Electric Dipole (Resonance) Transitions

- Only 1 e^- changes its (nl) state with Δl = -1 or +1
- Parity MUST change
- ΔL = -1, 0, or +1 ($0 \not\rightarrow 0$,no S → S term transitions)
- ΔJ = -1, 0, or +1 ($0 \not\rightarrow 0$ NOT allowed)
- ΔS = 0 (spin multiplicity does NOT change)

NII 1084.0A $^3P_0 - {}^3D_1^o$

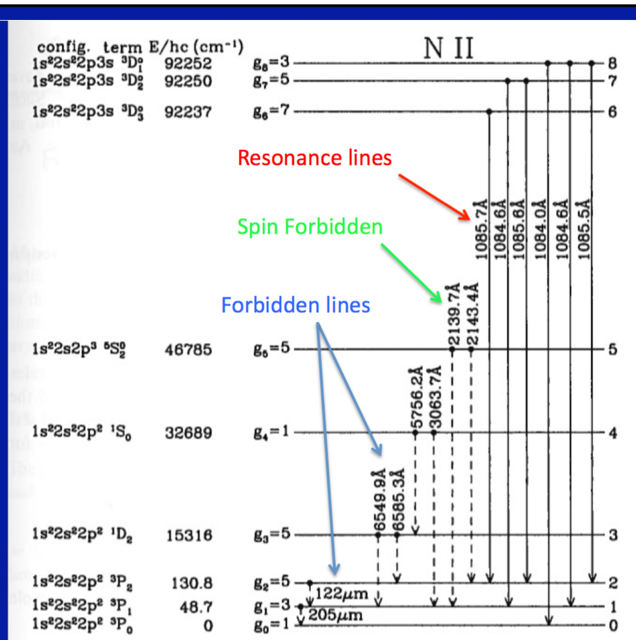


Figure 6.1 First nine energy levels of N II. Forbidden transitions are indicated by broken lines, and allowed transitions by solid lines; forbidden decays are not shown from levels that have permitted decay channels. Fine-structure splitting is not to scale.

Table 9.3 Selected[a] Resonance Lines[b] with $\lambda > 3300$ Å, $f_{\ell u} > 0.015$

	Configurations	ℓ	u	$E_\ell/hc\,(\mathrm{cm}^{-1})$	λ_{vac}(Å)	$f_{\ell u}$	Note
Na I	$2p^63s - 2p^63p$	$^2S_{1/2}$	$^2P^o_{3/2}$	0	5891.582	0.641	Na D_2
		$^2S_{1/2}$	$^2P^o_{1/2}$	0	5897.558	0.320	Na D_1
Al I	$3s^23p - 3s^24s$	$^2P^o_{1/2}$	$^2S_{1/2}$	0	3945.122	0.115	
		$^2P^o_{3/2}$	$^2S_{3/2}$	112.06	3962.641	0.12	
K I	$3p^64s - 3p^64p$	$^2S_{1/2}$	$^2P^o_{3/2}$	0	7667.01	0.682	
		$^2S_{1/2}$	$^2P^o_{1/2}$	0	7701.08	0.340	
Ca I	$3p^64s^2 - 3p^64s4p$	$^1S_0$	$^1P^o_1$	0	4227.918	1.750	
Ca II	$3p^64s - 3p^64p$	$^2S_{1/2}$	$^2P^o_{3/2}$	0	3934.77	0.682	Ca II K
		$^2S_{1/2}$	$^2P^o_{1/2}$	0	3969.59	0.33	Ca II H

