B_1	1	1	-1	-1	$z \quad R_z \quad xy$
B_2	1	-1	1	-1	$y \quad R_y \quad xz$
B_3	1	-1	-1	1	$x \quad R_x \quad yz$

D_{2d}	E	$2S_4$	C_2^z	$2C_2'$	$2\sigma_d$	
A_1	1	1	1	1	1	$x^2 + y^2; z^2$
A_2	1	1	1	-1	-1	R_z
B_1	1	-1	1	1	-1	$x^2 - y^2$
B_2	1	-1	1	-1	1	$z \quad xy$
E	2	0	-2	0	0	$(x, y) \quad (R_x, R_y) \quad (xz, yz)$

D_{2h}	E	C_2^z	C_2^y	C_2^x	i	σ^{xy}	σ^{xz}	σ^{yz}	
A_g	1	1	1	1	1	1	1	1	$x^2; y^2; z^2$
B_{1g}	1	1	-1	-1	1	1	-1	-1	$R_z \quad xy$
B_{2g}	1	-1	1	-1	1	-1	1	-1	$R_y \quad xz$
B_{3g}	1	-1	-1	1	1	-1	-1	1	$R_x \quad yz$
A_u	1	1	1	1	-1	-1	-1	-1	
B_{1u}	1	1	-1	-1	-1	-1	1	1	z
B_{2u}	1	-1	1	-1	-1	1	-1	1	y
B_{3u}	1	-1	-1	1	-1	1	1	-1	x

C_3	E	C_3	C_3^2	$\omega = \exp(2\pi i/3)$		
A	1	1	1	z	R_z	$x^2 + y^2; z^2$
$E \left\{ \right.$	1	ω	ω^2	$x - iy$	$R_x - iR_y$	$xz - iz; x^2 + 2ixy - y^2$
	1	ω^2	ω	$x + iy$	$R_x + iR_y$	$xz + iz; x^2 - 2ixy - y^2$

C_{3v}	E	$2C_3^z$	$3\sigma_v$			
A_1	1	1	1	z		$x^2 + y^2; z^2$
A_2	1	1	-1		R_z	
E	2	-1	0	(x, y)	(R_x, R_y)	$(xz, yz); (x^2 - y^2, 2xy)$

D_3	E	$2C_3^z$	$3C_2$			
A_1	1	1	1			$x^2 + y^2; z^2$
A_2	1	1	-1	z	R_z	
E	2	-1	0	(x, y)	(R_x, R_y)	$(xz, yz); (x^2 - y^2, 2xy)$

D_{3d}	E	$2C_3$	$3C_2$	i	$2S_6$	$3\sigma_d$	
A_{1g}	1	1	1	1	1	1	$x^2 + y^2; z^2$
A_{2g}	1	1	-1	1	1	-1	R_z
E_g	2	-1	0	2	-1	0	$(R_x, R_y) \quad (xz, yz); (x^2 - y^2, 2xy)$
A_{1u}	1	1	1	-1	-1	-1	
A_{2u}	1	1	-1	-1	-1	1	z
E_u	2	-1	0	-2	1	0	(x, y)

D_{3h}	E	$2C_3$	$3C_2$	σ_h	$2S_3$	$3\sigma_v$	
A'_1	1	1	1	1	1	1	$x^2 + y^2; z^2$
A'_2	1	1	-1	1	1	-1	R_z
E'	2	-1	0	2	-1	0	$(x, y) \quad (x^2 - y^2, 2xy)$
A''_1	1	1	1	-1	-1	-1	
A''_2	1	1	-1	-1	-1	1	z
E''	2	-1	0	-2	1	0	$(R_x, R_y) \quad (xz, yz)$

C_{4v}	E	$2C_4$	C_4^2	$2\sigma_v$	$2\sigma_d$	
A_1	1	1	1	1	1	$z \quad x^2 + y^2; z^2$
A_2	1	1	1	-1	-1	R_z
B_1	1	-1	1	1	-1	$x^2 - y^2$
B_2	1	-1	1	-1	1	xy
E	2	0	-2	0	0	$(x, y) \quad (R_x, R_y) \quad (xz, yz)$

Note: The σ_v planes in C_{4v} coincide with the xz and yz planes.

