Hydrogen atom – Bohr model

- Planetary model = electron orbits the central proton with angular momentum $L = n\hbar$, where n is quantum number (allowed orbits)

- Quantizing of energy: electron can change energy by “jumping” between allowed energies (absorption, emission)

- Basic conclusions:
  - Orbital radius: $r_n = n^2 r_1$
  - Orbital energy: $E_n = E_1/n^2$
    E_1 ground state energy ($E_1 < E_2 < E_3$)
  - Most stable state E_1, r_1 = **ground state**
  - Higher energy states = **excited state**

Hydrogen atom – Energy changes

- E_i = initial energy state
  E_f = final energy state
  change of energy: ΔE = $E_i - E_f$

$$h\nu = h\frac{c}{\lambda} = \left|E_f - E_i\right|$$

- This model works for hydrogen atom well, however, energies in other atoms cannot be determined

- Bohr model combines quantum description with simple mechanical description

$$\Delta E = \frac{E_1}{n_f^2} - \frac{E_1}{n_i^2} \longrightarrow \frac{1}{\lambda} = \frac{E_1}{hc}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

Hydrogen spectrum – emission and absorption

Spectral lines – changes with type of atom

$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$ Balmer series

$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$ Lyman series

$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$ Paschen series

$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{4^2} - \frac{1}{n^2}\right)$$ Brackett series

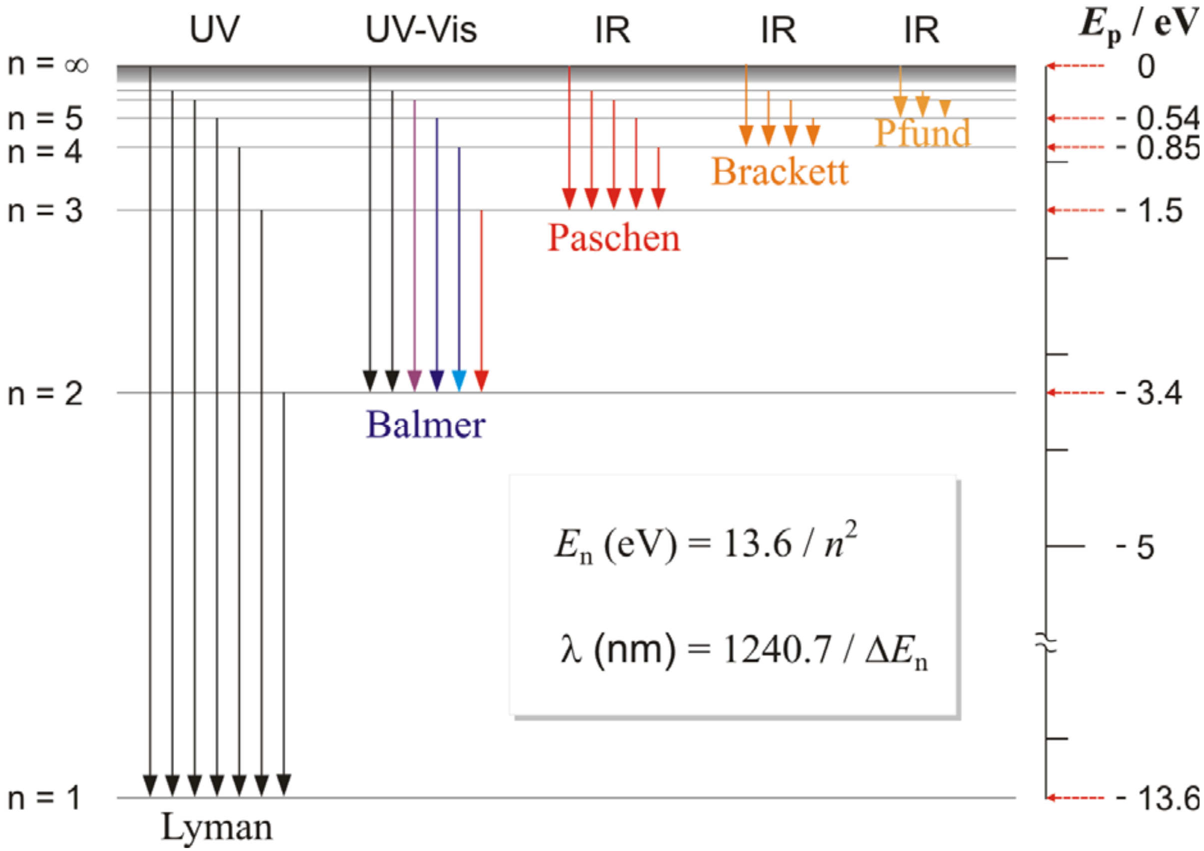
$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{5^2} - \frac{1}{n^2}\right)$$ Pfund series

