Ex5a, wis 21

Exercise 1

1 Early atomic physics

Please visit the website of (NIST) for obtaining a list of values for fundamental constants (i.e, electron mass).

It was well known that certain colours and so spectra are distinct features of different natural elements (atoms). We all see the yellow light of the street lamp which feature the sodium atom. One associates the color of light to a frequency and hence a certain wavelength. The Hydrogen moelcules when bombarded by electrons in electric discharge glow with a red color of 656 nm, then if you give it more energy you will see a blue light of 486 nm , these are called the Balmer α and β lines respectively.

(a) What is the wavenumber and frequency corresponding to these colors ?

(b) Normally an atom emits different colors when excited (by heating it or electric discharge or light), when viewed by you eye you will see the combination of different colors as only white light.
What can we use to differentiate the different colors?

(c) Using the following components (High voltage power supply; hydrogen element discharge tube) ,come up with an experiment to find out the different spectral lines of Hydrogen.

(d) To explain the discrete nature of different atomic spectral lines, Bohr has come up with a theory starting from a classical approach to describe the energy levels of the Hydrogen atom.
Here, we will try to arrive at this expression starting from simple principles in analogies to planetary motion.

  (a) If we imagine the electron orbiting the proton with a velocity ν which forces between the electron and the proton need to be balanced, write this down?

  (b) What is the total energy of the electron (both kinetic and potential)?

  (c) Classically an accelerated charge radiate energy, can this be the case for the electron in the Hydrogen atom, and why?

(d) Now let us assume that the electron is only allowed to have certain orbits, by quantizing the angular momentum $m_e v r = n\hbar$, use this assumption together with what you found from above to see that the radii of the allowed orbit is $r = a_0 n^2$

(e) a_0 is called the Bohr radius, give an expression for it in terms of the mass of the electron and other physical constants.

(f) Now, what is the energy expression in terms of the bohr radius?and for n =1 what is the energy in electron volts, cm^{-1}, THz, and Kelvin?

(g) We can form a muonic Hydrogen by replacing the electron with a muon, What would be the Bohr radius of a muon?, then what is the ratio of muon Bohr radius to the electron Bohr radius.

(h) An excited Hydrogen emits a photon from higher energy $n^{'}$ to lower energy n, what is the expression for the energy difference written in physical constants only, n and $n^{'}$.

(i) What is the most recent value for the Rydberg constant, look at the website `https://codata.org/`.

(j) Now using what we have derived calculate the energy difference between the energy level n =1 and n =2, what color is this?

2 Isotope shift

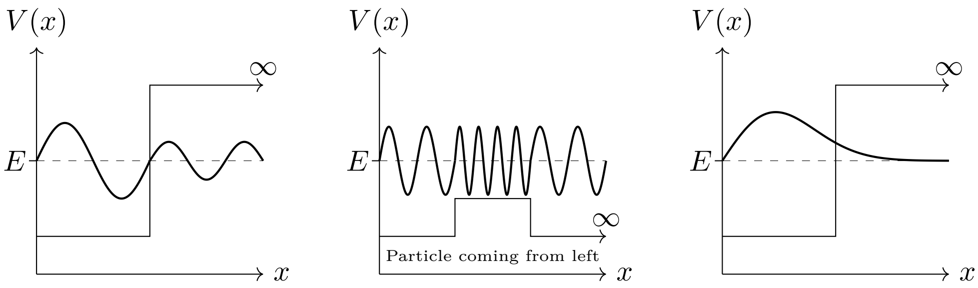
The deuteron has approximately twice the mass of the proton. Calculate the difference in the wavelength of the Balmer- α line in hydrogen and deuterium.

3 Potential Wells and Barriers

Remember the Schrödinger equation, (Please read chapter one and two of "Griffiths D.J - Introduction to quantum mechanics"):

$$E\Psi = \hat{H}\Psi = \left(\frac{\hat{p}^2}{2m} + V\right)\Psi$$

The following pictures show wave functions in different potentials. Which of these functions are allowed solutions for the specific eigenvalue problem, which are not? Why are they not allowed?



(a) (b) (c)