Table 9.4 Selected Resonance Lines[a] with $\lambda < 3000$ Å

C I	$2s^22p^2 - 2s^22p3s$	$^3P_0$	$^3P^o_1$	0	1656.928	0.140
		$^3P_1$	$^3P^o_2$	16.40	1656.267	0.0588
		$^3P_2$	$^3P^o_2$	43.40	1657.008	0.104
N II	$2s^22p^2 - 2s2p^3$	$^3P_0$	$^3D^o_1$	0	1083.990	0.115
		$^3P_1$	$^3D^o_2$	48.7	1084.580	0.0861
		$^3P_2$	$^3D^o_3$	130.8	1085.701	0.0957
N I	$2s^22p^3 - 2s^22p^23s$	$^4S^o_{3/2}$	$^4P_{5/2}$	0	1199.550	0.130
		$^4S^o_{3/2}$	$^4P_{3/2}$	0	1200.223	0.0862
O I	$2s^22p^4 - 2s^22p^33s$	$^3P_2$	$^3S^o_1$	0	1302.168	0.0520
		$^3P_1$	$^3S^o_1$	158.265	1304.858	0.0518
		$^3P_0$	$^3S^o_1$	226.977	1306.029	0.0519

Spin Forbidden (Semi-forbidden, Intercombination or Intersystem) Transitions

- Only 1 e^- changes its (nl) state with $\Delta l = -1$ or $+1$
- Parity MUST change
- $\Delta L = -1, 0,$ or $+1$ ($0 \not\to 0$, no S → S term transitions)
- $\Delta J = -1, 0,$ or $+1$ ($0 \not\to 0$ NOT allowed)
- $\Delta S \neq 0$ (spin multiplicity does change)

NII] 2143.4A $^3P_2 - {}^5S_2^o$

$\Delta S = +2$ but otherwise follows rules 1-4

Notation – single right-side bracket

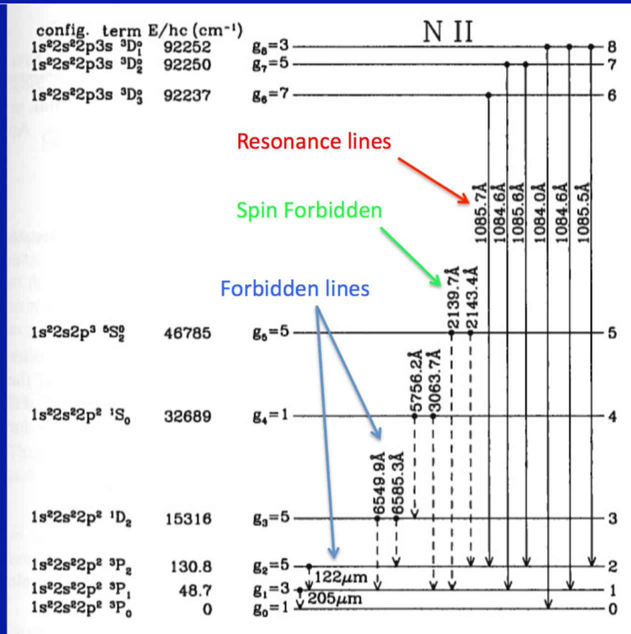


Figure 6.1 First nine energy levels of N II. Forbidden transitions are indicated by broken lines, and allowed transitions by solid lines; forbidden decays are not shown from levels that have permitted decay channels. Fine-structure splitting is not to scale.

Forbidden Transitions

At least 1 of the following 4 rules is broken:

- Only 1 e^- changes its (nl) state with Δl = -1 or +1
- Parity MUST change
- ΔL = -1, 0, or +1 (0 $\not\rightarrow$ 0 ,no S → S term transitions)
- ΔJ = -1, 0, or +1 (0 $\not\rightarrow$ 0 NOT allowed)
- ΔS = *may or may not change*

