

# Atomic Physics

By

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DEPARTMENT OF PHYSICS



**Vivekanand College, Kolhapur  
( EMPOWERED AUTONOMOUS)**

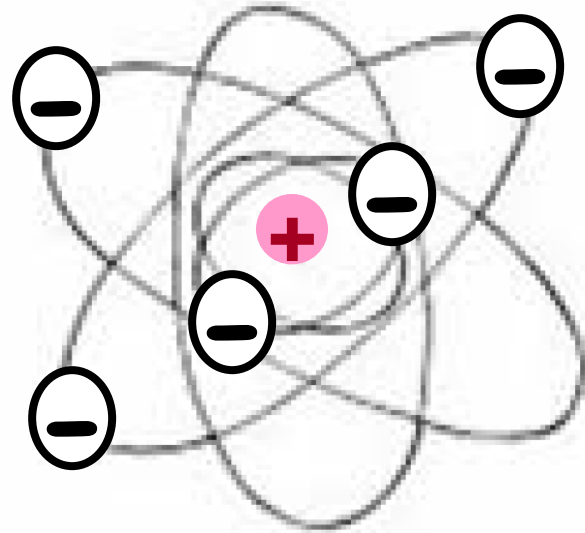
# Periodic table of elements

Elements in vertical rows have similar chemical properties

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt									
		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

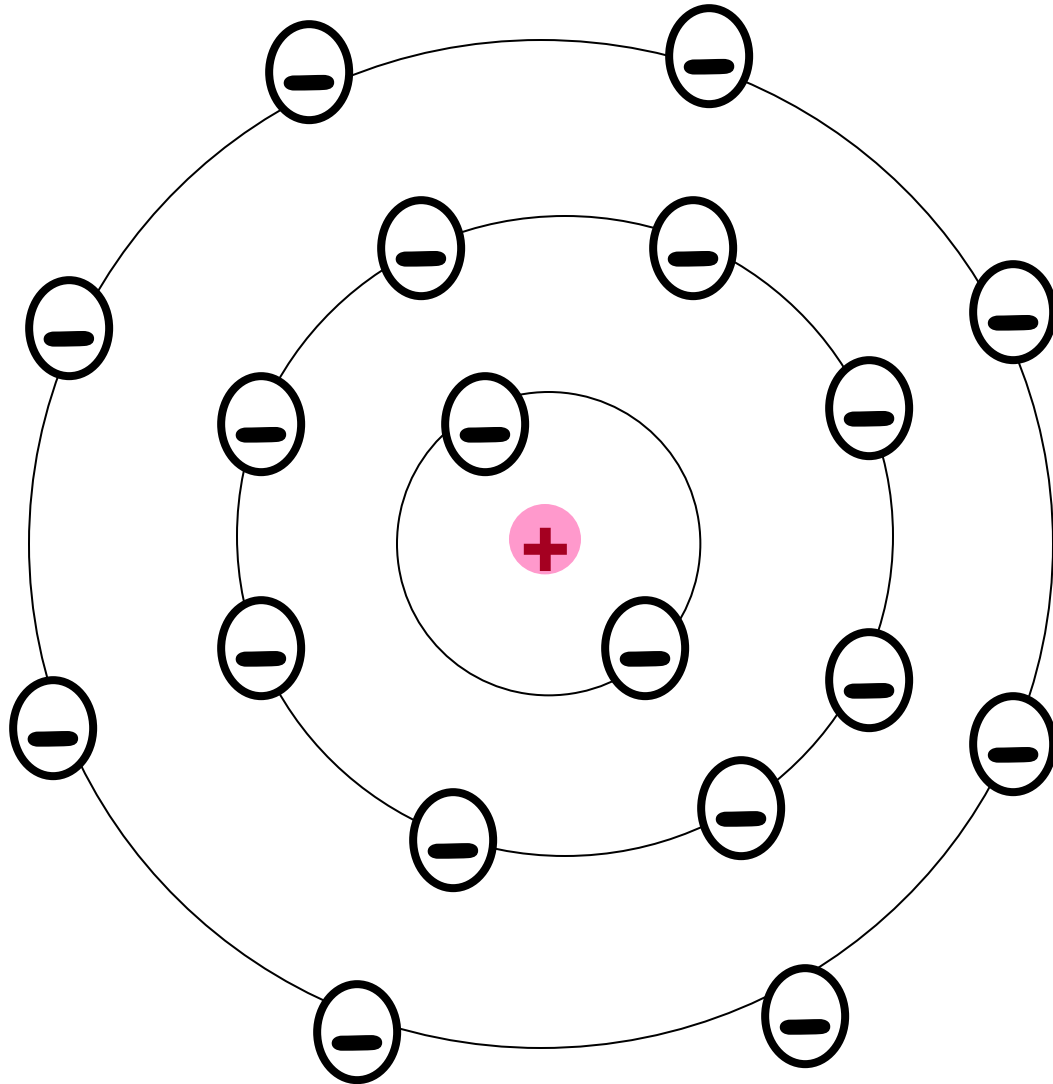
Inert gases

# Schroedinger's Equation for multi-electron Atoms



$$\frac{-\hbar^2}{2\mu} \frac{1}{r^2 \sin \theta} \left[ \sin \theta \frac{\partial}{\partial r} \left( r^2 \frac{\partial \Psi}{\partial r} \right) + \frac{\partial}{\partial \theta} \left( \sin \theta \frac{\partial \Psi}{\partial \theta} \right) + \frac{1}{\sin \theta} \frac{\partial^2 \Psi}{\partial \phi^2} \right] - U(r) \Psi(r, \theta, \phi) = E \Psi(r, \theta, \phi)$$

# Solutions give energy levels that are clustered in “shells”



<u>n</u>	<u># of states</u>
1	2
2	8
3a	8
3b	10
4a	8
4b	10
4c	14



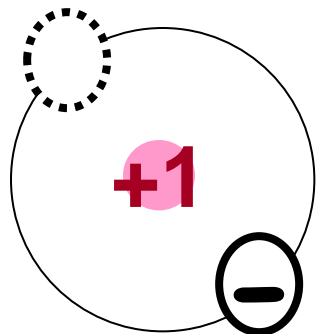
Wolfgang  
Pauli

# Pauli exclusion principle

**Only one electron per quantum state**

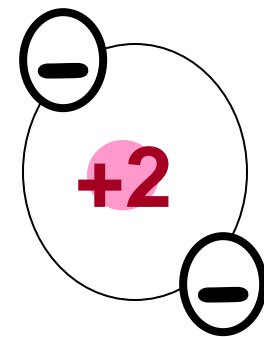
Once a quantum state is occupied  
additional electrons are *excluded*

