UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1997/98

Februari 1998

KTE 211- Teori Kumpulan dan Spektroskopi

Masa : [2 jam]

Jawab sebarang __EMPAT__ soalan.

Hanya EMPAT jawapan yang pertama sahaja akan diperiksa.

Jawab tiap-tiap soalan pada muka surat yang baru.

Kertas ini mengandungi LIMA soalan semuanya dan lampiran (17 muka surat)

1. Molekul berikatan enam, $Ni(en)_2Cl_2$ mempunyai dua struktur yang mungkin.

   (i)   Lukiskan kedua-dua struktur tersebut dan berikan kumpulan titik bagi setiap struktur.

   (ii)   Dapatkan perwakilan terturunkan dan perwakilan takterturunkan bagi setiap struktur di atas dengan menggunakan ikatan Ni-Cl sebagai fungsi dasar.

   (iii) Bagaimanakah simetri molekul membezakan di antara kedua-dua struktur tersebut? Jelaskan jawapan anda.

   (25 markah)

2. (a)   Ramalkan nombor kuantum spin I (sifar, setengah integer atau penuh) bagi setiap isotop berikut :-

   $^{11}_{5}B$ $^{27}_{13}Al$ $^{19}_{9}F$ $^{14}_{7}N$ $^{81}_{35}Br$
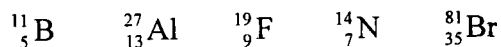
   (5 markah)

(b) Apakah yang dimaksudkan dengan pengkupelan spin-spin dalam resonans magnet nukleus?

(5 markah)

(c) Beberapa peralihan putaran bagi H^{79}Br diperhatikan pada nombor gelombang 138.57, 155.26 dan 188.53 cm^{-1} dengan kedua-dua yang pertama itu muncul sebagai garisan berturutan.

Terbitkan suatu ungkapan yang umum bagi tenaga peralihan putaran termasuk pemalar-pemalar putaran B dan erutan mengempar D.

Kiralah nilai B dan D bagi H^{79}Br dari data tersebut di atas.

(15 markah)

3. (a) Terangkan dengan jelas tiap-tiap istilah berikut :

(i) Paksi putaran wajar, C_n.
(ii) Paksi putaran-pemantulan, S_n.
(iii) Perwakilan terturunkan.
(iv) Jadual Karakter.

(10 markah)

(b) Di dalam kajian RMN, Hukum Taburan Boltzmann digunakan untuk menghitungkan bilangan nukleus pada paras tenaga yang berlainan. Bincangkan dengan menggunakan persamaan yang sesuai.

(5 markah)

(c)   Kedudukan jalur spektrum penyerapan mikrogelombang bagi molekul $H^{55}Cl$ pada suhu 300 K adalah seperti berikut :

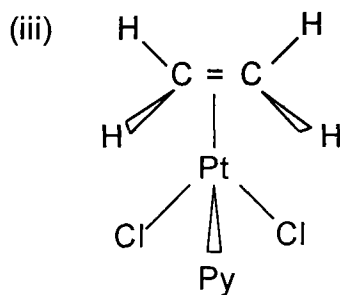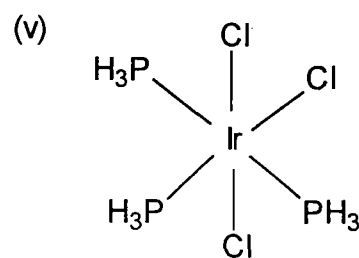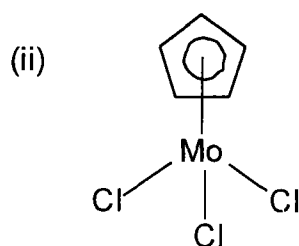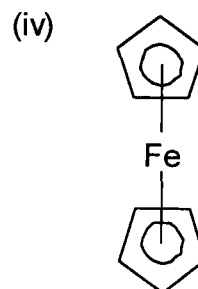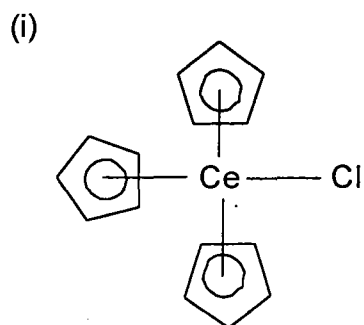| v/cm^{-1}	Keamatan
104.10	Lemah
124.30	Sederhana
145.03	Sederhana
165.51	Kuat
185.86	Sederhana

(i)   Tentukan peralihan $J \longrightarrow J'$ yang memberikan tiap-tiap jalur di atas.