D_4	E	$2C_4$	C_4^2	$2C_2$	$2C_2'$	
A ₁	1	1	1	1	1	z R_z (x, y) (R_x, R_y)
A ₂	1	1	1	-1	-1	
B ₁	1	-1	1	1	-1	
B ₂	1	-1	1	-1	1	
E	2	0	-2	0	0	

D_{4d}	E	$2S_8$	$2C_4$	$2S_8^3$	C_4^2	$4C_2$	$4\sigma_d$	
A ₁	1	1	1	1	1	1	1	R_z z (x, y)
A ₂	1	1	1	1	1	-1	-1	
B ₁	1	-1	1	-1	1	1	-1	
B ₂	1	-1	1	-1	1	-1	1	
E ₁	2	$\sqrt{2}$	0	$-\sqrt{2}$	-2	0	0	
E ₂	2	0	-2	0	2	0	0	$(x^2 - y^2, 2xy)$ (xz, yz)
E ₃	2	$-\sqrt{2}$	0	$\sqrt{2}$	-2	0	0	

D_{4h}	E	$2C_4$	C_4^2	$2C_2$	$2C_2'$	i	$2S_4$	σ_h	$2\sigma_v$	$2\sigma_d$	
A _{1g}	1	1	1	1	1	1	1	1	1	1	R_z (R_x, R_y)
A _{2g}	1	1	1	-1	-1	1	1	1	-1	-1	
B _{1g}	1	-1	1	1	-1	1	-1	1	1	-1	
B _{2g}	1	-1	1	-1	1	1	-1	1	-1	1	
E _g	2	0	-2	0	0	2	0	-2	0	0	
A _{1u}	1	1	1	1	1	-1	-1	-1	-1	-1	z (x, y)
A _{2u}	1	1	1	-1	-1	-1	-1	-1	1	1	
B _{1u}	1	-1	1	1	-1	-1	1	-1	-1	1	
B _{2u}	1	-1	1	-1	1	-1	1	-1	1	-1	
E _u	2	0	-2	0	0	-2	0	2	0	0	

Note: The C_2 axes in D_{4h} coincide with the x and y axes, and the σ_v planes with the xz and yz planes.

Note that the quantities $\eta_{\pm} \equiv \frac{1}{2}(\sqrt{5} \pm 1)$ satisfy $\eta_{\pm}^2 = 1 \pm \eta_{\pm}$ and $\eta_+ \eta_- = 1$.

C_{5v}	E	$2C_5$	$2C_5^2$	$5\sigma_v$	$\eta_{\pm} = \frac{1}{2}(\sqrt{5} \pm 1)$
A ₁	1	1	1	1	z R_z (x, y) (R_x, R_y)
A ₂	1	1	1	-1	
E ₁	2	η_-	$-\eta_+$	0	
E ₂	2	$-\eta_+$	η_-	0	

D_5	E	$2C_5$	$2C_5^2$	$5C_2$	$\eta_{\pm} = \frac{1}{2}(\sqrt{5} \pm 1)$
A ₁	1	1	1	1	z R_z (x, y) (R_x, R_y)
A ₂	1	1	1	-1	
E ₁	2	η_-	$-\eta_+$	0	
E ₂	2	$-\eta_+$	η_-	0	

D_{5d}	E	$2C_5$	$2C_5^2$	$5C_2$	i	$2S_{10}^3$	$2S_{10}$	$5\sigma_d$	$\eta_{\pm} = \frac{1}{2}(\sqrt{5} \pm 1)$
A _{1g}	1	1	1	1	1	1	1	1	R_z (R_x, R_y)
A _{2g}	1	1	1	-1	1	1	1	-1	
E _{1g}	2	η_-	$-\eta_+$	0	2	η_-	$-\eta_+$	0	
E _{2g}	2	$-\eta_+$	η_-	0	2	$-\eta_+$	η_-	0	
A _{1u}	1	1	1	1	-1	-1	-1	-1	
A _{2u}	1	1	1	-1	-1	-1	-1	1	z (x, y)
E _{1u}	2	η_-	$-\eta_+$	0	-2	$-\eta_-$	η_+	0	
E _{2u}	2	$-\eta_+$	η_-	0	-2	η_+	$-\eta_-$	0	