# Light elements



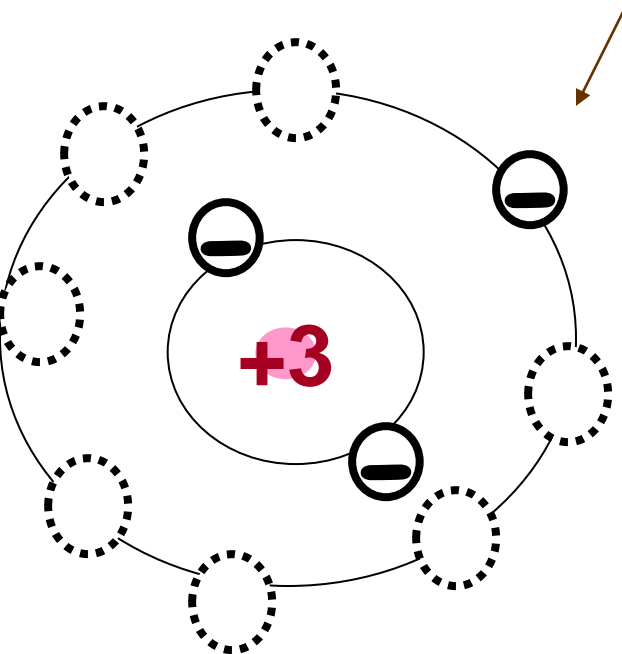
Hydrogen

1 electron in  
outermost shell

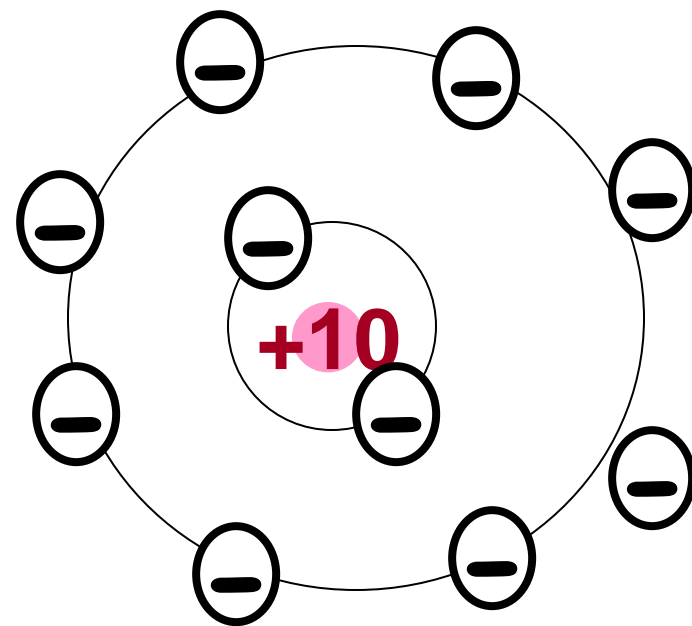


Helium

outermost  
shell is full



Lithium



Neon

# Periodic table of elements

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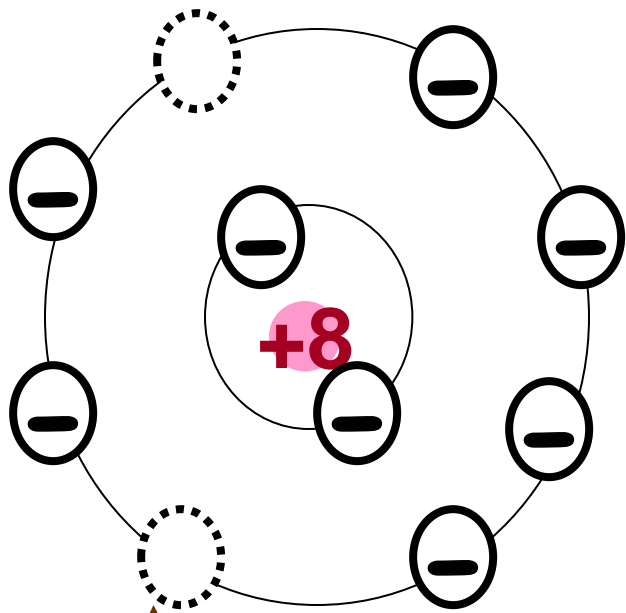
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		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb												
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1 e<sup>-</sup> in outer shell