$$R_\infty = 1{,}097 \cdot 10^7 \ \mathrm{m}^{-1}$$

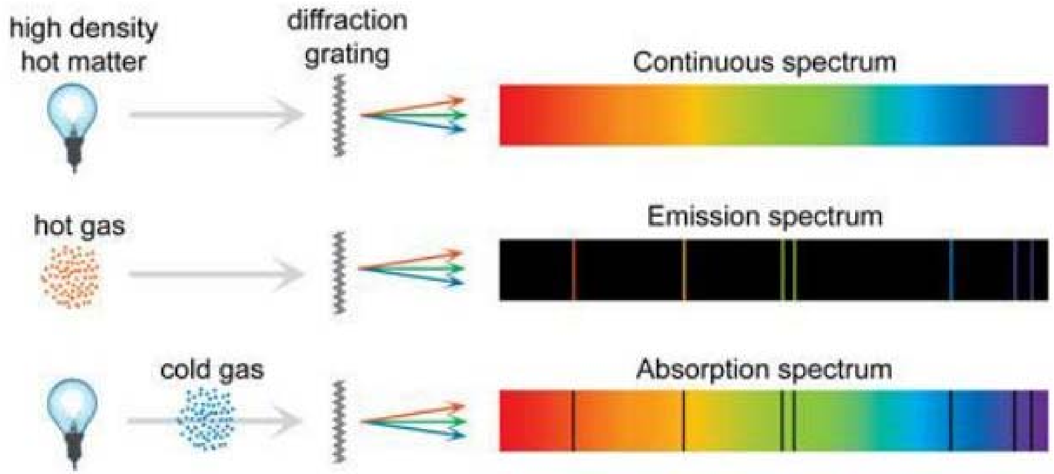
Rydberg constant

$$\sigma = \frac{1}{\lambda} = R_\infty \left(\frac{1}{s^2} - \frac{1}{n^2}\right), \ n > s$$

HRW: Ch39



UV
UV-Vis
IR
IR
IR
E_p / eV
n = ∞
n = 5
n = 4
n = 3
n = 2
n = 1
0
- 0.54
- 0.85
- 1.5
- 3.4
- 5
- 13.6
Pfund
Brackett
Paschen
Balmer
Lyman
E_n (eV) = 13.6 / n^2
λ (nm) = 1240.7 / ΔE_n



high density hot matter
diffraction grating
Continuous spectrum
hot gas
Emission spectrum
cold gas
Absorption spectrum

Schrödinger's equation and Hydrogen atom

3D electron trap – 3 quantum numbers

main (principal) quantum number $\boldsymbol{n}$
radial part of the wave equation = quantizing of energies

orbital quantum number $\boldsymbol{l}$
polar part of the wave equation = magnitude of angular momentum

Orbital magnetic quantum number $\boldsymbol{m_l}$
azimuthal part of the wave equation = orientation of the angular momentum vector in the space

discrete energy states $$E_n = -\frac{me^4}{32\pi^2\varepsilon_0^2\hbar^2}\frac{1}{n^2}$$

$$n \geq 1 \qquad (n = 1, 2, 3, \ldots)$$

$$l \leq n - 1 \qquad (l = 0, 1, 2, \ldots, n - 1)$$

$$|m_l| \leq l \qquad (m_l = -l, -l + 1, \ldots, -1, 0, 1, \ldots, l - 1, l)$$

Spin angular momentum

every electron has intrinsic spin angular momentum $\vec{S}$

Spin magnitude is quantized – spin quantum number s $\quad s = \frac{1}{2}$

S_z spin component is quantized –

– spin magnetic quantum number $\quad m_s = \pm\frac{1}{2}$

Pauli exclusion principle

no two electrons in a trap can have the same quantum state (= set of quantum numbers) => n, l, m_l, m_s differs