(5 markah)

(ii)   Terangkan perubahan jarak antara jalur dalam spektrum tersebut.

(5 markah)

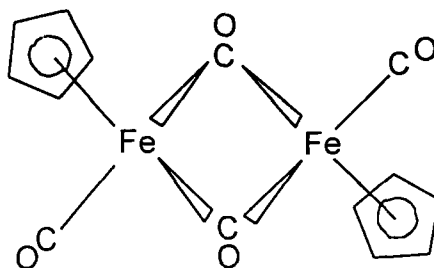4. (a) Nyatakan kumpulan titik bagi tiap-tiap molekul berikut :

(i)

(iv)

(ii)

(v)

(iii)

(10 markah)

(b) Berpandukan molekul yang sesuai, dapatkan perwakilan-perwakilan Γp_x, Γp_y dan Γp_z bagi kumpulan titik C_{2h}.

(10 markah)

(c)   Bagi sebatian berikut :

Huraikan secara ringkas cara penentuan kumpulan titik bagi sebatian tersebut.
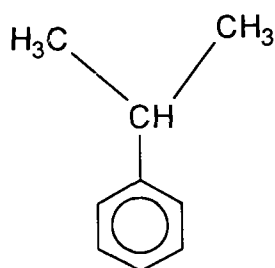
Dapatkan perwakilan terturunkan bagi sebatian tersebut.

(5 markah)

5.   (a)   Terangkan istilah-istilah berikut :

(i)   Proses persantaian spin-spin.

(ii)   Anjakan kimia, δ.

(iii)   Kesan perlindungan (shielding) dan pendelindungan (deshielding).

(10 markah)

(b)   Ramalkan corak spektrum RMN ^{1}H dan julat anjakan kimia (δ) bagi puncak-puncak yang paling mungkin untuk sebatian berikut :

(5 markah)

(c)   Spektrum RMN ^{1}H bagi sebatian ditunjukkan dalam Rajah 1. Cadangkan satu struktur molekul yang sesuai bagi sebatian C_9H_8O tersebut dengan memberikan sebab yang munasabah.

(10 markah)

Anjakan Kimia δ (ppm)
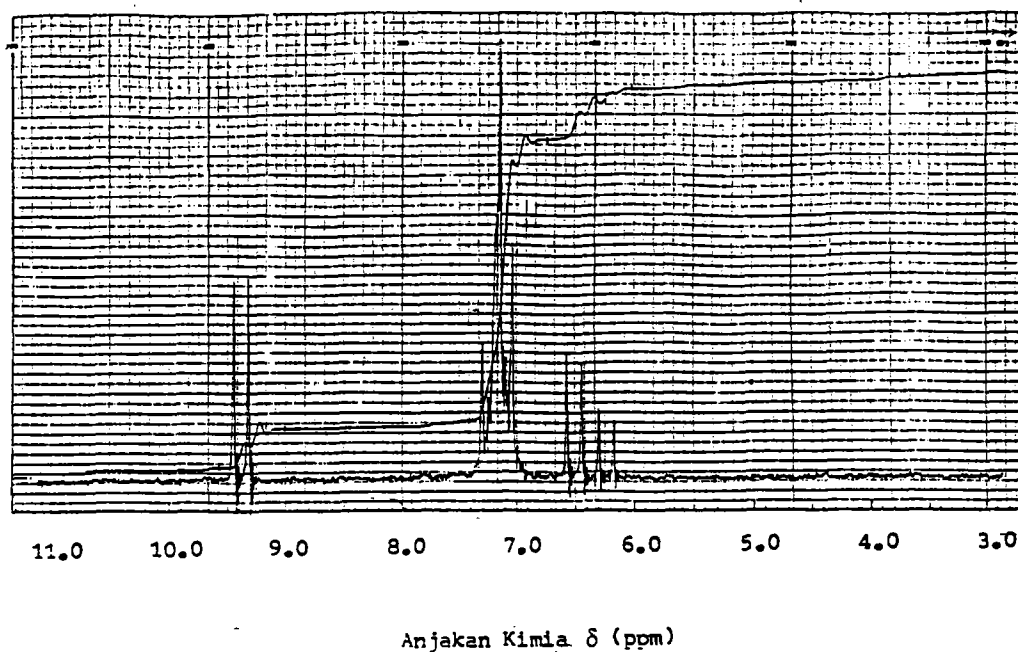
Rajah 1 : Spektrum RMN 'H bagi sebatian C_9H_8O