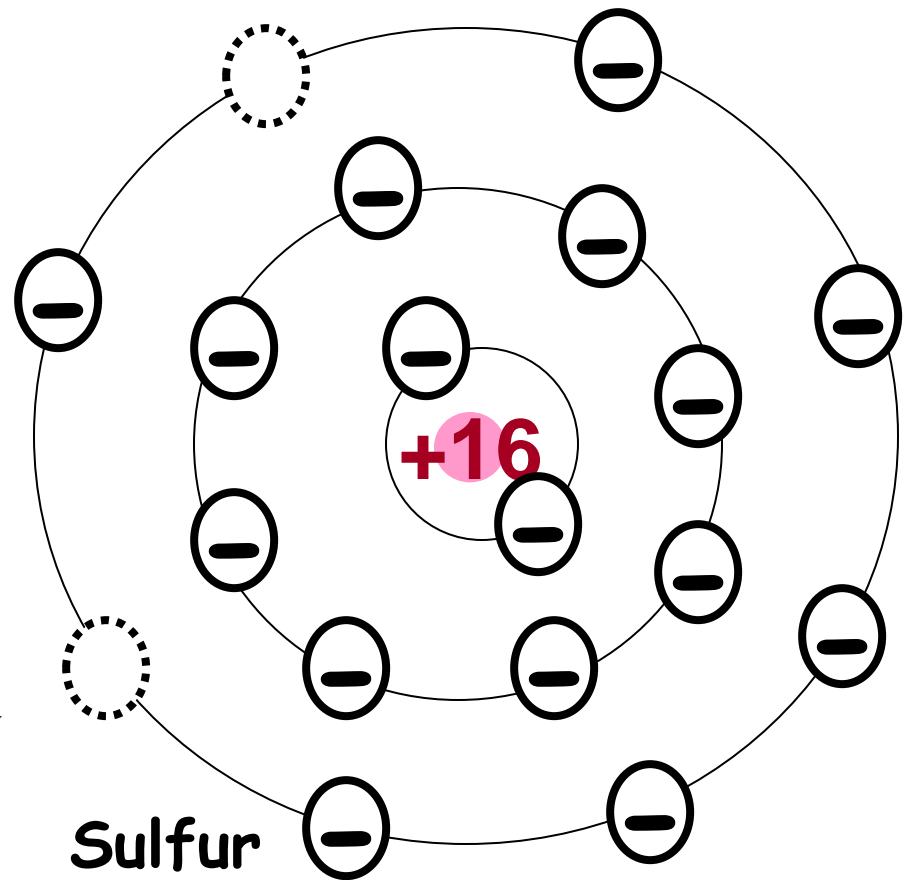
Filled outer shell



# Chemical properties depend upon the outermost shell configuration



Oxygen



Sulfur

Outermost shells  
Have 2 vacancies

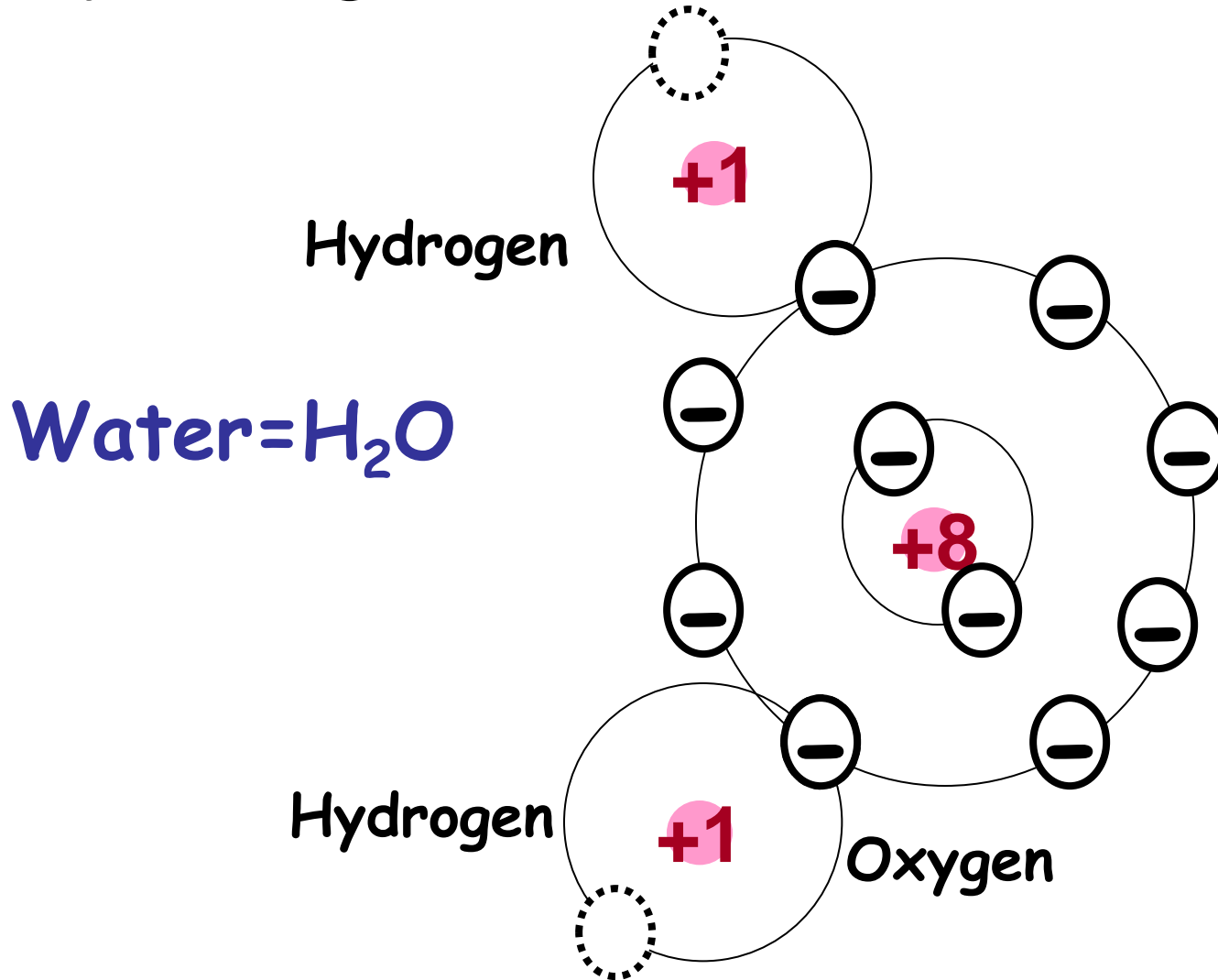


# Periodic table of elements

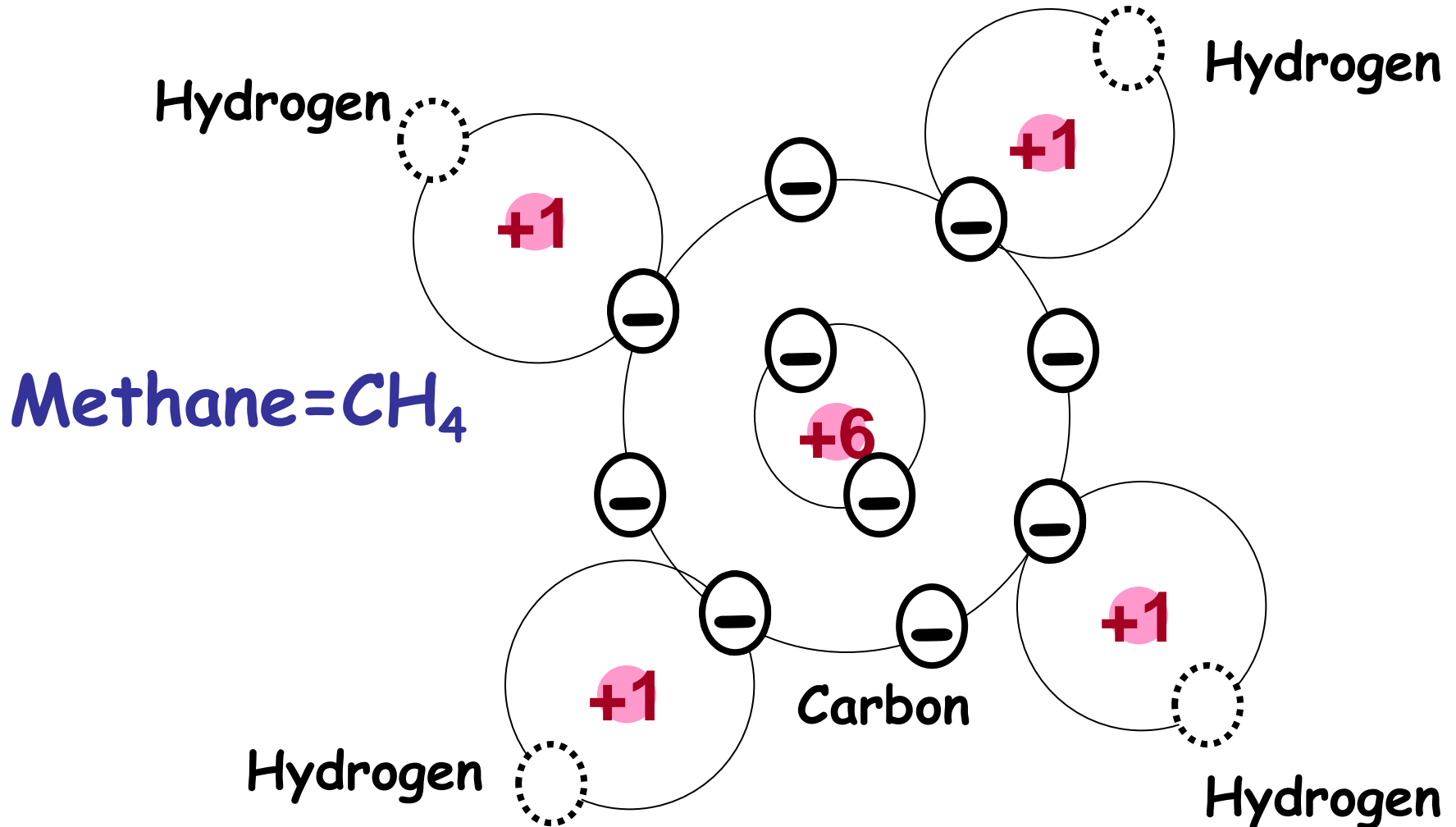
The periodic table of elements is displayed with various color-coded groups. A yellow vertical bar highlights the two columns of elements in the p-block (groups 13-18), with the text "2 vacancies in outer shell" written vertically next to it. This indicates that these elements have two empty orbitals in their outermost shell available for bonding.