[NII] 6549.9A $^3P_1 - {}^1D_2$

Parity does not change – breaks rule 2

Notation – double brackets

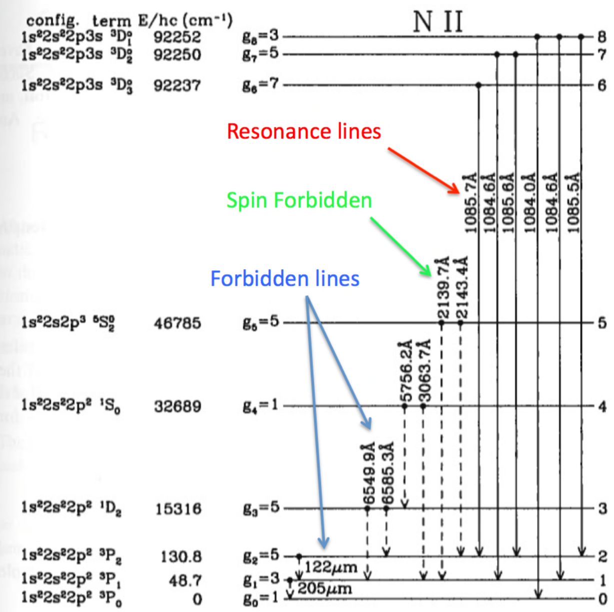


Figure 6.1 First nine energy levels of N II. Forbidden transitions are indicated by broken lines, and allowed transitions by solid lines; forbidden decays are not shown from levels that have permitted decay channels. Fine-structure splitting is not to scale.

Multipole Transition Rules

Allowed transitions		Electric dipole (E1)	Magnetic dipole (M1)	Electric quadrupole (E2)	Magnetic quadrupole (M2)	Electric octupole (E3)	Magnetic octupole (M3)
Rigorous rules	(1)	$\Delta J = 0, \pm 1$ $(J = 0 \not\leftrightarrow 0)$		$\Delta J = 0, \pm 1, \pm 2$ $(J = 0 \not\leftrightarrow 0, 1;\ \frac{1}{2} \not\leftrightarrow \frac{1}{2})$		$\Delta J = 0, \pm 1, \pm 2, \pm 3$ $(0 \not\leftrightarrow 0, 1, 2;\ \frac{1}{2} \not\leftrightarrow \frac{1}{2}, \frac{3}{2};\ 1 \not\leftrightarrow 1)$	
	(2)	$\Delta M_J = 0, \pm 1$		$\Delta M_J = 0, \pm 1, \pm 2$		$\Delta M_J = 0, \pm 1, \pm 2, \pm 3$	
Parity	(3)	$\pi_f = -\pi_i$	$\pi_f = \pi_i$		$\pi_f = -\pi_i$		$\pi_f = \pi_i$
LS coupling	(4)	One electron jump $\Delta l = \pm 1$	No electron jump $\Delta l = 0$, $\Delta n = 0$	None or one electron jump $\Delta l = 0, \pm 2$	One electron jump $\Delta l = \pm 1$	One electron jump $\Delta l = \pm 1, \pm 3$	One electron jump $\Delta l = 0, \pm 2$
	(5)	If $\Delta S = 0$ $\Delta L = 0, \pm 1$ $(L = 0 \not\leftrightarrow 0)$	If $\Delta S = 0$ $\Delta L = 0$	If $\Delta S = 0$ $\Delta L = 0, \pm 1, \pm 2$ $(L = 0 \not\leftrightarrow 0, 1)$		If $\Delta S = 0$ $\Delta L = 0, \pm 1, \pm 2, \pm 3$ $(L = 0 \not\leftrightarrow 0, 1, 2;\ 1 \not\leftrightarrow 1)$	
Intermediate coupling	(6)	If $\Delta S = \pm 1$ $\Delta L = 0, \pm 1, \pm 2$		If $\Delta S = \pm 1$ $\Delta L = 0, \pm 1, \pm 2, \pm 3$ $(L = 0 \not\leftrightarrow 0)$	If $\Delta S = \pm 1$ $\Delta L = 0, \pm 1$ $(L = 0 \not\leftrightarrow 0)$	If $\Delta S = \pm 1$ $\Delta L = 0, \pm 1, \pm 2, \pm 3, \pm 4$ $(L = 0 \not\leftrightarrow 0, 1)$	If $\Delta S = \pm 1$ $\Delta L = 0, \pm 1, \pm 2$ $(L = 0 \not\leftrightarrow 0)$