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LAMPIRAN

Character Tables
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THE NONAXIAL GROUPS

C_1	E
A	1

C_s	E	σ_h		
A'	1	1	x, y, R_z	x^2, y^2, z^2, xy
A''	1	−1	z, R_x, R_y	yz, xz

C_i	E	i		
A_g	1	1	R_x, R_y, R_z	$x^2, y^2, z^2, xy, xz, yz$
A_u	1	−1	x, y, z	

THE AXIAL GROUPS

► *The C_n Groups*

C_2	E	C_2		
A	1	1	z, R_z	x^2, y^2, z^2, xy
B	1	−1	x, y, R_x, R_y	yz, xz

C_3	E	C_3	C_3^2	$\varepsilon = \exp(2\pi i/3)$	
A	1	1	1	z, R_z	$x^2 + y^2, z^2$
E	$\begin{Bmatrix} 1 & \varepsilon & \varepsilon^* \\ 1 & \varepsilon^* & \varepsilon \end{Bmatrix}$			$(x, y), (R_x, R_y)$	$(x^2 - y^2, xy), (yz, xz)$

C_4	E	C_4	C_2	C_4^3		
A	1	1	1	1	z, R_z	x^2+y^2, z^2
B	1	-1	1	-1		x^2-y^2, xy
E	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} i \\ -i \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\left.\begin{matrix} -i \\ i \end{matrix}\right\}$	$(x, y), (R_x, R_y)$	(xz, yz)

C_5	E	C_5	C_5^2	C_5^3	C_5^4	$\varepsilon = \exp(2\pi i/5)$	
A	1	1	1	1	1	z, R_z	x^2+y^2, z^2
E_1	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^2 \\ \varepsilon^{2*} \end{matrix}$	$\begin{matrix} \varepsilon^{2*} \\ \varepsilon^2 \end{matrix}$	$\left.\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}\right\}$	$(x, y), (R_x, R_y)$	(yz, xz)
E_2	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon^2 \\ \varepsilon^{2*} \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\left.\begin{matrix} \varepsilon^{2*} \\ \varepsilon^2 \end{matrix}\right\}$		(x^2-y^2, xy)

C_6	E	C_6	C_3	C_2	C_3^2	C_6^5	$\varepsilon = \exp(2\pi i/6)$	
A	1	1	1	1	1	1	z, R_z	x^2+y^2, z^2
B	1	-1	1	-1	1	-1		
E_1	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}$	$\left.\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}\right\}$	$(x, y),\ (R_x, R_y)$	(xz, yz)
E_2	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}$	$\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$	$\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}$	$\left.\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}\right\}$		(x^2-y^2, xy)

C_7	E	C_7	C_7^2	C_7^3	C_7^4	C_7^5	C_7^6	$\varepsilon = \exp(2\pi i/7)$	
A	1	1	1	1	1	1	1	z, R_z	x^2+y^2, z^2
E_1	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^2 \\ \varepsilon^{2*} \end{matrix}$	$\begin{matrix} \varepsilon^3 \\ \varepsilon^{3*} \end{matrix}$	$\begin{matrix} \varepsilon^{3*} \\ \varepsilon^3 \end{matrix}$	$\begin{matrix} \varepsilon^{2*} \\ \varepsilon^2 \end{matrix}$	$\left.\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}\right\}$	$(x, y),\ (R_x, R_y)$	(xz, yz)
E_2	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon^2 \\ \varepsilon^{2*} \end{matrix}$	$\begin{matrix} \varepsilon^{3*} \\ \varepsilon^3 \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^3 \\ \varepsilon^{3*} \end{matrix}$	$\left.\begin{matrix} \varepsilon^{2*} \\ \varepsilon^2 \end{matrix}\right\}$		(x^2-y^2, xy)
E_3	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon^3 \\ \varepsilon^{3*} \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} \varepsilon^2 \\ \varepsilon^{2*} \end{matrix}$	$\begin{matrix} \varepsilon^{2*} \\ \varepsilon^2 \end{matrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\left.\begin{matrix} \varepsilon^{3*} \\ \varepsilon^3 \end{matrix}\right\}$		