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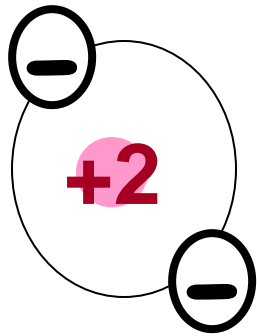
Atoms combine to form *molecules* by filling outer shells



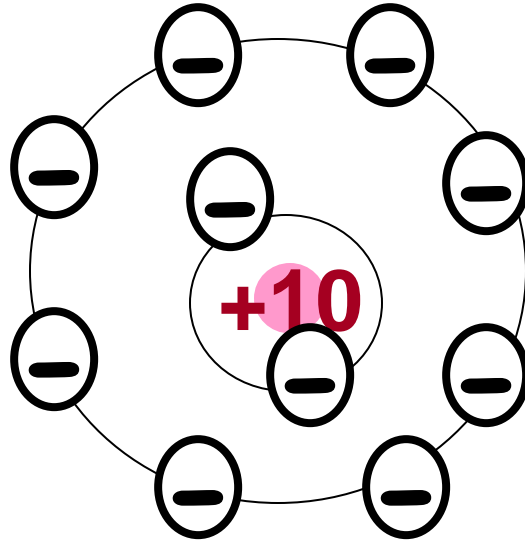
# Atoms combine to form molecules by filling outer shells



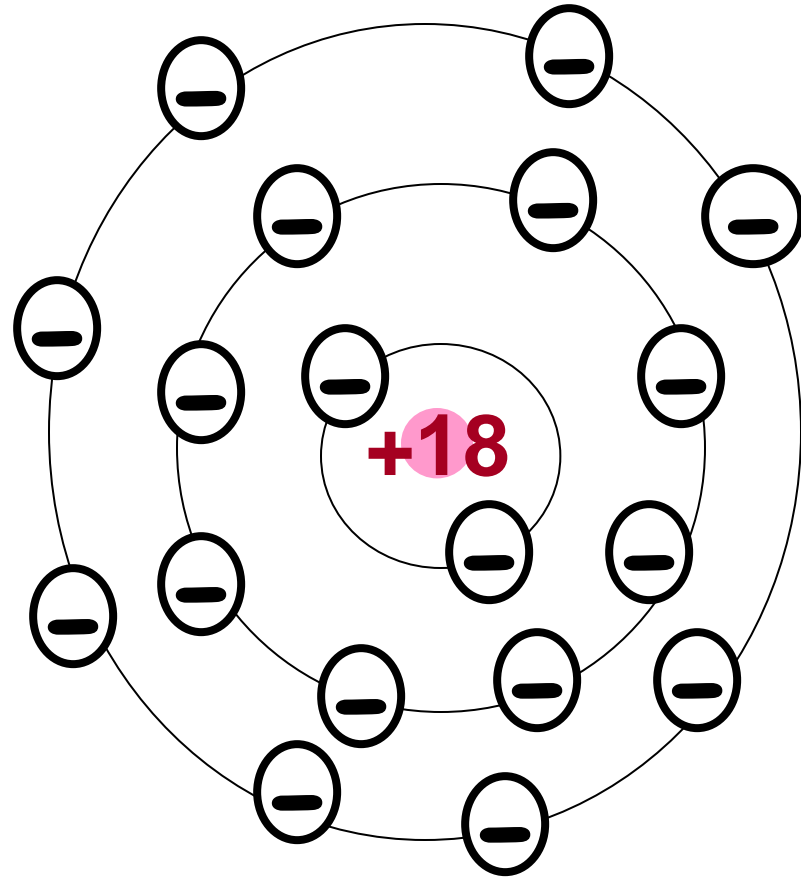
# Elements with full outer shells don't form molecules



Helium



Neon



Argon

**Noble gasses**

# Periodic table revisited

Elements in vertical rows have same outer shell configurations

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3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne											
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar											
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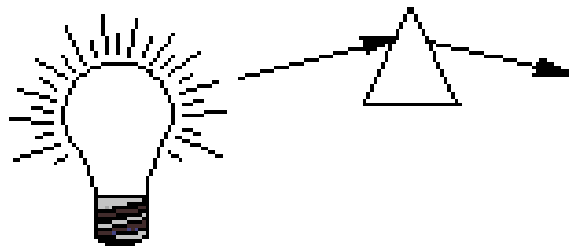
**1 elec in outer shell** (points to Group 1)

**4 e<sup>-</sup> in outer shell** (points to Group 14)

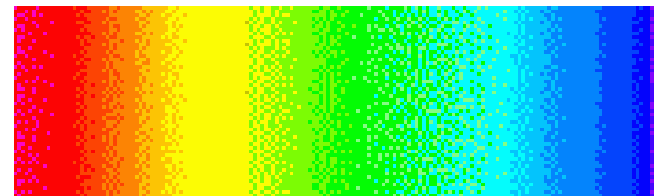
**2 vacancies in outer shell** (points to Group 16)