D_{5h}	E	$2C_5$	$2C_5^2$	$5C_2$	σ_h	$2S_5$	$2S_5^3$	$5\sigma_v$	$\eta_{\pm} = \frac{1}{2}(\sqrt{5} \pm 1)$		
A_1'	1	1	1	1	1	1	1	1	(x, y)	R_z	$x^2 + y^2; z^2$
A_2'	1	1	1	-1	1	1	1	-1			
E_1'	2	η_-	$-\eta_+$	0	2	η_-	$-\eta_+$	0			
E_2'	2	$-\eta_+$	η_-	0	2	$-\eta_+$	η_-	0			
A_1''	1	1	1	1	-1	-1	-1	-1	z	(R_x, R_y)	(xz, yz)
A_2''	1	1	1	-1	-1	-1	-1	1			
E_1''	2	η_-	$-\eta_+$	0	-2	$-\eta_-$	η_+	0			
E_2''	2	$-\eta_+$	η_-	0	-2	η_+	$-\eta_-$	0			

C_{6v}	E	$2C_6$	$2C_6^2$	C_6^3	$3\sigma_v$	$3\sigma_d$	
A_1	1	1	1	1	1	1	z R_z $x^2 + y^2; z^2$
A_2	1	1	1	1	-1	-1	
B_1	1	-1	1	-1	1	-1	
B_2	1	-1	1	-1	-1	1	(x, y) (R_x, R_y) (xz, yz) $(x^2 - y^2, 2xy)$
E_1	2	1	-1	-2	0	0	
E_2	2	-1	-1	2	0	0	

D_6	E	$2C_6$	$2C_6^2$	C_6^3	$3C_2$	$3C_2'$			
A_1	1	1	1	1	1	1	z	R_z	$x^2 + y^2; z^2$
A_2	1	1	1	1	-1	-1			
B_1	1	-1	1	-1	1	-1			
B_2	1	-1	1	-1	-1	1	(x, y)	(R_x, R_y)	(xz, yz) $(x^2 - y^2, 2xy)$
E_1	2	1	-1	-2	0	0			
E_2	2	-1	-1	2	0	0			

D_{6h}	E	$2C_6$	$2C_6^2$	C_6^3	$3C_2$	$3C_2'$	i	$2S_3$	$2S_6$	σ_h	$3\sigma_d$	$3\sigma_v$		
A _{1g}	1	1	1	1	1	1	1	1	1	1	1	1	R_z	$x^2 + y^2; z^2$
A _{2g}	1	1	1	1	-1	-1	1	1	1	1	-1	-1		
B _{1g}	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1		
B _{2g}	1	-1	1	-1	-1	1	1	-1	1	-1	-1	1	(R_x, R_y)	(xz, yz) $(x^2 - y^2, 2xy)$
E _{1g}	2	1	-1	-2	0	0	2	1	-1	-2	0	0		
E _{2g}	2	-1	-1	2	0	0	2	-1	-1	2	0	0		
A _{1u}	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	z	
A _{2u}	1	1	1	1	-1	-1	-1	-1	-1	-1	1	1		
B _{1u}	1	-1	1	-1	1	-1	-1	1	-1	1	-1	1		
B _{2u}	1	-1	1	-1	-1	1	-1	1	-1	1	1	-1	(x, y)	
E _{1u}	2	1	-1	-2	0	0	-2	-1	1	2	0	0		
E _{2u}	2	-1	-1	2	0	0	-2	1	1	-2	0	0		

T	E	$4C_3$	$4C_3^2$	$3C_2$	$\omega = \exp(2\pi i/3)$		
A	1	1	1	1	$x^2 + y^2 + z^2$		
E {	1	ω	ω^2	1	$z^2 + \omega^2 x^2 + \omega y^2$		
	1	ω^2	ω	1	$z^2 + \omega x^2 + \omega^2 y^2$		
T	3	0	0	-1	(x, y, z)	(R_x, R_y, R_z)	(yz, xz, xy)

T_d	E	$8C_3$	$3C_2$	$6S_4$	$6\sigma_d$		
A ₁	1	1	1	1	1	$x^2 + y^2 + z^2$	
A ₂	1	1	1	-1	-1		
E	2	-1	2	0	0	$((2z^2 - x^2 - y^2), \sqrt{3}(x^2 - y^2))$	
T ₁	3	0	-1	1	-1	(R_x, R_y, R_z)	
T ₂	3	0	-1	-1	1	(x, y, z)	(yz, xz, xy)