C_8	E	C_8	C_4	C_2	C_4^3	C_8^3	C_8^5	C_8^7	$\varepsilon = \exp(2\pi i/8)$	
A	1	1	1	1	1	1	1	1	z, R_z	x^2+y^2, z^2
B	1	-1	1	1	1	-1	-1	-1		
E_1	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} i \\ -i \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} -i \\ i \end{matrix}$	$\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}$	$\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}$	$\left.\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}\right\}$	$(x, y),\ (R_x, R_y)$	(xz, yz)
E_2	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} i \\ -i \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} -i \\ i \end{matrix}$	$\begin{matrix} i \\ -i \end{matrix}$	$\left.\begin{matrix} -i \\ i \end{matrix}\right\}$		(x^2-y^2, xy)
E_3	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}$	$\begin{matrix} i \\ -i \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} -i \\ i \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\left.\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}\right\}$		

► *The S_n Groups*

S_4	E	S_4	C_2	S_4^3		
A	1	1	1	1	R_z	$x^2 + y^2, z^2$
B	1	−1	1	−1	z	$x^2 - y^2, xy$
E	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}i \\ -i\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-i \\ i\end{matrix}$	$(x, y), (R_x, R_y)$	(xz, yz)

S_6	E	C_3	C_3^2	i	S_6^5	S_6	$\varepsilon = \exp(2\pi i/3)$	
A_g	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
E_g	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$\begin{matrix}1 \\ 1\end{matrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	(R_x, R_y)	$(x^2 - y^2, xy),$ (xy, yz)
A_u	1	1	1	−1	−1	−1	z	
E_u	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$	$\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$	(x, y)	

S_8	E	S_8	C_4	S_8^3	C_2	S_8^5	C_4^3	S_8^7	$\varepsilon = \exp(2\pi i/8)$	
A	1	1	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
B	1	−1	1	−1	1	−1	1	−1	z	
E_1	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}i \\ -i\end{matrix}$	$\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$	$\begin{matrix}-i \\ i\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$(x, y),$ (R_x, R_y)	
E_2	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}i \\ -i\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-i \\ i\end{matrix}$	$\begin{matrix}1 \\ 1\end{matrix}$	$\begin{matrix}i \\ -i\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-i \\ i\end{matrix}$		$(x^2 - y^2, xy)$
E_3	$\begin{Bmatrix}1 \\ 1\end{Bmatrix}$	$\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$	$\begin{matrix}-i \\ i\end{matrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$\begin{matrix}i \\ -i\end{matrix}$	$\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$		(xz, yz)

► *The C_{nv} Groups*

C_{2v}	E	C_2	$\sigma_v(xz)$	$\sigma_v'(yz)$		
A_1	1	1	1	1	z	x^2, y^2, z^2
A_2	1	1	−1	−1	R_z	xy
B_1	1	−1	1	−1	x, R_y	xz
B_2	1	−1	−1	1	y, R_x	yz

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

C-4   **APPENDIX C**

C_{4v}	E	$2C_4$	C_2	$2\sigma_v$	$2\sigma_d$		
A_1	1	1	1	1	1	z	$x^2 + y^2, z^2$
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	$(x, y), (R_x, R_y)$	(xz, yz)

C_{5v}	E	$2C_5$	$2C_5^2$	$5\sigma_v$		
A_1	1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	1	-1	R_z	
E_1	2	$2\cos 72°$	$2\cos 144°$	0	$(x, y), (R_x, R_y)$	(xz, yz)
E_2	2	$2\cos 144°$	$2\cos 72°$	0		$(x^2 - y^2, xy)$

C_{6v}	E	$2C_6$	$2C_3$	C_2	$3\sigma_v$	$3\sigma_d$		
A_1	1	1	1	1	1	1	z	$x^2 + y^2, z^2$
A_2	1	1	1	1	-1	-1	R_z	
B_1	1	-1	1	-1	1	-1		
B_2	1	-1	1	-1	-1	1		
E_1	2	1	-1	-2	0	0	$(x, y), (R_x, R_y)$	(xz, yz)
E_2	2	-1	-1	2	0	0		$(x^2 - y^2, xy)$

► *The* C_{nh} *Groups*

C_{2h}	E	C_2	i	σ_h		
A_g	1	1	1	1	R_z	x^2, y^2, z^2, xy
B_g	1	-1	1	-1	R_x, R_y	xz, yz
A_u	1	1	-1	-1	z	
B_u	1	-1	-1	1	x, y	