**Outer shell is full** (points to Group 18)

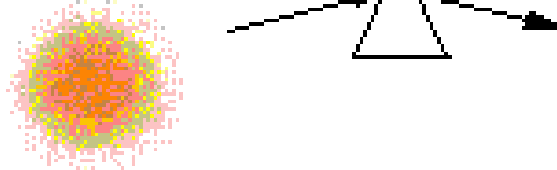
# Quantum theory & Atomic spectra



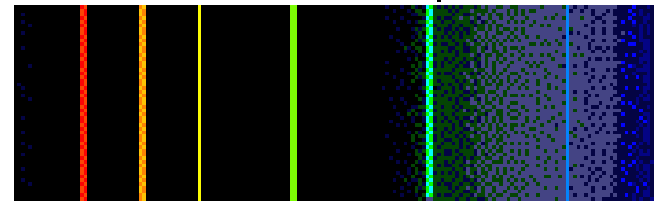
Continuum Spectrum



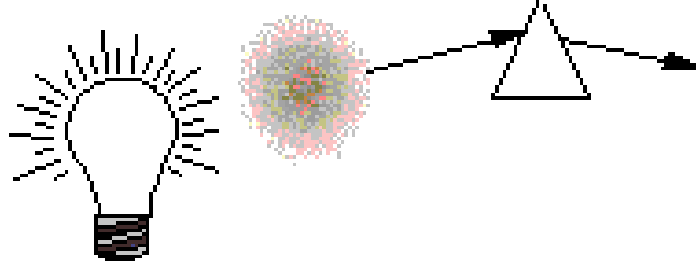
Hot Gas



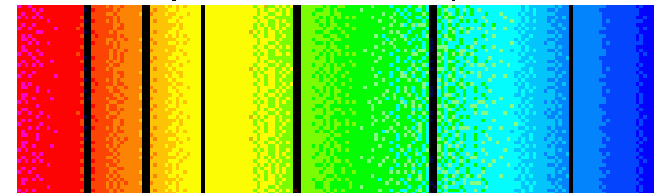
Emission Line Spectrum



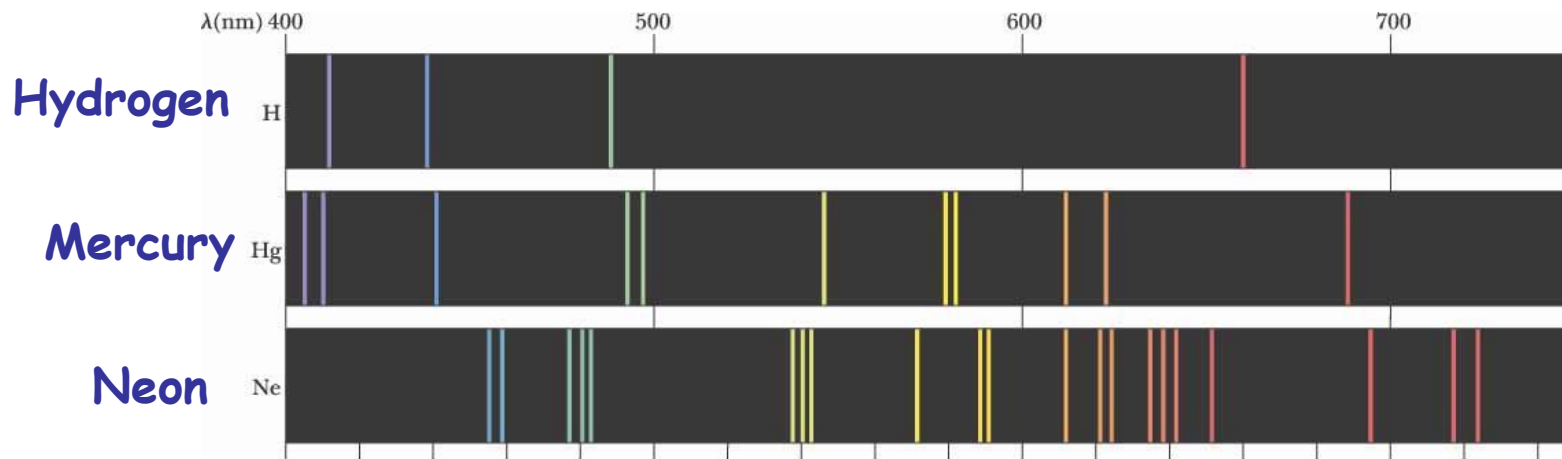
Cold Gas



Absorption Line Spectrum



# Spectra are atomic “signatures”

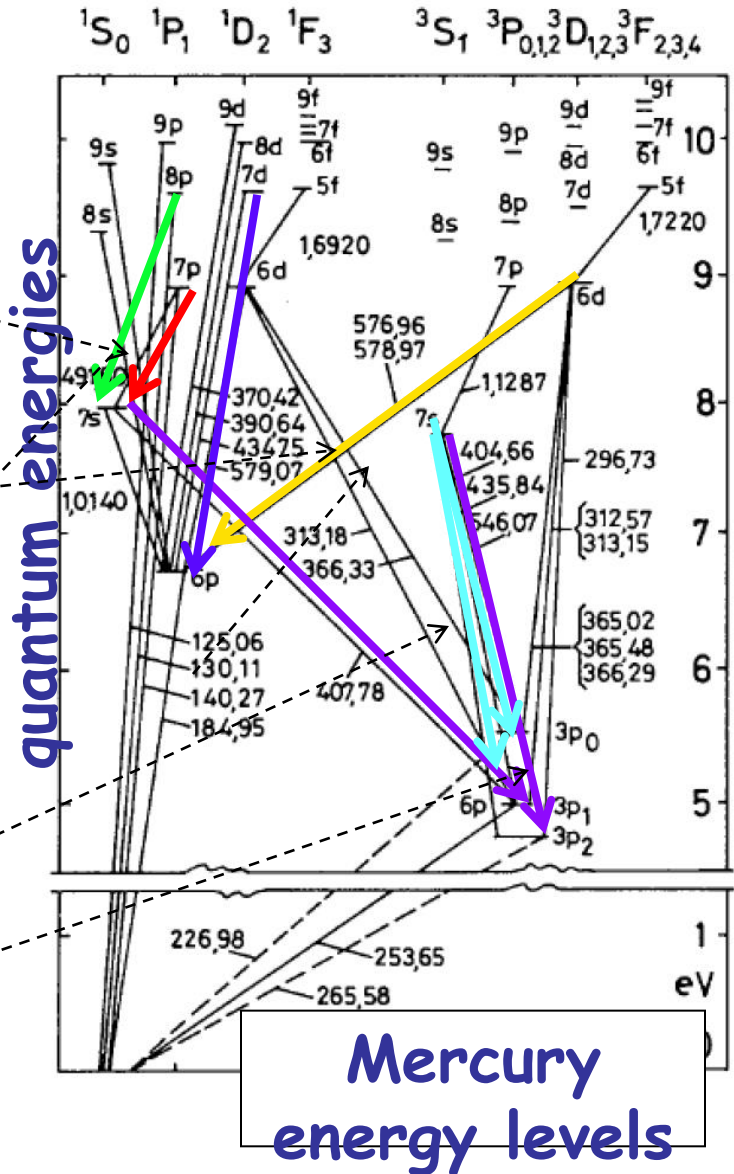
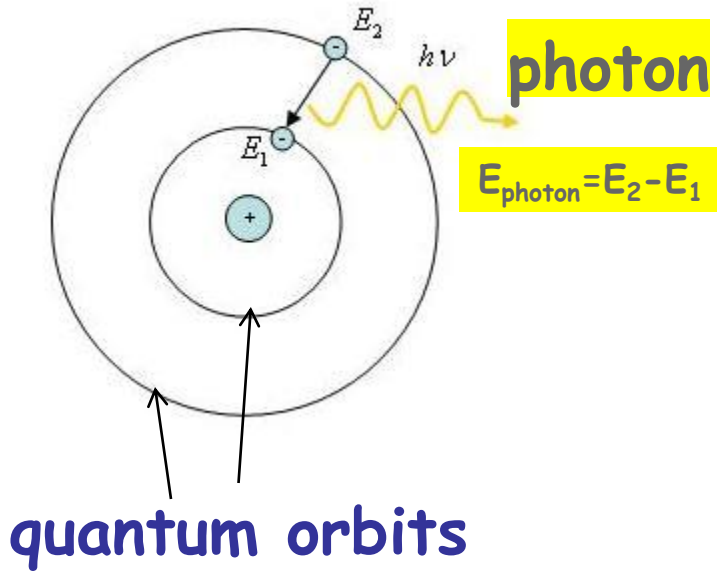




# Decoding atomic spectra

## Mercury spectrum

"quantum jump"