O	E	$6C_4$	$3C_4^2$	$8C_3$	$6C_2$		
A ₁	1	1	1	1	1	$x^2 + y^2 + z^2$	
A ₂	1	-1	1	1	-1		
E	2	0	2	-1	0	$((2z^2 - x^2 - y^2), \sqrt{3}(x^2 - y^2))$	
T ₁	3	1	-1	0	-1	(x, y, z)	(R_x, R_y, R_z)
T ₂	3	-1	-1	0	1	(xz, xy, yz)	

O_h	E	$8C_3$	$6C_2$	$6C_4$	$3C_4^2$	i	$6S_4$	$8S_6$	$3\sigma_h$	$6\sigma_d$		
A _{1g}	1	1	1	1	1	1	1	1	1	1	$x^2 + y^2 + z^2$	
A _{2g}	1	1	-1	-1	1	1	-1	1	1	-1		
E _g	2	-1	0	0	2	2	0	-1	2	0	$((2z^2 - x^2 - y^2), \sqrt{3}(x^2 - y^2))$	
T _{1g}	3	0	-1	1	-1	3	1	0	-1	-1	(R_x, R_y, R_z)	
T _{2g}	3	0	1	-1	-1	3	-1	0	-1	1	(xz, xy, yz)	
A _{1u}	1	1	1	1	1	-1	-1	-1	-1	-1		
A _{2u}	1	1	-1	-1	1	-1	1	-1	-1	1		
E _u	2	-1	0	0	2	-2	0	1	-2	0		
T _{1u}	3	0	-1	1	-1	-3	-1	0	1	1	(x, y, z)	
T _{2u}	3	0	1	-1	-1	-3	1	0	1	-1		

I_h	E	$12C_5$	$12C_5^2$	$20C_3$	$15C_2$	i	$12S_{10}^3$	$12S_{10}$	$20S_6$	15σ	$\eta_{\pm} = \frac{1}{2}(\sqrt{5} \pm 1)$	
A _g	1	1	1	1	1	1	1	1	1	1	$x^2 + y^2 + z^2$	
T _{1g}	3	η_+	$-\eta_-$	0	-1	3	η_+	$-\eta_-$	0	-1	(R_x, R_y, R_z)	
T _{2g}	3	$-\eta_-$	η_+	0	-1	3	$-\eta_-$	η_+	0	-1		
G _g	4	-1	-1	1	0	4	-1	-1	1	0		
H _g	5	0	0	-1	1	5	0	0	-1	1		
A _u	1	1	1	1	1	-1	-1	-1	-1	-1		
T _{1u}	3	η_+	$-\eta_-$	0	-1	-3	$-\eta_+$	η_-	0	1	(x, y, z)	
T _{2u}	3	$-\eta_-$	η_+	0	-1	-3	η_-	$-\eta_+$	0	1		
G _u	4	-1	-1	1	0	-4	1	1	-1	0		
H _u	5	0	0	-1	1	-5	0	0	1	-1		

$C_{\infty v}$	E	$2C^z(\alpha)$	$\cdots$	$\infty\sigma_v$	
$\Sigma^+ (A_1)$	1	1	$\cdots$	1	z
$\Sigma^- (A_2)$	1	1	$\cdots$	-1	$x^2 + y^2; z^2$
$\Pi (E_1)$	2	$2\cos\alpha$	$\cdots$	0	R_z
$\Delta (E_2)$	2	$2\cos 2\alpha$	$\cdots$	0	$(x, y) (R_x, R_y) (xz, yz)$
$\Phi (E_3)$	2	$2\cos 3\alpha$	$\cdots$	0	$(x^2 - y^2, 2xy)$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	