C_{3h}	E	C_3	C_3^2	σ_h	S_3	S_3^5	$\varepsilon = \exp(2\pi i/3)$	
A'	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
E'	$\begin{cases}1 \\ 1\end{cases}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$\begin{matrix}1 \\ 1\end{matrix}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\left.\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}\right\}$	(x, y)	$(x^2 - y^2, xy)$
A''	1	1	1	-1	-1	-1	z	
E''	$\begin{cases}1 \\ 1\end{cases}$	$\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$	$\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$	$\begin{matrix}-1 \\ -1\end{matrix}$	$\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$	$\left.\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}\right\}$	(R_x, R_y)	(xz, yz)

C_{4h}	E	C_4	C_2	C_4^3	i	S_4^3	σ_h	S_4		
A_g	1	1	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
B_g	1	−1	1	−1	1	−1	1	−1		$x^2 - y^2, xy$
E_g	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}i \\ -i\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-i \\ i\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}i \\ -i\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\left.\begin{matrix}-i \\ i\end{matrix}\right\}$								(R_x, R_y)	(xz, yz)
A_u	1	1	1	1	−1	−1	−1	−1	z	
B_u	1	−1	1	−1	−1	1	−1	1		
E_u	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}i \\ -i\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-i \\ i\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-i \\ i\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\left.\begin{matrix}i \\ -i\end{matrix}\right\}$								(x, y)	

C_{5h}	E	C_5	C_5^2	C_5^3	C_5^4	σ_h	S_5	S_5^7	S_5^3	S_5^9	$\varepsilon = \exp(2\pi i/5)$	
A'	1	1	1	1	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
E_1'	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}$ $\left.\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}\right\}$										(x, y)	
E_2'	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\left.\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}\right\}$											$(x^2 - y^2, xy)$
A''	1	1	1	1	1	−1	−1	−1	−1	−1	z	
E_1''	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}-\varepsilon^2 \\ -\varepsilon^{2*}\end{matrix}$ $\begin{matrix}-\varepsilon^{2*} \\ -\varepsilon^2\end{matrix}$ $\left.\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}\right\}$										(R_x, R_y)	(xz, yz)
E_2''	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon^2 \\ \varepsilon^{2*}\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^{2*} \\ \varepsilon^2\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon^2 \\ -\varepsilon^{2*}\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\left.\begin{matrix}-\varepsilon^{2*} \\ -\varepsilon^2\end{matrix}\right\}$											

C_{6h}	E	C_6	C_3	C_2	C_3^2	C_6^5	i	S_3^5	S_6^5	σ_h	S_6	S_3	$\varepsilon = \exp(2\pi i/6)$	
A_g	1	1	1	1	1	1	1	1	1	1	1	1	R_z	$x^2 + y^2, z^2$
B_g	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1		
E_{1g}	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\left.\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}\right\}$												(R_x, R_y)	(xz, yz)
E_{2g}	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\left.\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}\right\}$													$(x^2 - y^2, xy)$
A_u	1	1	1	1	1	1	−1	−1	−1	−1	−1	−1	z	
B_u	1	−1	1	−1	1	−1	−1	1	−1	1	−1	1		
E_{1u}	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\left.\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}\right\}$												(x, y)	
E_{2u}	$\left\{\begin{matrix}1 \\ 1\end{matrix}\right.$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}1 \\ 1\end{matrix}$ $\begin{matrix}-\varepsilon^* \\ -\varepsilon\end{matrix}$ $\begin{matrix}-\varepsilon \\ -\varepsilon^*\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}$ $\begin{matrix}-1 \\ -1\end{matrix}$ $\begin{matrix}\varepsilon^* \\ \varepsilon\end{matrix}$ $\left.\begin{matrix}\varepsilon \\ \varepsilon^*\end{matrix}\right\}$													

THE DIHEDRAL GROUPS

▶ *The* D_n *Groups*

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, R_z	xy
B_2	1	−1	1	−1	y, R_y	xz
B_3	1	−1	−1	1	x, R_x	yz

D_3	E	$2C_3$	$3C_2$	(x axis is coincident with C_2)	
A_1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	−1	z, R_z	
E	2	−1	0	$(x, y), (R_x, R_y)$	$(x^2 − y^2, xy), (xz, yz)$

D_4	E	$2C_4$	$C_2(=C_4^2)$	$2C_2'$	$2C_2''$	(x axis coincident with C_2')	
A_1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	−1	−1	z, 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	$(x, y), (R_x, R_y)$	(xz, yz)