Helium

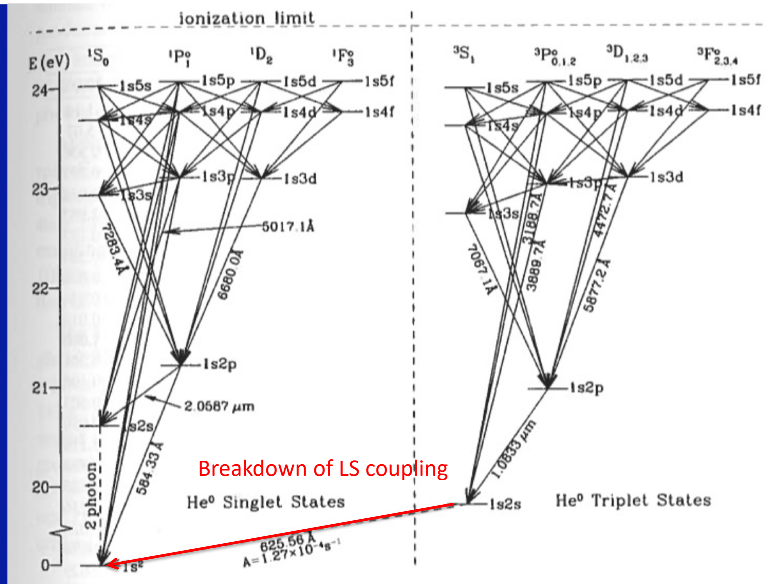
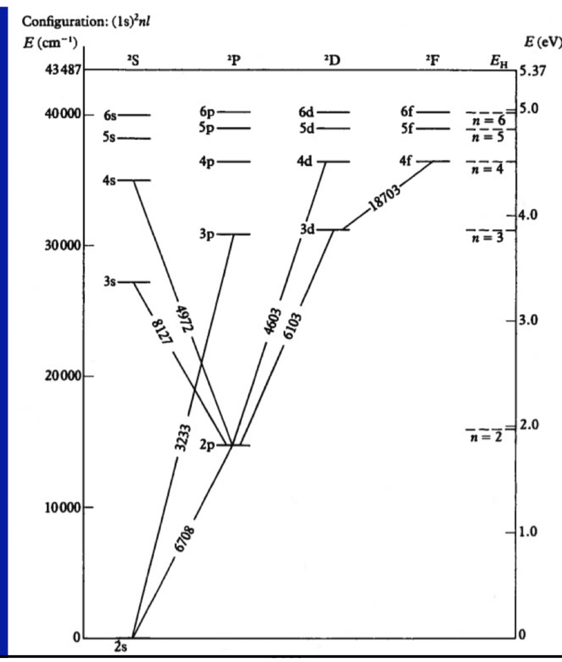
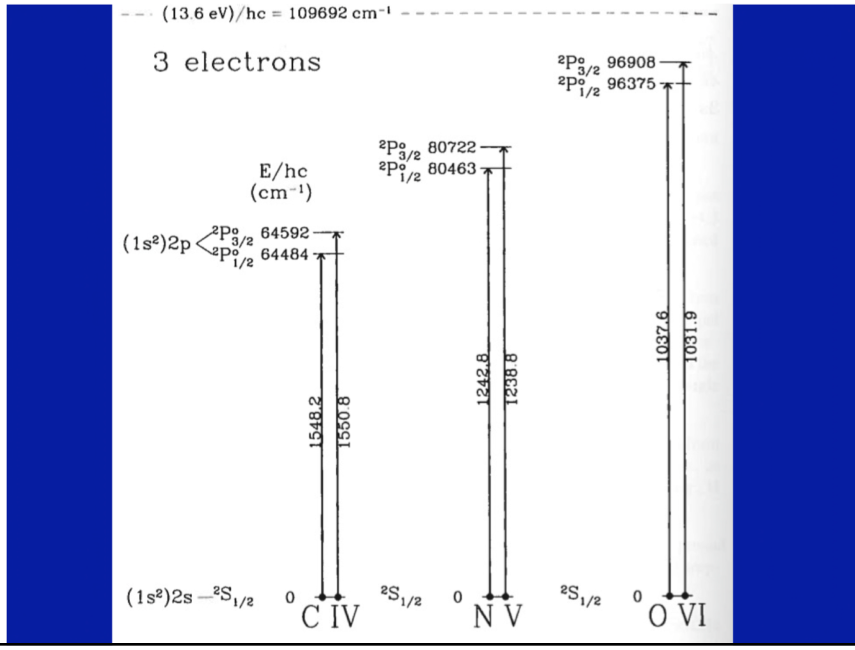


Figure 14.3 Radiative decay pathways for He^0 (see text). Selected lines are labeled by vacuum wavelength.