fermions	half-integer spin	proton, neutron, electron
bosons	zero or integer spin	

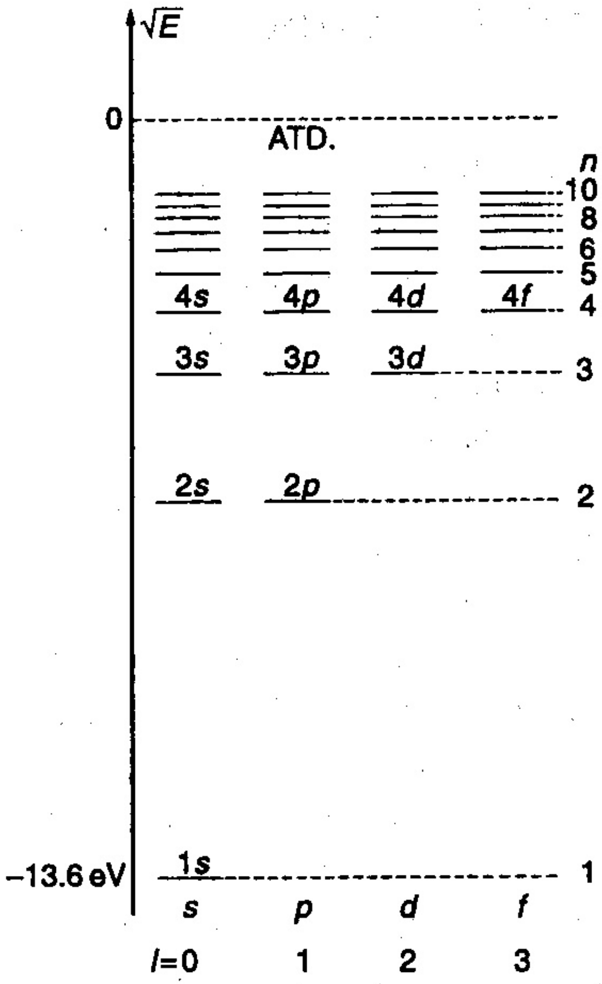
Electron configurations

Principal quantum number n	1	2	3	4	5		**shells n**
letter representation	K	L	M	N	O		
Orbital quantum number l	0	1	2	3	4	5	**subshells nl**
letter representation	*s*	*p*	*d*	*f*	*g*	*h*	

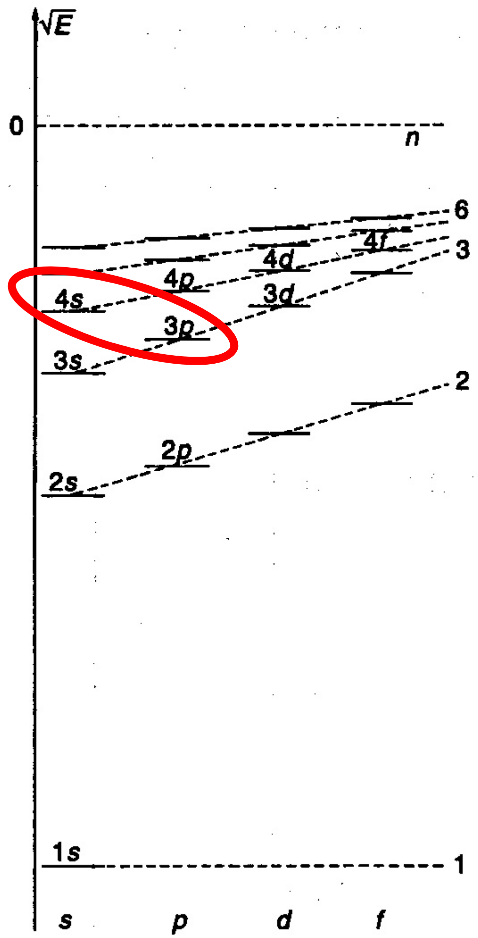
Subshell 2(2l+1) electrons = 2l+1 possibilities m_l + 2m_s

	s	*p*	*d*	*f*	*g*	*h*
l =	0	1	2	3	4	5
n = 1	1*s*					
n = 2	2*s*	2*p*				
n = 3	3*s*	3*p*	3*d*			
n = 4	4*s*	4*p*	4*d*	4*f*		
n = 5	5*s*	5*p*	5*d*	5*f*	5*g*	
n = 6	6*s*	6*p*	6*d*	6*f*	6*g*	6*h*

El. configuration 1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p* 5*s* 4*d* 5*p* 6*s* 4*f* 5*d* 6*p* 7*s* hydrogen