D_5	E	$2C_5$	$2C_5^2$	$5C_2$	(x axis coincident with C_2)	
A_1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	−1	z, R_z	
E_1	2	$2 \cos 72°$	$2 \cos 144°$	0	$(x, y), (R_x, R_y)$	(xz, yz)
E_2	2	$2 \cos 144°$	$2 \cos 72°$	0		$(x^2 − y^2, xy)$

D_6	E	$2C_6$	$2C_3$	C_2	$3C_2'$	$3C_2''$	(x axis coincident with C_2')	
A_1	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	1	−1	−1	z, R_z	
B_1	1	−1	1	−1	1	−1		
B_2	1	−1	1	−1	−1	1		
E_1	2	1	−1	−2	0	0	$(x, y), (R_x, R_y)$	(xz, yz)
E_2	2	−1	−1	2	0	0		$(x^2 − y^2, xy)$

► *The D_{nh} Groups*

D_{2h}	E	$C_2(z)$	$C_2(y)$	$C_2(x)$	i	$\sigma(xy)$	$\sigma(xz)$	$\sigma(vz)$		
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	xy
B_{2g}	1	-1	1	-1	1	-1	1	-1	R_y	xz
B_{3g}	1	-1	-1	1	1	-1	-1	1	R_x	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	

D_{3h}	E	$2C_3$	$3C_2$	σ_h	$2S_3$	$3\sigma_v$		(x axis coincident with C_2)
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)	$(x^2 - y^2, xy)$
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)	(xz, yz)

D_{4h}	E	$2C_4$	C_2	$2C_2'$	$2C_2''$	i	$2S_4$	σ_h	$2\sigma_v$	$2\sigma_d$		(x axis coincident with C_2')
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	R_z	
B_{1g}	1	-1	1	1	-1	1	-1	1	1	-1		$x^2 - y^2$
B_{2g}	1	-1	1	-1	1	1	-1	1	-1	1		xy
E_g	2	0	-2	0	0	2	0	-2	0	0	(R_x, R_y)	(xz, 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	z	
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	(x, y)	

D_{5h}	E	$2C_5$	$2C_5^2$	$5C_2$	σ_h	$2S_5$	$2S_5^3$	$5\sigma_v$		(x axis coincident with C_2)
A_1'	1	1	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2'	1	1	1	-1	1	1	1	-1	R_z	
E_1'	2	$2\cos 72°$	$2\cos 144°$	0	2	$2\cos 72°$	$2\cos 144°$	0	(x, y)	
E_2'	2	$2\cos 144°$	$2\cos 72°$	0	2	$2\cos 144°$	$2\cos 72°$	0		$(x^2 - y^2, xy)$
A_1''	1	1	1	1	-1	-1	-1	-1		
A_2''	1	1	1	-1	-1	-1	-1	1	z	
E_1''	2	$2\cos 72°$	$2\cos 144°$	0	-2	$-2\cos 72°$	$-2\cos 144°$	0	(R_x, R_y)	(xz, yz)
E_2''	2	$2\cos 144°$	$2\cos 72°$	0	-2	$-2\cos 144°$	$-2\cos 72°$	0		

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D_{6h}	E	$2C_6$	$2C_3$	C_2	$3C_2'$	$3C_2''$	i	$2S_3$	$2S_6$	σ_h	$3\sigma_d$	$3\sigma_e$	(x axis coincident with C_2')	
A_{1g}	1	1	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	-1	-1	R_z	
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		
E_{1g}	2	1	-1	-2	0	0	2	1	-1	-2	0	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	-1	-1	2	0	0	2	-1	-1	2	0	0		$(x^2 - y, xy)$
A_{1u}	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1		
A_{2u}	1	1	1	1	-1	-1	-1	-1	-1	-1	1	1	z	
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		
E_{1u}	2	1	-1	-2	0	0	-2	-1	1	2	0	0	(x, y)	
E_{2u}	2	-1	-1	2	0	0	-2	1	1	-2	0	0		