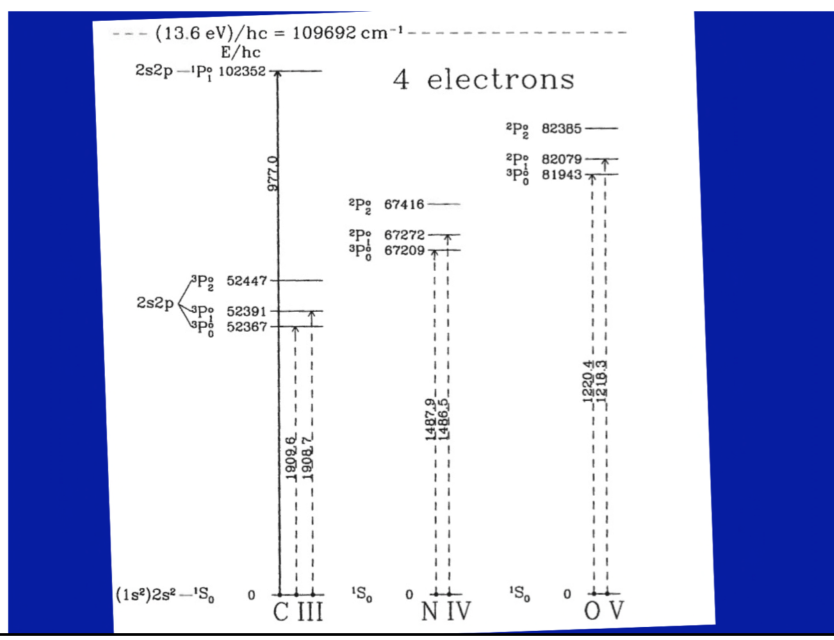
Lithium



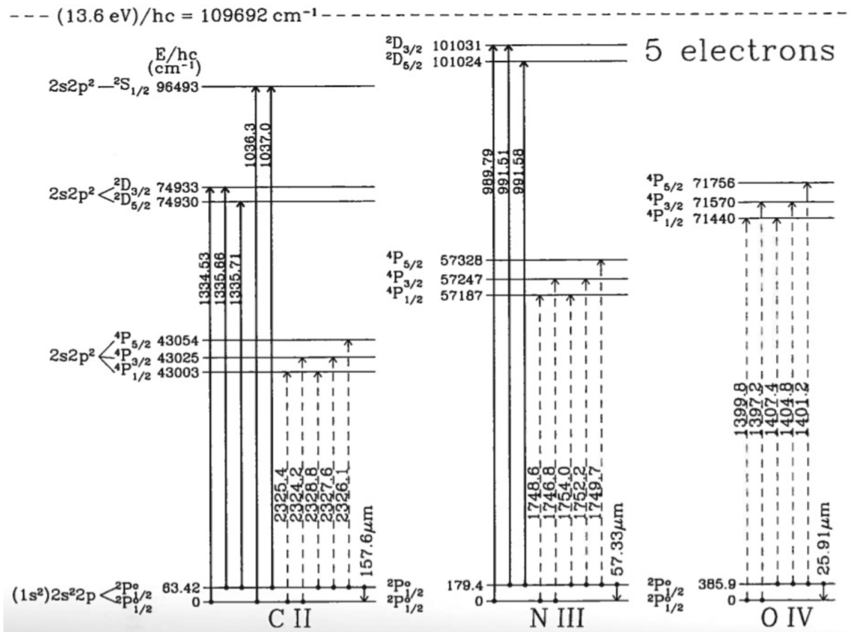
Lithium-like Ions



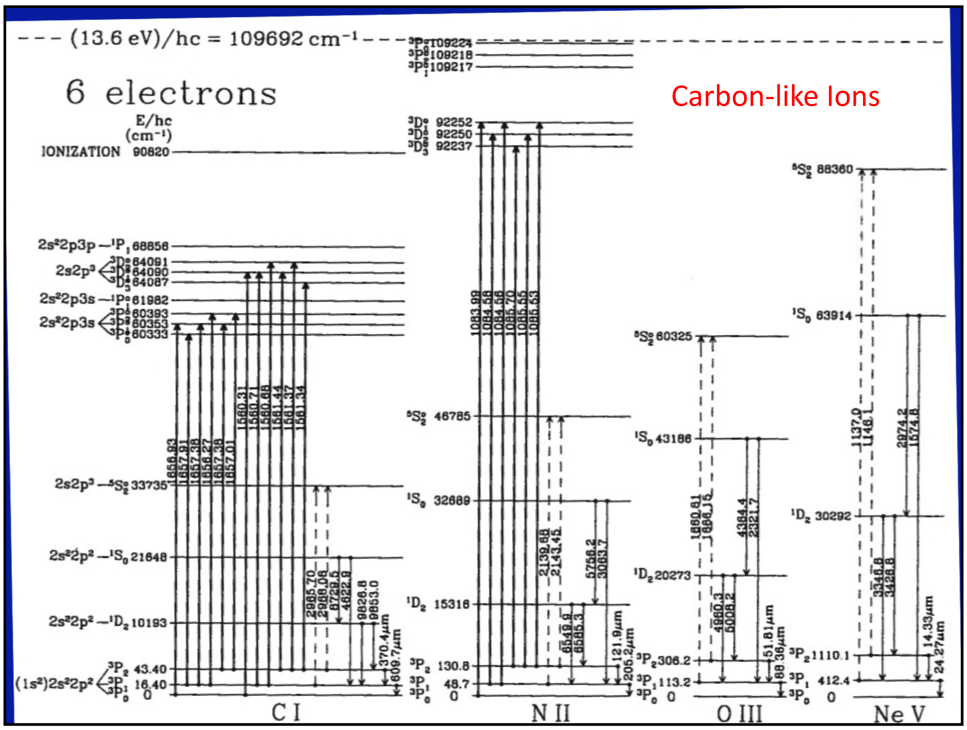
Beryllium-like Ions



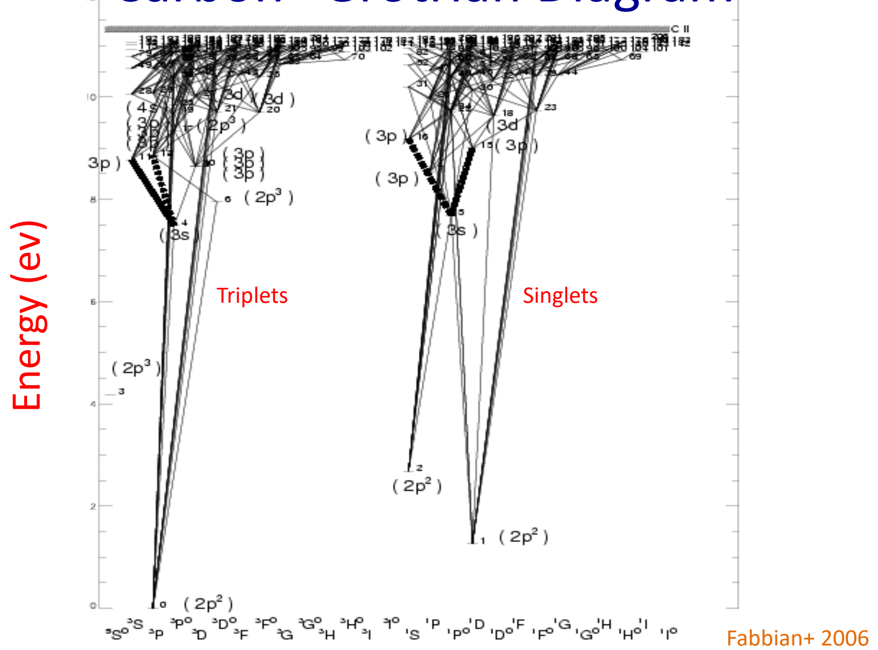
Boron-like Ions

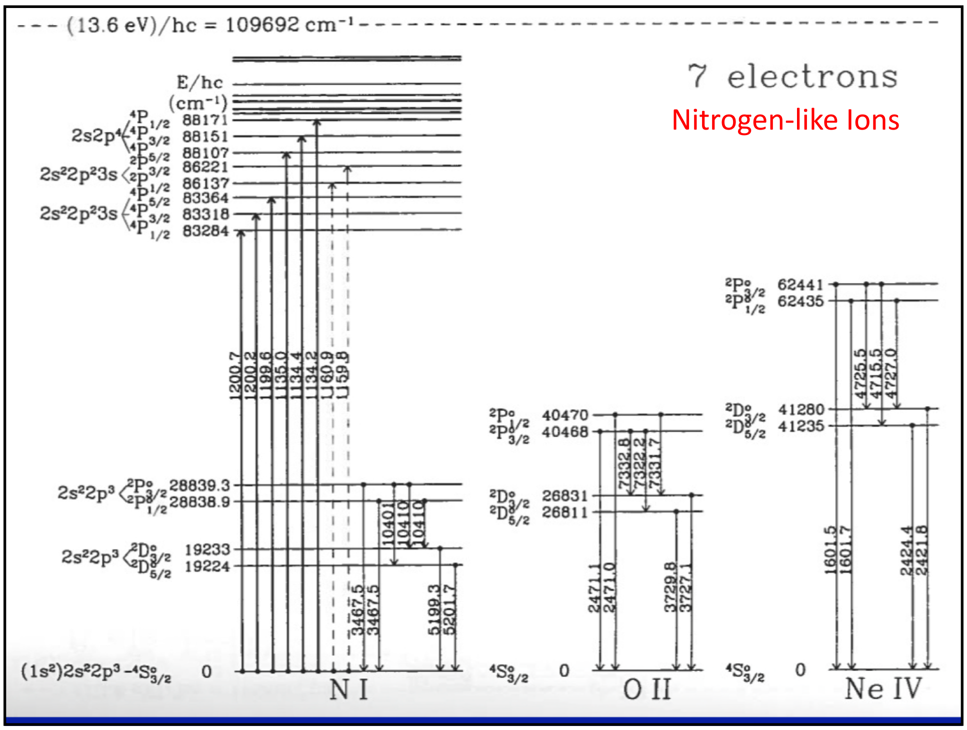


