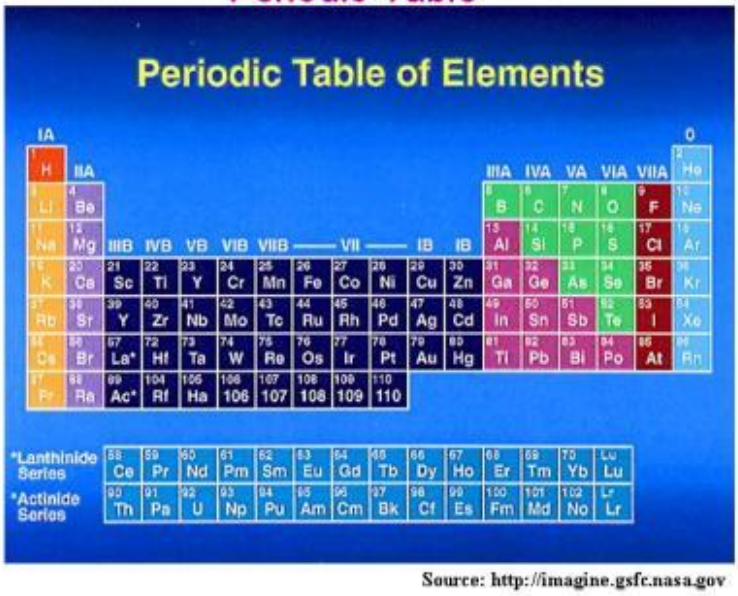
1. Physics 13: Atoms, Spectra Periodic Table

Physics 13: Atoms, Spectra
Periodic Table



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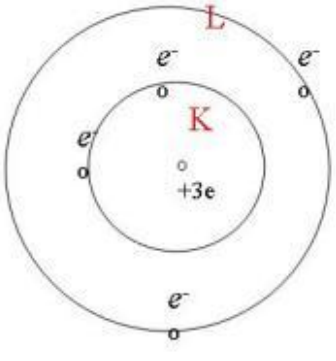
2. Beryllium and beyond

Beryllium and beyond



- $_4$Be - $1s^2 2s^2$
- Screening and repulsion
- Pairing as in He
- Less active than alkali (>He)
- Alkali Earth ns^2

$_4$Be, $_{12}$Mg, $_{20}$Ca, $_{38}$Sr, $_{56}$Ba, $_{88}$Ra

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3. Rules for ground state atoms

Rules for ground state atoms

- Each additional e^- goes into lowest possible energy level
- Total of $2(2l + 1)$ for each l subshell

- e^- configuration determines chemical properties
- E levels shift as they get filled
- 1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p
- Full sub-shells: ns^2 np^6 nd^{10} nf^{14} ng^{18}

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4. More elements

More elements

- $_5B$ $1s^2 2s^2 2p^1$
- $_6C$ " $2p^2$
- $_7N$ " $2p^3$
- $_8O$ " $2p^4$
- $_9F$ " $2p^5$ one empty p orbital⇒active - Halogen
- $_{10}Ne$ " $2p^6$ filled L shell E_{ion}=21.6 eV biggest in set Inert gas

$E_{ionization}$ grows with Z but not quite as Z^2

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5. More elements cont'd (2)

More elements 2

- $_{11}$Na $1s^2 2s^2 2p^6 3s^1$ E_{ion}=5.14 eV weakly bound
  3s e^- is far out & shielded - Alkali metal
- $_{17}$Cl " $3s^2 3p^5$ Halogen - active
- $_{18}$Ar " $3s^2 3p^6$ Inert gas - closed sub-shell
- $_{19}$K " $3s^2 3p^6 4s^1$ (4s penetrates into prob. cloud)
  Alkali metal
- $_{20}$Ca " $3s^2 3p^6 4s^2$ Alkali earth
- $_{21}$Sc "$3s^2 3p^6$ $3d^1$ $4s^2$ begins Transition metals
- $_{22}$Ti " " $3d^2$ $4s^2$ as 3d states get filled

