

1e Werkcollege SdM: Atoms and Molecules: 2009

8 Juni 2009

- 1) Consider light particles (photons) at a (vacuum) wavelength of 500 nm.
Use the relations: $\lambda = c/\nu$, $E=h\nu$, $E=qV$ and calculate:
 - the frequency in Hz
 - the energy in Joule and
 - in electron-volt (eV)
 - wavenumber in cm^{-1} .
 - what is the momentum (*Ned: impuls*) of such a photon ?
 - what is the wavelength in air ?Calculate the Rydberg constant (13.6056981 eV) R_∞ in cm^{-1} .

- 2) In 1997 the Nobel Prize in physics was given for “Laser Cooling Techniques”. To understand what that is about, solve the following problem.
The thermal velocity of hydrogen atoms is approximately 2000 m/s. Assume an H-atom travelling in the direction of a laser beam of Lyman- α photons.
 - How many absorptions are necessary to stop the H-atom ? *Hint: use momentum transfer.*Assume that there are enough photons in the laser beam, so that the H-atom will be in the excited state half of the time. The excited state lifetime (average time before spontaneous emission) is 1.5 nanoseconds.
 - How much time does it take to stop the H-atom ?
 - What is the stopping distance ?
 - Calculate the acceleration a ($= \Delta v/\Delta t$) imposed by the laser beam.

- 3) Consider the “Lyman- α ” transition in atomic hydrogen. This is the transition between $n=2$ and $n=1$ levels. What is the isotope shift for this transition between normal hydrogen and deuterium (having an additional neutron in the nucleus). Take for the masses: $M_D=2M_H$. Calculate also the transition frequency for “positronium”, where the proton is replaced by a positively charged electron (positron) with mass m_e .
Extend the same procedure to the example of a heavy Rydberg system where the electron is replaced by a H^- particle (which you may consider as a point-like particle, in an approximation): what is the Rydberg constant of the $H+H^-$ system bound by the $1/r$ Coulomb force.

- 4) The hydrogen atom H in the ground state ($n=1$) has a different mass than one in the excited state ($n=2$). What is the relative difference ?

- 5) What elements have characteristic K_α Röntgen emissions at 0.8364 nm, 0.2111 nm and 0.1798 nm respectively.

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