$D_{\infty h}$	E	$2C^z(\alpha)$	$\cdots$	$\infty\sigma_v$	i	$2S^z(\alpha)$	$\cdots$	∞C_2	
$\Sigma_g^+ (A_{1g})$	1	1	$\cdots$	1	1	1	$\cdots$	1	$x^2 + y^2; z^2$
$\Sigma_g^- (A_{2g})$	1	1	$\cdots$	-1	1	1	$\cdots$	-1	R_z
$\Pi_g (E_{1g})$	2	$2\cos\alpha$	$\cdots$	0	2	$-2\cos\alpha$	$\cdots$	0	$(R_x, R_y) (xz, yz)$
$\Delta_g (E_{2g})$	2	$2\cos 2\alpha$	$\cdots$	0	2	$2\cos 2\alpha$	$\cdots$	0	$(x^2 - y^2, 2xy)$
$\Phi_g (E_{3g})$	2	$2\cos 3\alpha$	$\cdots$	0	2	$-2\cos 3\alpha$	$\cdots$	0	
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	
$\Sigma_u^+ (A_{1u})$	1	1	$\cdots$	1	-1	-1	$\cdots$	-1	z
$\Sigma_u^- (A_{2u})$	1	1	$\cdots$	-1	-1	-1	$\cdots$	1	
$\Pi_u (E_{1u})$	2	$2\cos\alpha$	$\cdots$	0	-2	$2\cos\alpha$	$\cdots$	0	(x, y)
$\Delta_u (E_{2u})$	2	$2\cos 2\alpha$	$\cdots$	0	-2	$-2\cos 2\alpha$	$\cdots$	0	
$\Phi_u (E_{3u})$	2	$2\cos 3\alpha$	$\cdots$	0	-2	$2\cos 3\alpha$	$\cdots$	0	
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	

Symmetry representations

Selected tables for descent in symmetry

C_{2v}	C_2	C_s (E, σ^{xz})	C_s (E, σ^{yz})
A_1	A	A'	A'
A_2	A	A''	A''
B_1	B	A'	A''
B_2	B	A''	A'

D_{3h}	C_{3v}	C_{2v} ($\sigma_h \rightarrow \sigma^{yz}$)	C_s (E, σ_h)	C_s (E, σ_v)
A'_1	A_1	A_1	A'	A'
A'_2	A_2	B_2	A'	A''
E'	E	$A_1 \oplus B_2$	$2A'$	$A' \oplus A''$
A''_1	A_2	A_2	A''	A''
A''_2	A_1	B_1	A''	A'
E''	E	$A_2 \oplus B_1$	$2A''$	$A' \oplus A''$

$D_{\infty h}$ (x, y, z)	C_{2v} $\rightarrow (x, z, y)$
Σ_g^+	A_1
Σ_g^-	B_1
Π_g	$A_2 \oplus B_2$
Δ_g	$A_1 \oplus B_1$
$\cdots$	$\cdots$
Σ_u^+	B_2
Σ_u^-	A_2
Π_u	$A_1 \oplus B_1$
Δ_u	$A_2 \oplus B_2$
$\cdots$	$\cdots$

$O(3)$	O_h	T_d
S_g	A_{1g}	A_1
P_g	T_{1g}	T_1
D_g	$E_g \oplus T_{2g}$	$E \oplus T_2$
F_g	$A_{2g} \oplus T_{1g} \oplus T_{2g}$	$A_2 \oplus T_1 \oplus T_2$
G_g	$A_{1g} \oplus E_g \oplus T_{1g} \oplus T_{2g}$	$A_1 \oplus E \oplus T_1 \oplus T_2$
$\cdots$	$\cdots$	$\cdots$
S_u	A_{1u}	A_2
P_u	T_{1u}	T_2
D_u	$E_u \oplus T_{2u}$	$E \oplus T_1$
F_u	$A_{2u} \oplus T_{1u} \oplus T_{2u}$	$A_1 \oplus T_2 \oplus T_1$
G_u	$A_{1u} \oplus E_u \oplus T_{1u} \oplus T_{2u}$	$A_2 \oplus E \oplus T_2 \oplus T_1$
$\cdots$	$\cdots$	$\cdots$

Reduction formula

$$\Gamma = a_1 \Gamma^{(1)} \oplus a_2 \Gamma^{(2)} \oplus \dots \oplus a_n \Gamma^{(n)}$$