# 1924 Otto Laporte

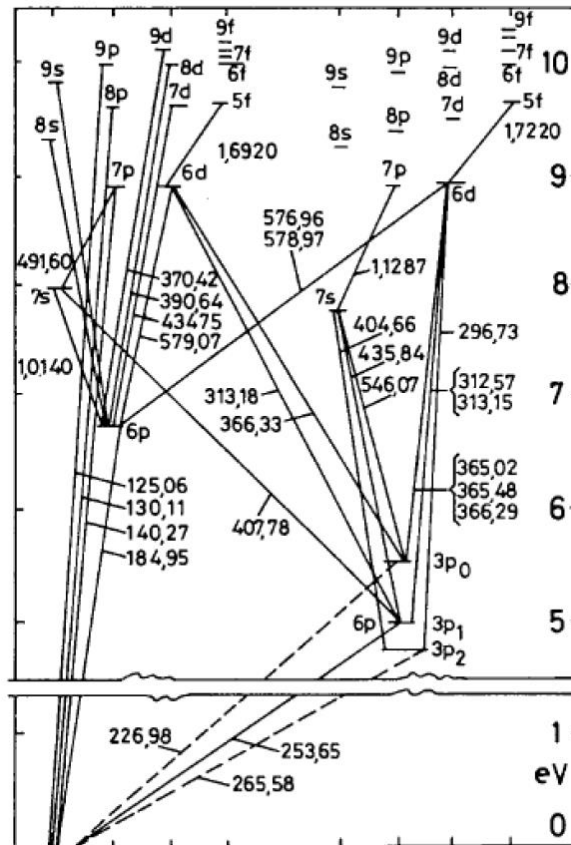
Allowed quantum states are either even or odd

even odd even odd even odd even odd

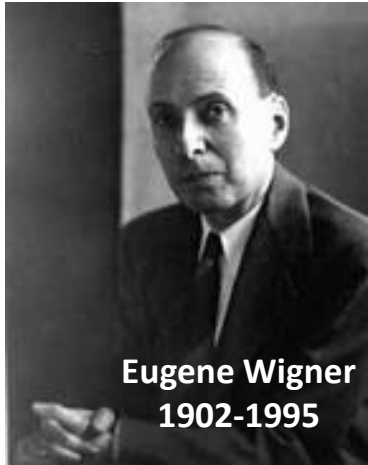
Laport rule

even → odd OK  
 odd → even OK

even ↘ even not allowed  
 odd ↘ odd not allowed



# Laporte rule is a consequence of Left-Right symmetry of Nature

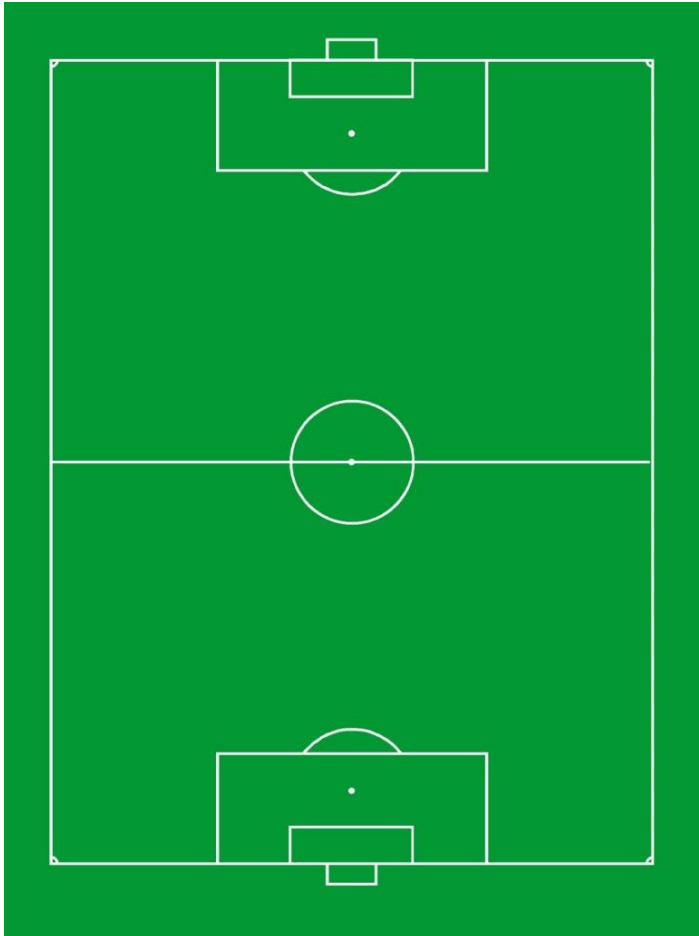


Left  $\leftrightarrow$  Right symmetry  
= “Parity” symmetry

1963 Nobel Physics prize “for the discovery and application  
of fundamental symmetry principles”

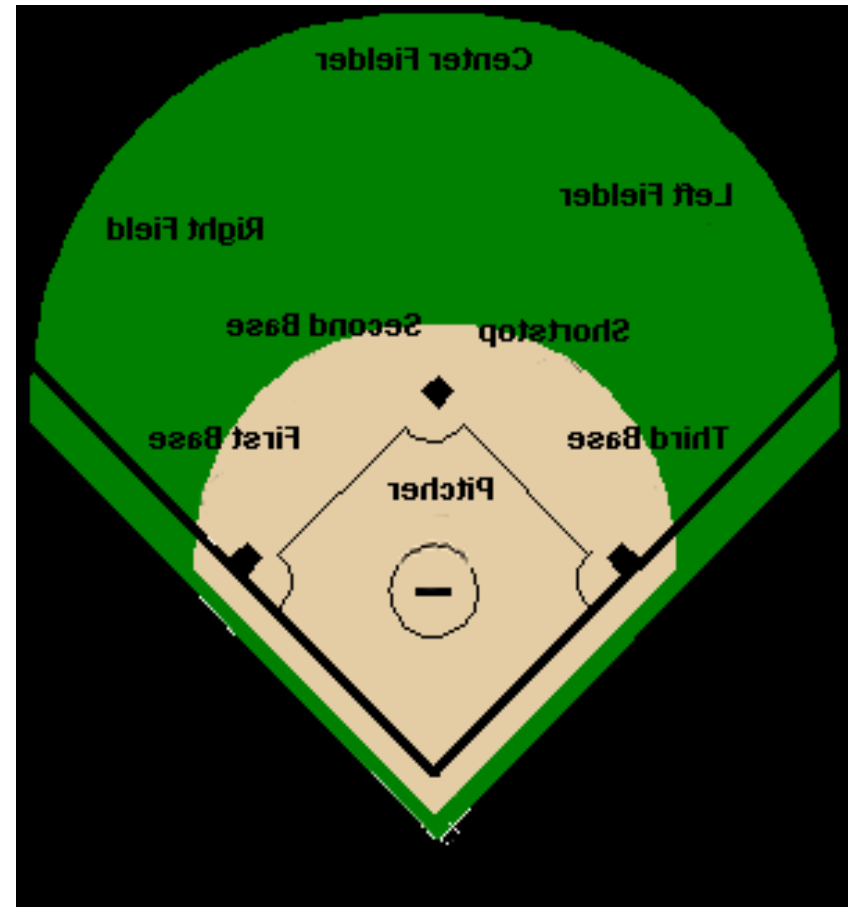
**P = Parity =  $L \leftrightarrow R$  /  $R \leftrightarrow L$**