other atoms



Periodic table of elements

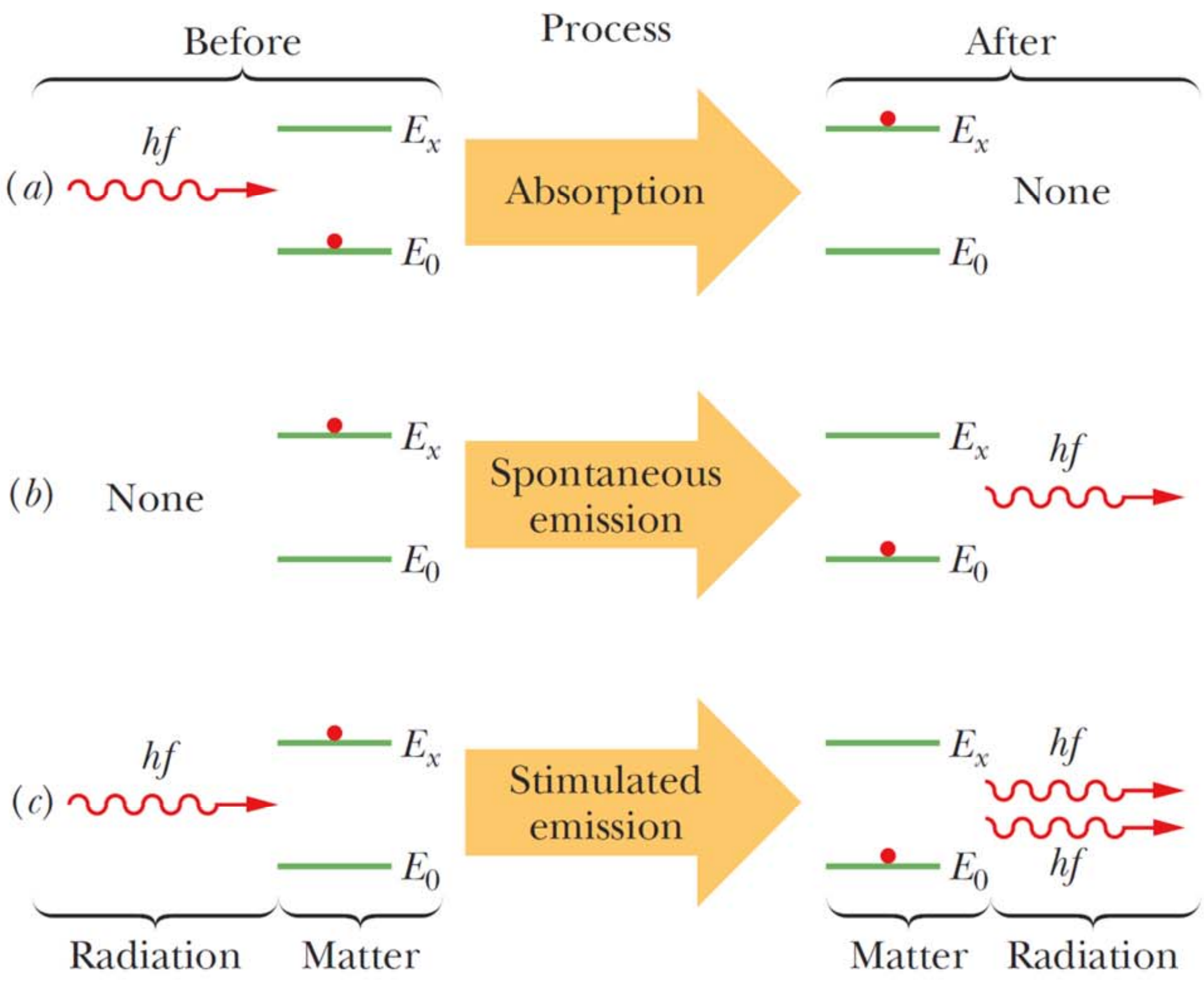
- Alkali metals
- Alkaline-earth metals
- Transition metals
- Other metals
- Other nonmetals
- Halogens
- Noble gases
- Rare-earth elements (21, 39, 57–71) and lanthanoid elements (57–71 only)
- Actinoid elements

period \ group	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	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
5	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
6	55 Cs	56 Ba	57 La	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
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

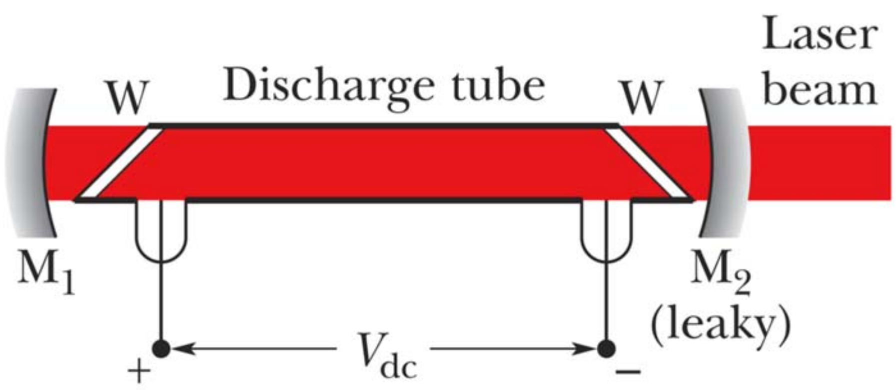
lanthanoid series 6	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
actinoid series 7	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

closed or open subshell = different chemistry of atoms

Lasers



These are three ways that radiation (light) can interact with matter. The third way is the basis of lasing.



$$He^* + Ne \rightarrow He + Ne^*$$