$$a_k = \frac{1}{h} \sum_R \chi^{(k)}(R)^* \chi(R)$$

Projection operator

$$\mathcal{P}^{(k)} \propto \sum_R \chi^{(k)}(R)^* R$$

Direct products

Generally

$$\chi^{\Gamma \otimes \Gamma'}(R) = \chi^{\Gamma}(R) \chi^{\Gamma'}(R)$$

Selected tables of direct products

C_{3v}	A ₁	A ₂	E		
A ₁	A ₁	A ₂	E		
A ₂		A ₁	E		
E			A ₁ $\oplus$ [A ₂] $\oplus$ E		
$C_{\infty v}$	Σ^+	Σ^-	Π	Δ	
Σ^+	Σ^+	Σ^-	Π	Δ	
Σ^-		Σ^+	Π	Δ	
Π			$\Sigma^+ \oplus [\Sigma^-] \oplus \Delta$	$\Pi \oplus \Phi$	
Δ				$\Sigma^+ \oplus [\Sigma^-] \oplus \Gamma$	
T_d or O	A ₁	A ₂	E	T ₁	T ₂
A ₁	A ₁	A ₂	E	T ₁	T ₂
A ₂		A ₁	E	T ₂	T ₁
E			A ₁ $\oplus$ [A ₂] $\oplus$ E	T ₁ $\oplus$ T ₂	T ₁ $\oplus$ T ₂
T ₁				A ₁ $\oplus$ E $\oplus$ [T ₁] $\oplus$ T ₂	A ₂ $\oplus$ E $\oplus$ T ₁ $\oplus$ T ₂
T ₂					A ₁ $\oplus$ E $\oplus$ [T ₁] $\oplus$ T ₂

Square brackets [] indicate the antisymmetrised component of the product.

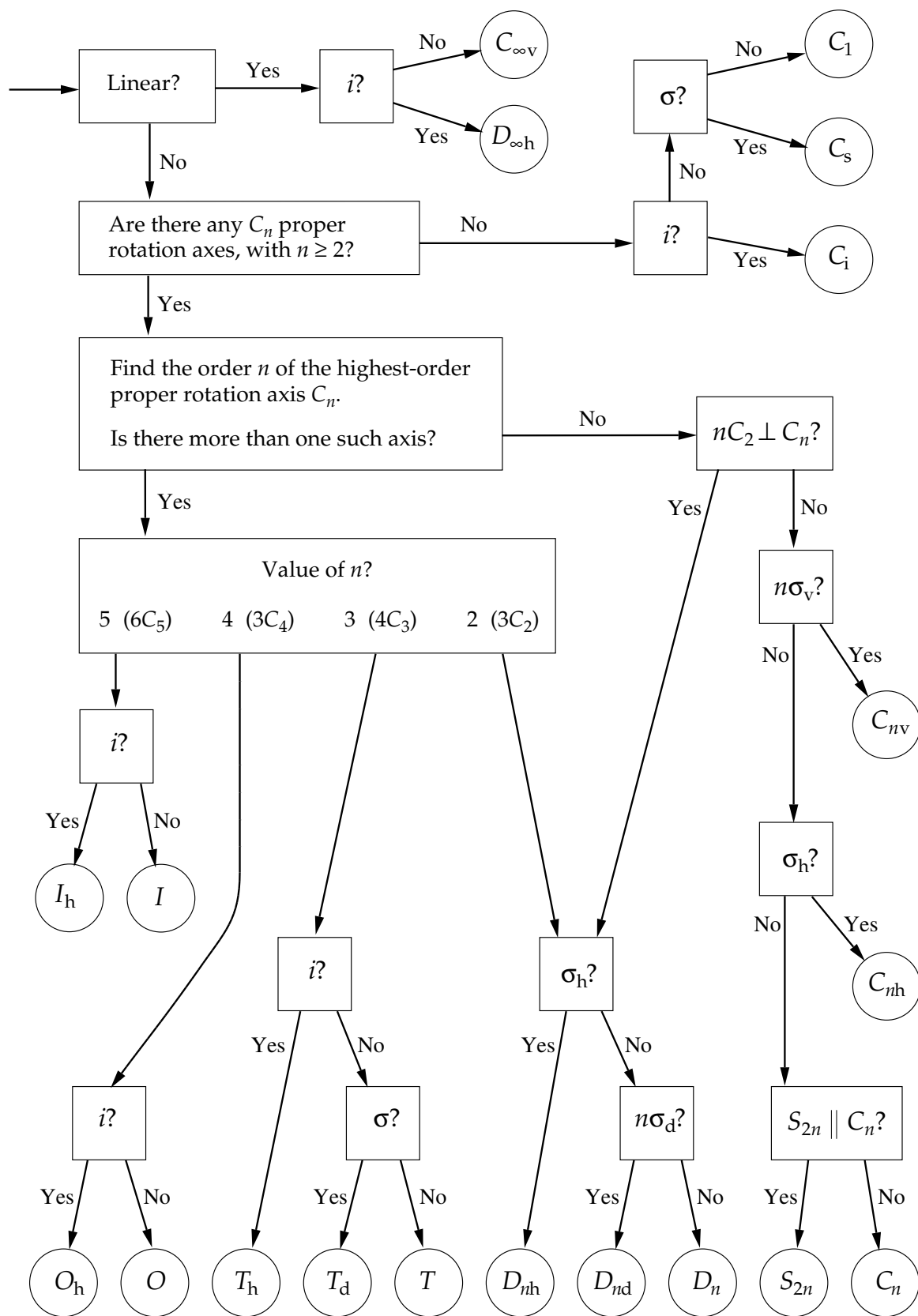
For point groups with a centre of inversion,