D_{8h}	E	$2C_8$	$2C_8^3$	$2C_4$	C_2	$4C_2'$	$4C_2''$	i	$2S_8^3$	$2S_8$	$2S_4$	σ_h	$4\sigma_c$	$4\sigma_d$	(x axis coincident with C_2')	
A_{1g}	1	1	1	1	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	1	1	-1	-1	R_z	
B_{1g}	1	-1	-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	-1	1		
E_{1g}	2	$\sqrt{2}$	$-\sqrt{2}$	0	-2	0	0	2	$\sqrt{2}$	$-\sqrt{2}$	0	-2	0	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	0	0	-2	2	0	0	2	0	0	-2	2	0	0		$(x^2 - y^2, xy)$
E_{3g}	2	$-\sqrt{2}$	$\sqrt{2}$	0	-2	0	0	2	$-\sqrt{2}$	$\sqrt{2}$	0	-2	0	0		
A_{1u}	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1		
A_{2u}	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	1	1	z	
B_{1u}	1	-1	-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	1	-1		
E_{1u}	2	$\sqrt{2}$	$-\sqrt{2}$	0	-2	0	0	-2	$-\sqrt{2}$	$\sqrt{2}$	0	2	0	0	(x, y)	
E_{2u}	2	0	0	-2	2	0	0	-2	0	0	2	-2	0	0		
E_{3u}	2	$-\sqrt{2}$	$\sqrt{2}$	0	-2	0	0	-2	$\sqrt{2}$	$-\sqrt{2}$	0	2	0	0		

► *The D_{nd} Groups*

D_{2d}	E	$2S_4$	C_2	$2C_2'$	$2\sigma_d$	(x axis coincident with C_2')	
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	xy
E	2	0	-2	0	0	$(x, y), (R_x, R_y)$	(xz, yz)

D_{3d}	E	$2C_3$	$3C_2$	i	$2S_6$	$3\sigma_d$	(x axis coincident with C_2)	
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)	$(x^2 - y^2, xy); (xz, yz)$
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_{8d}	E	$2S_8$	$2C_4$	$2S_8^3$	C_2	$4C_2'$	$4\sigma_d$	(x axis coincident with C_2')	
A_1	1	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2	1	1	1	1	1	−1	−1	R_z	
B_1	1	−1	1	−1	1	1	−1		
B_2	1	−1	1	−1	1	−1	1	z	
E_1	2	$\sqrt{2}$	0	$-\sqrt{2}$	−2	0	0	(x, y)	
E_2	2	0	−2	0	2	0	0		$(x^2 - y^2, xy)$
E_3	2	$-\sqrt{2}$	0	$\sqrt{2}$	−2	0	0	(R_x, R_y)	(xz, yz)

D_{5d}	1	$2C_5$	$2C_5^2$	$5C_2$	i	$2S_{10}^3$	$2S_{10}$	$5\sigma_d$	(x axis coincident with C_2)	
A_{1g}	1	1	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_{2g}	1	1	1	−1	1	1	1	−1	R_z	
E_{1g}	2	2 cos 72°	2 cos 144°	0	2	2 cos 72°	2 cos 144°	0	(R_x, R_y)	(xz, yz)
E_{2g}	2	2 cos 144°	2 cos 72°	0	2	2 cos 144°	2 cos 72°	0		$(x^2 - y^2, xy)$
A_{1u}	1	1	1	1	−1	−1	−1	−1		
A_{2u}	1	1	1	−1	−1	−1	−1	1	z	
E_{1u}	2	2 cos 72°	2 cos 144°	0	−2	−2 cos 72°	−2 cos 144°	0	(x, y)	
E_{2u}	2	2 cos 144°	2 cos 72°	0	−2	−2 cos 144°	−2 cos 72°	0		

D_{6d}	E	$2S_{12}$	$2C_6$	$2S_4$	$2C_3$	$2S_{12}^5$	C_2	$6C_2'$	$6\sigma_d$	(x axis coincident with C_2)	
A_1	1	1	1	1	1	1	1	1	1		$x^2 + z^2, z^2$
A_2	1	1	1	1	1	1	1	−1	−1	R_z	
B_1	1	−1	1	−1	1	−1	1	1	−1		
B_2	1	−1	1	−1	1	−1	1	−1	1	z	
E_1	2	$\sqrt{3}$	1	0	−1	$-\sqrt{3}$	−2	0	0	(x, y)	
E_2	2	1	−1	−2	−1	1	2	0	0		$(x^2 - y^2, xy)$
E_3	2	0	−2	0	2	0	−2	0	0		
E_4	2	−1	−1	2	−1	−1	2	0	0		
E_5	2	$-\sqrt{3}$	1	0	−1	$\sqrt{3}$	−2	0	0	(R_x, R_y)	(xz, yz)