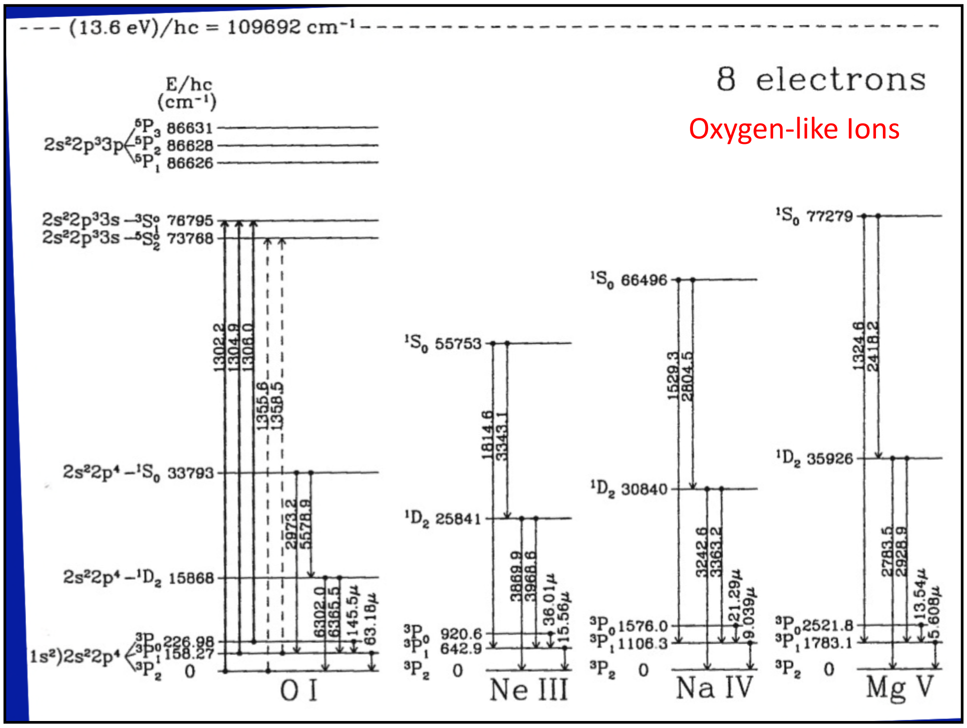
Carbon-like Ions



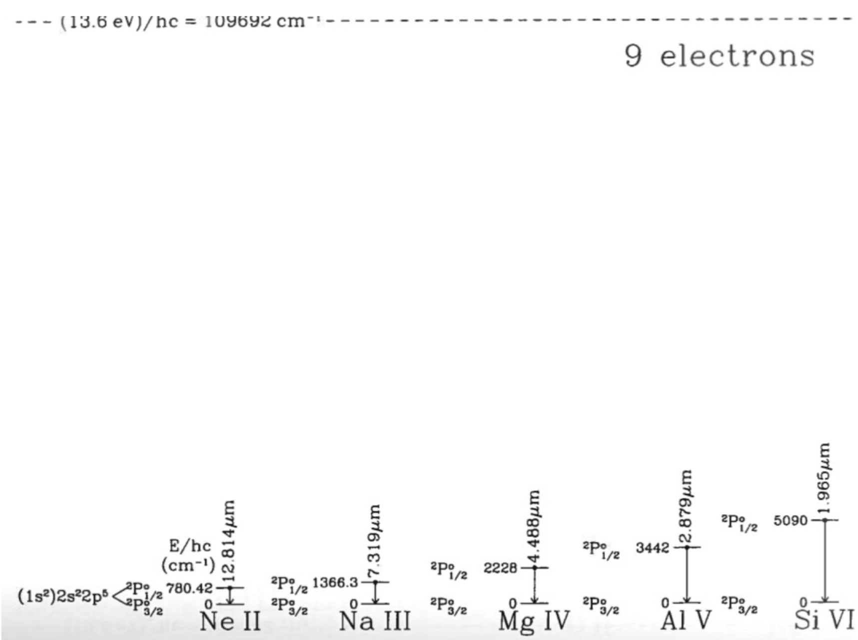
Carbon “Grotrian Diagram”







Fluorine-like Ions



Nuclear Spin

Atomic Number	Element	Symbol	Mass Number	Mass (amu)	Relative Abundance (%)	Spin
1	Hydrogen	H	1	1.00782519	99.9850	$\frac{1}{2}$
			2	2.0141022	0.01492	1
2	Helium	He	3	3.0160297	1.37×10^{-4}	$\frac{1}{2}$
			4	4.0026031	99.999863	0
3	Lithium	Li	6	6.015125	7.42	1
			7	7.016004	92.58	$\frac{3}{2}$
4	Beryllium	Be	9	9.012186	100	$\frac{3}{2}$
5	Boron	B	10	10.0129388	19.61	3
			11	11.0093053	80.39	$\frac{3}{2}$
6	Carbon	C	12	12.0000000	98.893	0
			13	13.0033544	1.107	$\frac{1}{2}$
7	Nitrogen	N	14	14.0030744	99.6337	1
			15	15.0001077	0.3663	$\frac{1}{2}$
8	Oxygen	O	16	15.9949150	99.759	0
			17	16.999133	0.0374	$\frac{5}{2}$
			18	17.9991600	0.2039	0
9	Fluorine	F	19	18.9984046	100	$\frac{1}{2}$