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6. More elements cont'd (3)

More elements 3

- $_{23}$V " $3d^3 4s^2$
- $_{24}$Cr " $3d^5 4s^1$ switched - "balancing act"
- $_{25}$Mn " $3d^5 4s^2$
- $_{26}$Fe " $3d^6 4s^2$
- $_{27}$Co " $3d^7 4s^2$
- $_{28}$Ni " $3d^8 4s^2$
- $_{29}$Cu " $3d^{10} 4s^1$ switched - good conductor
- $_{30}$Zn " $3d^{10} 4s^2$ filled sub-shell
  - last transition metal

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7. Some element properties

Some element properties

- E_{ion} vs. Z depends on difficulty in removing outermost, **valence** electron
  - Peaks at Z=2, 10, 18, 36, 54 Inert gases
  - or 1s, 2s2p, 3s3p, 4s4p3d, 4d5s5p
  - Valleys for alkali metals
- Atomic radii vs.Z varies oppositely for valence *e*
- Electrical resistivity vs. Z (low for s^1 atoms)
- Magnetic susceptibility $\mu_0 M = \chi B$ (~L&S)
  - Paramagnetic $\chi>0$, diamagnetic $\chi<0$, ferromagnetic

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8. Spectra

Spectra

- $E_i - E_f = hf$ $\Delta l = \pm 1$, $\Delta m_l = 0$ or ± 1
- ~ Optical for outer valence electron transitions (E_γ =1.8-3 eV) selection rules & $\Delta j = \pm 1$ or 0 j=0 not→0
- Doublets due to ***L•S*** splittings

e.g. $_{11}$Na: $3p(^2P_{1/2}) \rightarrow 3s(^2S_{1/2})$ λ=589.59 nm
$3p(^2P_{3/2}) \rightarrow 3s(^2S_{1/2})$ λ=588.99 nm
single valence e^- outside closed (n=2) shell

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9. X-Ray spectra

X-Ray spectra

- E_γ = several keV

  e^- drops to vacancy in K or L shell

  $E_n \cong -[(Z-1)^2/n^2]\ 13.6$ eV

  especially for n=1 or 2

  K_α lines satisfy $\sqrt{f} \sim Z$ (Moseley)

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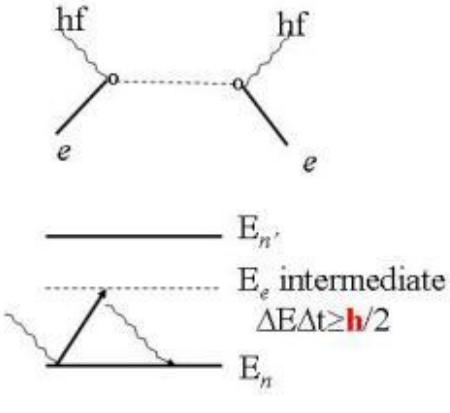
10. Scattering of light by atoms

Scattering of light by atoms

- Elastic or Rayleigh prob or $\sigma \sim 1/\lambda^4$

  Blue skies!

  atom (or molecule) is excited to an E_e which is not an *eigenvalue* of the system



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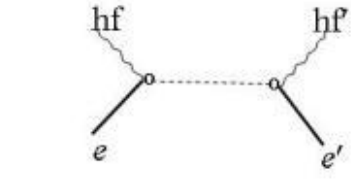
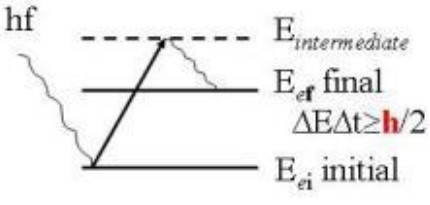
11. Inelastic scattering

Inelastic scattering

- Inelastic or Raman scattering





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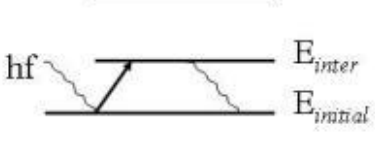
12. Resonance absorption

Resonance absorption

- When *E(intermediate)* is an eigenvalue probability to absorb photon is enhanced.