**Football**



**Field (& rules) of football are parity symmetric**

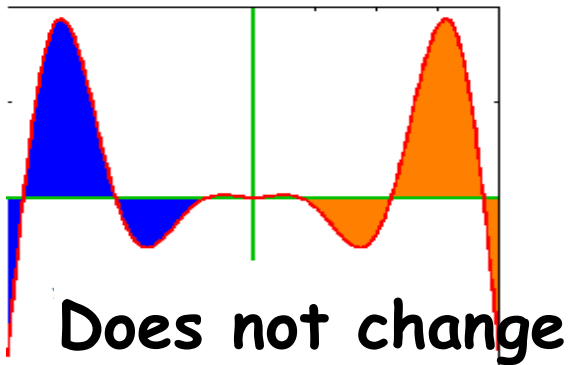
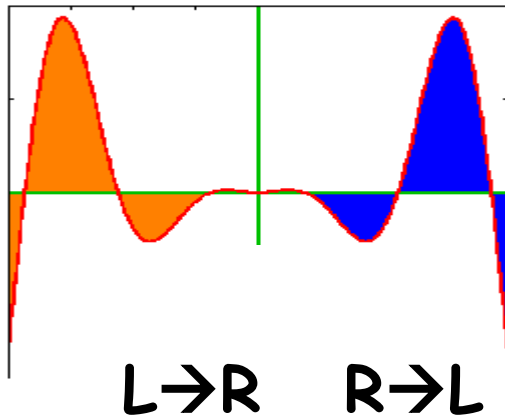
**Baseball**



**Rules of baseball are not parity symmetric**

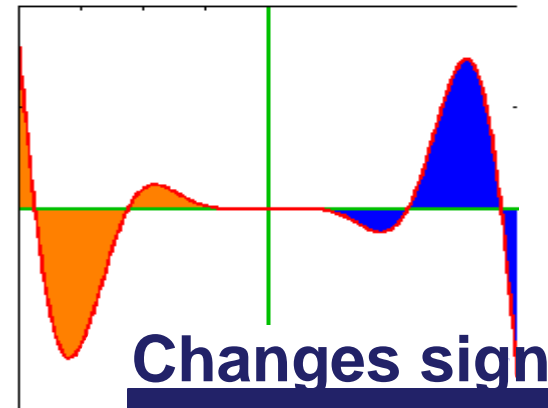
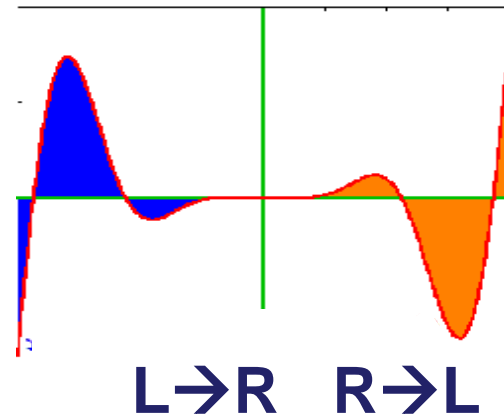
# Even & Odd quantum functions