THE CUBIC GROUPS

▶ *Tetrahedral Groups*

T	E	$4C_3$	$4C_3^2$	$3C_2$	$\varepsilon = \exp(2\pi i/3)$	
A	1	1	1	1		$x^2 + y^2 + z^2$
E	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$		$(2z^2 - x^2 - y^2, x^2 - y^2)$
T	3	0	0	−1	$(R_x, R_y, R_z), (x, y, z)$	(xy, xz, yz)

T_h	E	$4C_3$	$4C_3^2$	$3C_2$	i	$4S_6$	$4S_6^5$	$3\sigma_h$	($\varepsilon = \exp(2\pi i/3)$)	
A_g	1	1	1	1	1	1	1	1		$x^2 + y^2 + z^2$
A_u	1	1	1	1	-1	-1	-1	-1		
E_g	$\begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$		$(2z^2 - x^2 - y^2,$ $x^2 - y^2)$
E_u	$\begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$	$\begin{matrix} \varepsilon \\ \varepsilon^* \end{matrix}$	$\begin{matrix} \varepsilon^* \\ \varepsilon \end{matrix}$	$\begin{matrix} 1 \\ 1 \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$	$\begin{matrix} -\varepsilon \\ -\varepsilon^* \end{matrix}$	$\begin{matrix} -\varepsilon^* \\ -\varepsilon \end{matrix}$	$\begin{matrix} -1 \\ -1 \end{matrix}$		
T_g	3	0	0	-1	3	0	0	-1	(R_x, R_y, R_z)	(xz, yz, xy)
T_u	3	0	0	-1	-3	0	0	1	(x, y, z)	

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		$(2z^2 - x^2 - y^2, x^2 - y^2)$
T_1	3	0	-1	1	-1	(R_x, R_y, R_z)	
T_2	3	0	-1	-1	1	(x, y, z)	(xy, xz, yz)

► *Octahedral Groups*

O	E	$6C_4$	$3C_2(=C_4^2)$	$8C_3$	$6C_2$		
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		$(2z^2 - x^2 - y^2, x^2 - y^2)$
T_1	3	1	-1	0	-1	$(R_x, R_y, R_z), (x, y, z)$	
T_2	3	-1	-1	0	1		(xy, xz, yz)

O_h	E	$8C_3$	$6C_2$	$6C_4$	$3C_2(=C_4^2)$	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		$(2z^2 - x^2 - y^2, x^2 - y^2)$
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, yz, xy)
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		

Pemalar Asas dalam Kimia Fizik

Simbol	Keterangan	Nilai
N_A	Nombor Avogadro	6.022×10^{23} mol^{-1}
F	Pemalar Faraday	96,500 C mol^{-1}, atau coulomb per mol, elektron
e	Cas elektron	4.80×10^{-10} esu 1.60×10^{-19} C atau coulomb
m_e	Jisim elektron	9.11×10^{-28} g 9.11×10^{-31} kg
m_p	Jisim proton	1.67×10^{-24} g 1.67×10^{-27} kg
h	Pemalar Planck	6.626×10^{-27} erg s 6.626×10^{-34} J s
c	Halaju cahaya	3.0×10^{10} cm s^{-1} 3.0×10^{8} m s^{-1}
R	Pemalar gas	8.314×10^{7} erg K^{-1} mol^{-1} 8.314 J K^{-1} mol^{-1} 0.082 l atm K^{-1} mol^{-1} 1.987 cal K^{-1} mol^{-1}
k	Pemalar Boltzmann	1.380×10^{-16} erg K^{-1} molekul^{-1} 1.380×10^{-23} J K^{-1} molekul^{-1}
g		981 cm s^{-2} 9.81 m s^{-2}
1 atm		76 cmHg 1.013×10^{6} dyne cm^{-2} 101,325 N m^{-2}
$2.303 \dfrac{RT}{F}$		0.0591 V, atau volt, pada 25 °C

Berat Atom yang Berguna

H = 1.0	C = 12.0	I = 126.9	Fe = 55.8	As = 74.9
Br = 79.9	Cl = 35.5	Ag = 107.9	Pb = 207.0	Xe = 131.1
Na = 23.0	K = 39.1	N = 14.0	Cu = 63.5	F = 19.0
O = 16.0	S = 32.0	P = 31.0	Ca = 40.1	Mg = 24.0
Sn = 118.7	Cs = 132.9	Te = 128.0		