$$g \otimes g = g \qquad u \otimes u = g \qquad g \otimes u = u.$$

For point groups with a horizontal mirror plane,

$$' \otimes ' = ' \qquad '' \otimes '' = ' \qquad ' \otimes '' = ''.$$

Flow chart for determining molecular point groups



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Space groups

General Equivalent Positions (GEPs) and Special Equivalent Positions (SEPs)

P2₁

GEPs:

$$2 \text{ @ } (x_n, y_n, z_n), (-x_n, \frac{1}{2} + y_n, -z_n)$$

SEPs:

None

P2₁/c

GEPs:

$$4 \text{ @ } (x_n, y_n, z_n), (-x_n, \frac{1}{2} + y_n, \frac{1}{2} - z_n), (x_n, \frac{1}{2} - y_n, \frac{1}{2} + z_n), (-x_n, -y_n, -z_n)$$

SEPs:

4 pairs:

$$2 \text{ @ } (0, 0, 0) \text{ and } (0, \frac{1}{2}, \frac{1}{2})$$

$$2 \text{ @ } (0, 0, \frac{1}{2}) \text{ and } (0, \frac{1}{2}, 0)$$

$$2 \text{ @ } (\frac{1}{2}, 0, 0) \text{ and } (\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$$

$$2 \text{ @ } (\frac{1}{2}, \frac{1}{2}, 0) \text{ and } (\frac{1}{2}, 0, \frac{1}{2})$$

P2₁2₁2₁

GEPs:

$$4 \text{ @ } (x_n, y_n, z_n), (-x_n, \frac{1}{2} + y_n, \frac{1}{2} - z_n), (\frac{1}{2} + x_n, \frac{1}{2} - y_n, -z_n), (\frac{1}{2} - x_n, -y_n, \frac{1}{2} + z_n)$$

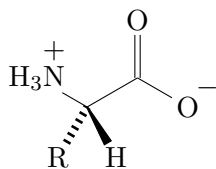
SEPs:

None

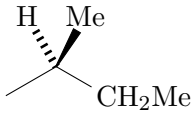
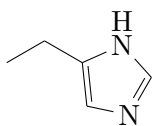
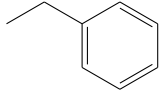
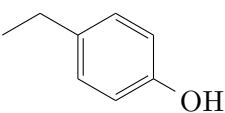
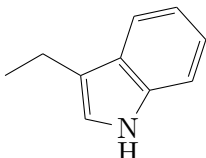
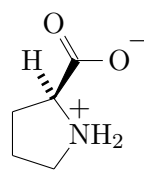
Parameters for selected magnetic nuclei

isotope	natural abundance (%)	spin, I
^1H	100	$\frac{1}{2}$
^2H	1.5×10^{-2}	1
^3H	0	$\frac{1}{2}$
^6Li	7	1
^7Li	93	$\frac{3}{2}$
^{10}B	20	3
^{11}B	80	$\frac{3}{2}$
^{13}C	1	$\frac{1}{2}$
^{14}N	100	1
^{15}N	0.4	$\frac{1}{2}$
^{17}O	3.7×10^{-2}	$\frac{5}{2}$
^{19}F	100	$\frac{1}{2}$
^{23}Na	100	$\frac{3}{2}$
^{27}Al	100	$\frac{5}{2}$
^{29}Si	5	$\frac{1}{2}$
^{31}P	100	$\frac{1}{2}$
^{51}V	100	$\frac{7}{2}$
^{57}Fe	2	$\frac{1}{2}$
^{77}Se	8	$\frac{1}{2}$
^{103}Rh	100	$\frac{1}{2}$
^{107}Ag	52	$\frac{1}{2}$
^{109}Ag	48	$\frac{1}{2}$
^{113}Cd	12	$\frac{1}{2}$
^{119}Sn	9	$\frac{1}{2}$
^{129}Xe	26	$\frac{1}{2}$
^{195}Pt	34	$\frac{1}{2}$
^{203}Tl	30	$\frac{1}{2}$
^{205}Tl	70	$\frac{1}{2}$
^{207}Pb	23	$\frac{1}{2}$

