Homework Solutions, Physics 117
Home Work Problem Set #13

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Solutions by JJG

Ch 23: CQ 24, 38, 52; Ex 15, 20, 23
Ch 24 CQ 1, 6; Ex 1, 7 (& Ex 13 added)

23: CQ 24 In the simplest view the electrons are in fact falling into the nucleus, but their tangential velocity is too large to allow the electric force exerted by the (charged) nucleus upon them to pull them any closer, — in complete analogy with the plan[ets] travelling around the sun, which are also falling freely towards the sun, but never get any closer because of their tangential velocities.

But this simple view is false because it overlooks the fact that a CHARGED electron in a circular orbit will generate outgoing electromagnetic waves which will carry away energy and allow it to spiral into the nucleus. Rutherford's model offers nothing which can prevent this.

The stability of the electronic orbits requires an explicit hypothesis that certain (particular) quantized orbits are stable against such classical electromagnetic emission, and can only emit Electro-Magnetic radiation if they jump from one allowed orbit with its discrete quantized energy into another allowed orbit with a lower discrete quantized energy. In such a jump a photon is emitted with energy, hf, equal to the energy difference of the two orbits. This hypothesis therefore explains why only specific frequencies occur in the emission & absorption spectra. Once in the lowest available level, the electron can no longer emit electromagnetic radiation.

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23: Q 38 The energy of a photon depends upon (and is uniquely defined by) its frequency: $E_{photon} = hf$. When a photon is absorbed to eject a photoelectron, Energy is conserved, so that the energy transferred to the electron in the metal is equal to hf. Since the electron may lose some energy in escaping from the metal, it may have a final KE less than hf, but never a KE more than hf. Thus hf defines the MAXIMUM KE of the photoelectron

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23: Q 52 In the periodic table Rn (Z = 86) occurs in the eighth column together with the inert gases, He, Ne, Ar, Kr, and Xe. It is therefore expected, like all of these inert gases, to occur as a monatomic gas which does not readily form molecules with any atom, not even with itself.

23: Ex 15 For $n = 4$, use result that radius of nth Bohr orbit is $r_n = n^2 \cdot r_1$ [See p 496, l2] and fact that $r_1 = 5.29 \times 10^{-11}$ m

Then $r_4 = (4)^2 (5.29) \times 10^{-11} m = 84.6 \times 10^{-11} = \boxed{8.46 \times 10^{-9} m = r_4}$

23: EX 20 $E = hf = 13.6 eV = 13.6 eV \times \left(\frac{1.6 \times 10^{-19} J}{eV}\right)$

Then $f = \frac{E}{h} = \frac{(13.6)(1.6 \times 10^{-19}) J}{6.63 \times 10^{-34} J\text{-}sec} = 3.28 \times 10^{15}/sec = \boxed{3.3 \times 10^{15} \text{ Hertz.}}$

From Fig 22.26 on p 471 & the text of p 471 the visible frequencies are $(4 < f_{vis} < 7.5) \times 10^{14}$ Hz. This frequency lies ABOVE the visible range.

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Solutions by [illegible]

23 : Ex 23 $\quad hf = E_{photon} = [6.63\times10^{-34}\,J\text{-}s][2\times10^{18}/sec] = 1.33\times10^{-15}\,J$

In eV, this energy is $= 1.33\times10^{-15}\,J \times \left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right) = 0.83\times10^{4}\,eV$ $\boxed{= 8.3\ keV}$

[Here 1 keV $= 10^{3}$ eV.]

24: Q1. Successes: Predicted spectral line energies for H quantitatively.

Excluded the classical spiralling in of electrons to the nucleus & the continuous photon spectra which that would imply & replaced it by the discrete line spectra actually seen.

Provided shell structure to explain the fact that electrons become more loosely bound as the atomic number, Z, increases across a line in the periodic table, but did not predict the true lengths of the table's periods.

Failures: Unable to predict the spectral lines (for higher Z's).

Unable to describe the splitting of the same expectedly single lines into multiple lines of nearly the same energy.

Did not allow a place for $L=0$ states in the spectrum.

Failed to describe the intensities of various lines quantitatively.

23 Q6 Consider 3 (or any odd integer number) of anti nodes moving around a loop. THEN if two are moving always out of phase (in opposite directions) with one another, then it is impossible for the third which is adjacent to both to be moving opposite to BOTH. Thus since every pair of adjacent anti nodes must move in opposite directions in order for a standing wave to occur, there must be an even number of them on the loop.

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24 Ex 1. $\lambda = h/p$ = De Broglie wave length of particle of momentum, p.

For V.W with $M = 1000\,kg$, $v = 30\,m/sec$, $p = 3\cdot 10^4 \frac{kg\,m}{sec}$

and $\lambda = \frac{6.6\times 10^{-34}(J\text{-}sec)/sec}{3.0\times 10^{4}(kg\text{-}m)} = \boxed{2.2\times 10^{-38}\,m}$ = De Broglie wave length of V.W.

24 Ex 7. What is speed of electron with De Broglie wave length $\lambda = 10^{-10}\,m$?

Since $\lambda = h/p$, we have $p = h/\lambda = mv \Rightarrow v = h/m\lambda$

i.e. $v = \frac{6.6\times 10^{-34}(J\text{-}sec)}{(9.1\times 10^{-31}\,kg)\cdot 10^{-10}\,m} = 7.3\times 10^{-34+31+10-1} = \boxed{7.3\times 10^{6}\,\frac{m}{sec}}$

23: Ex 13 [This solution is presented out of order because it (Ex 13) was once assigned in error, and is retained here as an extra, unassigned solution.]

According to the Bohr model, the angular momentum is $L_n = n\frac{h}{2\pi}$ where $n=1$ specifies the ground state.

Thus the Bohr Model says $L = h/2\pi$ in the ground state.

Actually in the true quantum mechanical description, the angular momentum of an e^- in the ground state of Hydrogen is zero, but the Bohr model did not allow an angular momentum of zero for an allowed orbit.

It was fortunate for the Bohr model, that even though the specified angular momentum was wrong, the energy values happened to be correct! As a result the model was developed further into Quantum Mechanics, and was NOT rejected out of hand.

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end HW Set # 13