## Even Function



Parity = +1

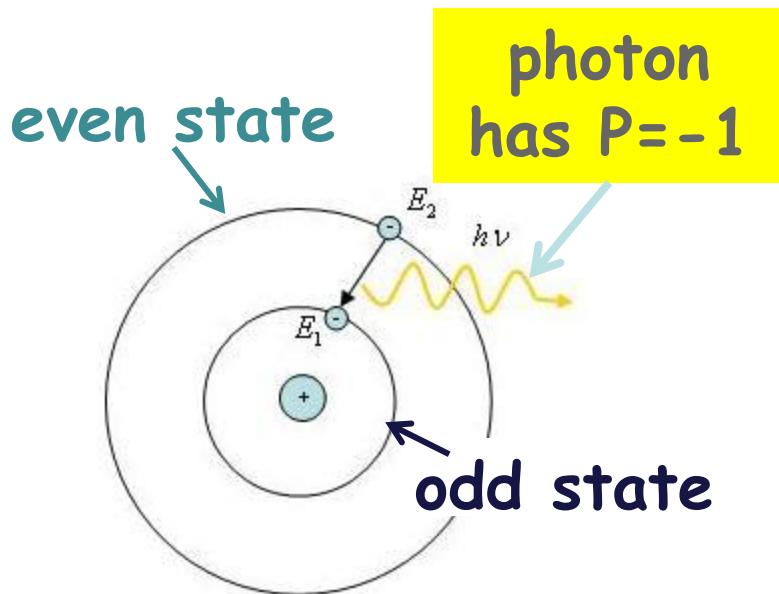
## Odd Function



Parity = -1

# Parity Conservation in QM

Left ↔ Right symmetry of Nature  
↓  
Conservation of Parity



**initially:**  
even state  
( $P_{\text{even}} = +1$ )

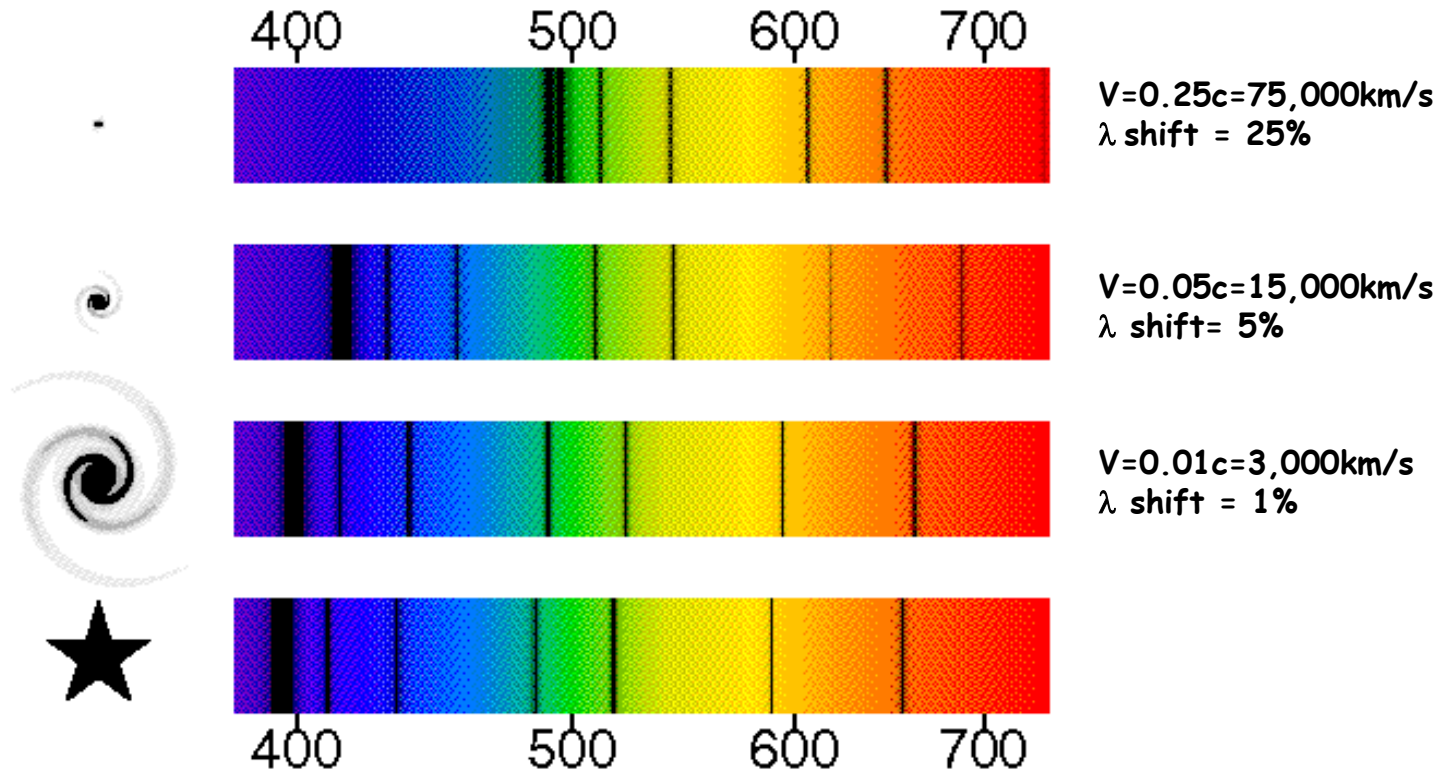
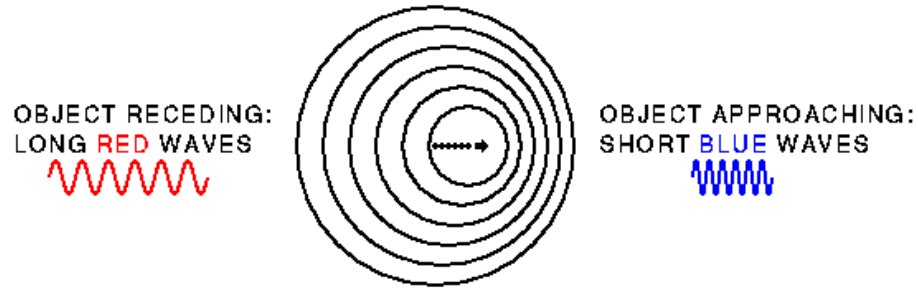
**finally:**  
odd state + Photon  
( $P_{\text{odd}} = -1$ ) ( $P_{\text{phot}} = -1$ )

$$P_{\text{initial}} = +1$$

$$P_{\text{final}} = (-1)(-1) = +1$$

Parity is conserved

# Atomic red shifts

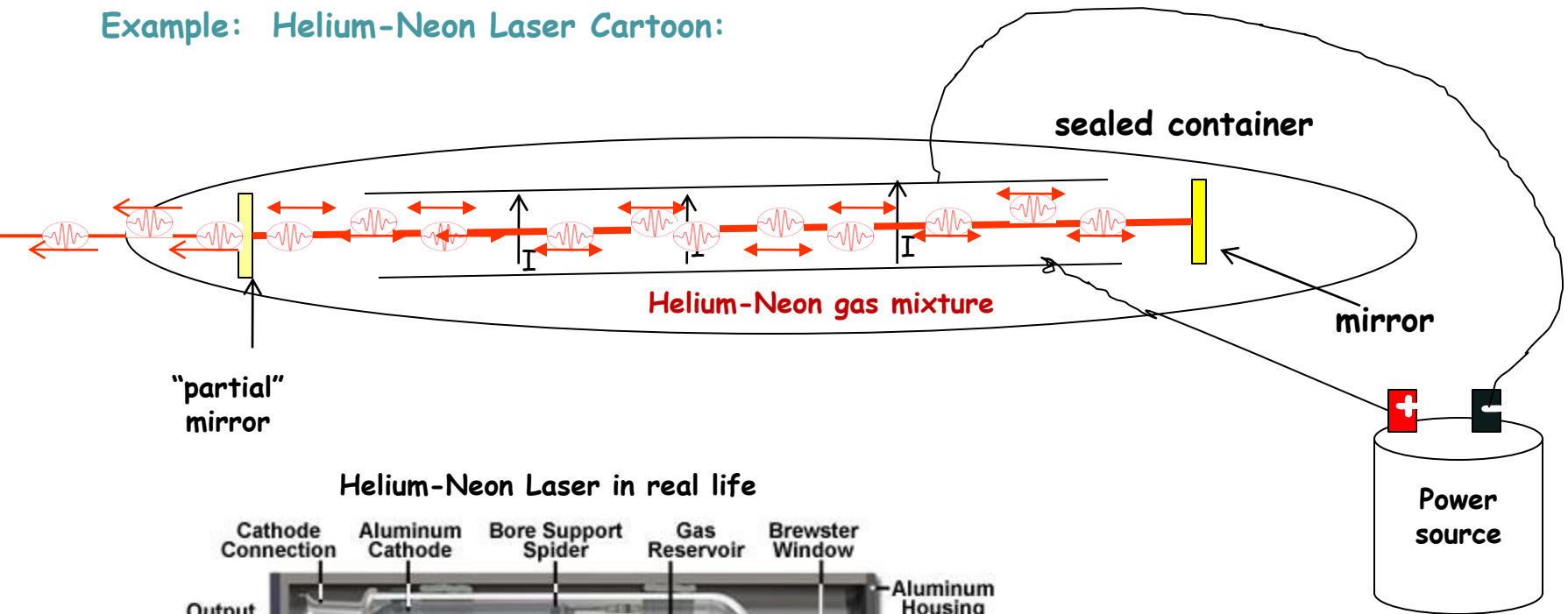




# Laser

– Light Amplification by Stimulated Emission of Radiation –

Example: Helium-Neon Laser Cartoon:



Helium-Neon Laser in real life

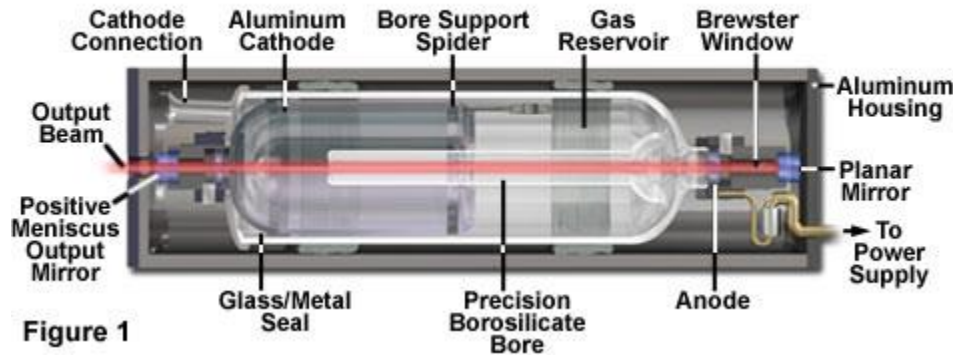


Figure 1

# Laser

– Light Amplification by Stimulated Emission of Radiation –