Amino acids

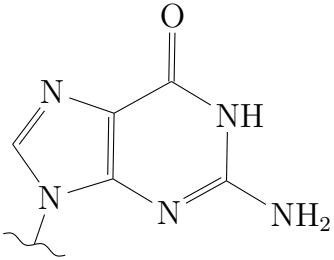
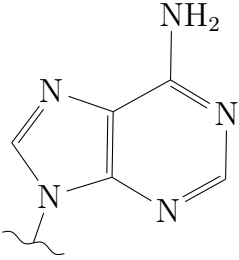
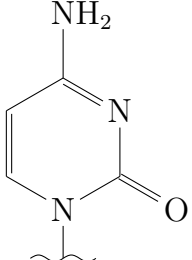
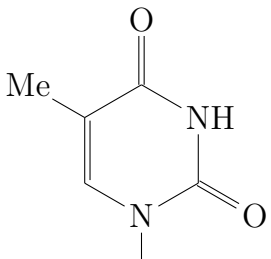
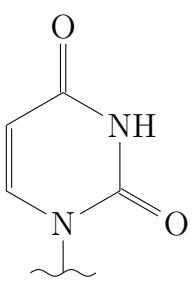


Name	Three-letter code	Single-letter code	Side chain, R =
Serine	Ser	S	$\text{—CH}_2\text{OH}$
Threonine	Thr	T	
Cysteine	Cys	C	$\text{—CH}_2\text{SH}$
Methionine	Met	M	$\text{—CH}_2\text{CH}_2\text{SMe}$
Aspartic acid	Asp	D	$\text{—CH}_2\text{COO}^-$
Asparagine	Asn	N	$\text{—CH}_2\text{CONH}_2$
Glutamic acid	Glu	E	$\text{—CH}_2\text{CH}_2\text{COO}^-$
Glutamine	Gln	Q	$\text{—CH}_2\text{CH}_2\text{CONH}_2$
Lysine	Lys	K	$\text{—CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_3^+$
Arginine	Arg	R	$\text{—CH}_2\text{CH}_2\text{CH}_2\text{NH—C}(\text{NH}_2)=\text{NH}_2^+$
Glycine	Gly	G	—H
Alanine	Ala	A	—Me

Name	Three-letter code	Single-letter code	Side chain, R =
Leucine	Leu	L	$\text{---CH}_2\text{CHMe}_2$
Isoleucine	Ile	I	
Valine	Val	V	---CHMe_2
Histidine	His	H	
Phenylalanine	Phe	F	
Tyrosine	Tyr	Y	
Tryptophan	Trp	W	
Proline*	Pro	P	

*For proline the complete structure of the amino acid is shown.

Nucleotide bases

Name	Abbreviation	Structure
Guanine	G	
Adenine	A	
Cytosine	C	
Thymine	T	
Uracil	U	

DNA codon table

		Second position							
		T	C	A	G				
First position	T	TTT	} Ser	TAT	} Tyr	TGT	} Cys	Third position	
		TTC		TCC		TAC			TGC
		TTA		TCA		TAA			TGA
		TTG		TCG		TAG			TGG
	C	CTT	} Pro	CAT	} His	CGT	} Arg		
		CTC		CCC		CAC			CGC
		CTA		CCA		CAA			CGA
		CTG		CCG		CAG			CGG
	A	ATT	} Thr	AAT	} Asn	AGT	} Ser		
		ATC		ACC		AAC			AGC
		ATA		ACA		AAA			AGA
		ATG		ACG		AAG			AGG
	G	GTT	} Ala	GAT	} Asp	GGT	} Gly		
		GTC		GCC		GAC			GGC
		GTA		GCA		GAA			GGA
		GTG		GCG		GAG			GGG