Reemission occurs after (random) time delay with varying phase.

Spontaneous emission
- uncorrelated phase



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13. Fluorescence

Fluorescence

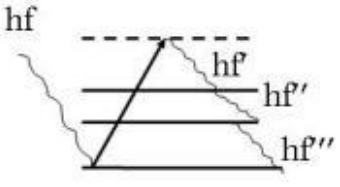
e.g. UV producing intense visible

$t \sim 10^{-8}$ sec

If an intermediate state is *metastable*

$t \sim 10^{-3}$ to 10^{2} sec

Phosphorescence



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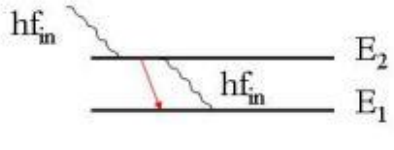
14. More scattering

More scattering

- Photoelectric effect: $hf > | E_i - E_\infty |$
  - from bound e^- to free e^-
- Compton scattering: $hf >> | E_i - E_\infty |$
  - From quasi-free e^- to free e^- & to lower $E(e^-)$+ hf'
- Stimulated emission: $hf_{in} = E_2 - E_1$ with e initially in higher E_2 - causes emission of hf_{in} in phase $hf_{in} \rightarrow 2(hf_{in})$



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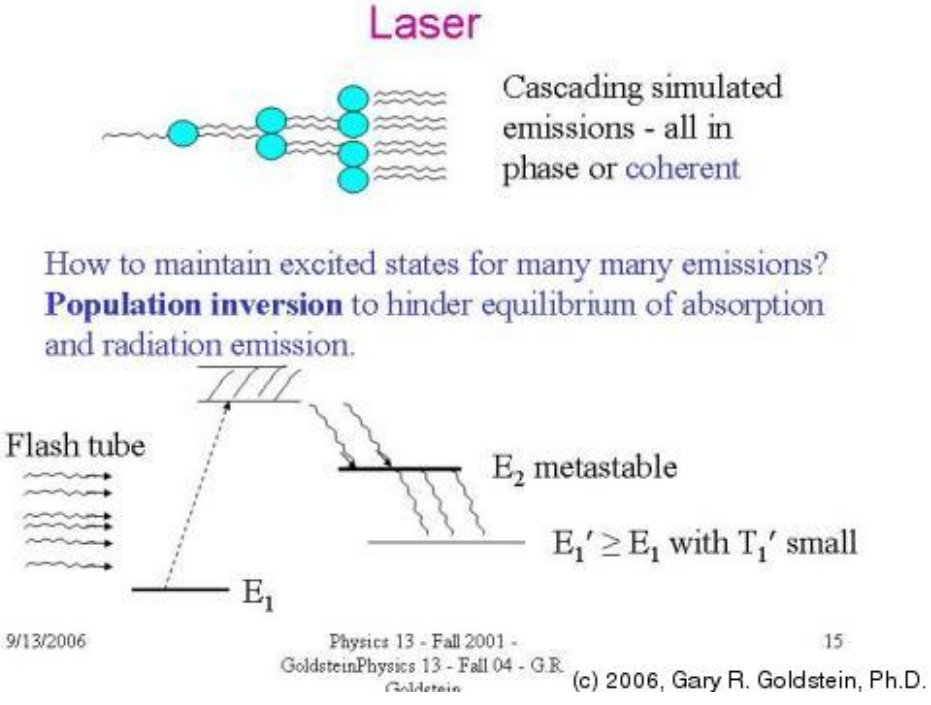
15. Laser



16. Laser geometry