PHYSICS

BOOKS - HC VERMA

BOHR'S MODEL AND PHYSICS OF THE ATOM

Example

1. Calculate the energy of a $He^{+} ion$ in its first excited state solution

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2. Calculate the wavelength of radiation emitted when He^{+} makes a transtion from the state $n = 3$ to the state $n = 2$

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3. The excitation energy of a hydrogen-like ion in its first excited state is $40.8eV$ Find the

energy needed to remove the electron from the ion

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Worked Out Example

1. Find the radius of Li^{++} ions in its ground state assuming Bohr 's model to be valid

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2. A particular hydrogen like radiation of frequency $2.467 \times 10^{15} Hz$ when it makes transition from $n = 2 \rightarrow n = 1$,What will be the frequency of the radiation emitted in a transition from $n = 3 \rightarrow n = 1$?

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3. Calculate the two highest wavelength of the radiation emitted when hydrogen atoms make transition from higher state to $n = 2$

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4. What is the wavelength of the radiation emitted when the electron in a hydrogen atom jumps from $n =$ infinity $\rightarrow n = 2$?

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5. (a)Find the wavelength of the radiation required to excited the electron is Li^{++} from the first to the third Bohr orbit (b) How many

spectral lines are obseved in the emission spactrum of the above excited system?

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6. Find the wavelength present in the radiation emitted when hydrogen atoms emitted to $n = 3$ states return to their ground state.

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7. How many different wavelengths may be observed in the spectrum from a hydrogen sample if the atoms excited to states with principal quantum number n?

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8. Monochromatic radiation of wavelength λ is incident on a hydrogen sample in ground state hydrogen atoms absorb a fraction of

light and subsequently emit radiation of six different wavelength .Find the value of λ

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9. The energy needed to detach the electron of a hydrogen like ion in ground state is a 4 Rydberg. (a) what is the wavelength of the radiation emitted when the electron jumps from the first excited state to the ground state? (b) What is the radius of the orbit for this atom?

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10. A hydrogen sample is prepared in a particular state A photon of energy $2.55eV$ get observed into the sample to take some of the electron in a farther excited state B find the quantum numbers of the state A and B

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11. (a) Find the maximum wavelength $\lambda_{90})$ of light which can ionize a hydrogen atom in its

ground (b) light of wavelength λ_0 is inclined on ahydrogen atom which is in its first excited state find the kinrtic energy of the electron coming out

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12. Derive an expression for the magnetic field at the site of the necleas in a hydrogen atom due to the circular motion of the electron Assume that the atom is in its ground state

and the answer in lerms of fandmental constants

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13. A lithium atom has three electrons. Assume the following simple picture of the atom Two electron moves close to the nucleus making up a spherical cloud it and the third moves outside the cloud in a circular orbit . Bohr's model can be used for the motion of this third electron but$n = 1$ state are not available to it.

Calculate the ionization energy of lithium in ground state using the above picture.

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14. A particle known as mu mean has a charge equal to that of no electron and mass 208 times the mass of the electron B moves in a circular orbit around a nucleus of charge $+3e$ Take the mass of the nucles to be infinite Assuming that the bohr's model is applicable to this system (a)drive an eqression for the

radius of the nth Bohr orbit (b) find the value of a for which the redius of the orbit it approninately the same as that at the first bohr for a hydrogen atom (c) find the wavelength of the radiation emitted when the u - mean jump from the orbit to the first orbit

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15. Find the wavelength in a hydrogen spectrum between the range $500nm \rightarrow 700nm$

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16. A beem of ultraviolet radius hacking wavelength between $100nm$ and $200nm$ is inclined on a sample of atomic hydrogen gos Assuming that the atoms are in ground state which wavelength will have low intensity in the transnilled been? If the energy of a photon is equal to the ground state it haslarge probobility of being observed by on atom in the ground state

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17. A neutron moving with a speed v makes a head-on collision with a hydrogen atom in ground state kept at rest. Find the Minimum Kinetic Energy of Neutron for which inelastic collision will be take place is (assume that mass of h-atom is nearly equal to the mass of neutron)

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18. Light corresponding to the transition $n = 4 \rightarrow n = 2$ in hydrogen atom falls on cesium metal (work function $= 1.9eV$) Find the maximum kinetic energy of the photoelectrons emitted

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19. A small particle of mass m move in such a way the potential energy $U = \frac{1}{2}m^2\omega^2r^2$ where omega is a constant and r is the

distance of the particle from the origin. Assuming Bohr's model of quantization of angular momentum and circular orbits , show that radius of the nth allowed orbit is proportional to √n

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Short Answer

1. How many wavelength are emitted by atomic hydrogen in visible range $(380nm - 780nm)$

? In the range $50nm \rightarrow 100nm$?

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2. The first excited energy of a He^{+} ion is the same as the ground state energy of hydrogen is it always true that one of the energies of any hydrogen like ion will be the same as the ground state energy of a hydrogen atom?

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3. Which wavelength will be emitting by a sample of atomic hydrogen gas (in ground state) if electron of energy $12.2eV$ collide with the atoms of the gas?

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4. When white radiation is passed through a sample of hydrogen gas at room temperature , absorption lines are observed in lyman series only Explain

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5. Balmer series was observed and analysed before the other series .Can you suggest a reason for such an order?

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6. What will be the energy corresponding to the first excited state of a hydrogen atom if the potential energy of the atom is taken to be $10eV$ when the electron is widely

separated from the proton ? Can be still write $E_n = E_1/n^2$, or , $r_n = a_0 n^2$?

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7. The differece is the frequency of series limit of lyman series and balmar series is equal to the frequency of the first line of the lyman series Explain

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8. The numeriecal value of ionization in eV equals the inoization potential in volts .Does the equally hold if thesequantities are inasured in some other units?

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9. We have stimulated and spontaneous emission .Do we also have stimulated absorption and spontaneous obsorption?

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10. An atom is in its excited state ,Does the probability of its coming to ground state depend on whether the radiation is already present or not? If you does it also depends on the wavelength of the radiation present?

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Obejective - I

1. The minimum orbital angular momentum of the electron in a hydrogen atom is

A. a) h

B. b) $h/2$

C. c) $h/2\pi$

D. d) h/λ

Answer: C

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2. Three photons coming from excited atoms hydrogen sample are pickedup .There energies are $12.1eV, 10.2eV \text{ and } 1.9eV$ these photons must come from

A. a simple atom

B. two atoms

C. three atoms

D. either two atoms or three atoms

Answer: D

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3. Suppose the electron in a hydrogen atom makes transition from $n = 3 \rightarrow n = 2$ in $10^{-8}s$ The order of the torque acting on the electron in this period, using the relation between torque and angular momentum as discussed in the chapter on rotational mechanics is

A. $10^{-34}Nm$

B. $10^{-24}Nm$

C. $10^{-42}Nm$

D. $10^{-8}Nm$

Answer: B

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4. In which of the following transition will the wavelength be minimum ?

A. $n = 5 \rightarrow n = 4$

B. $n = 4 \rightarrow n = 3$

C. $n = 3 \rightarrow n = 2$

D. $n = 2 \rightarrow n = 1$

Answer: D

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5. In which of the following system will the radius of the first orbit$(n = 1)$ be minimum?

A. a) Hydrogen atom

B. b) Deuterium atom

C. c) Single ionized helium

D. d) Doubly ionized lithium

Answer: D

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6. In which of the following system will the wavelength corresponding to $n = 2 \rightarrow n = 1$ be minimum ?

A. a) Hydrogen atom

B. b) Deuterium atom

C. c) Single ionized helium

D. d) Doubly ionized lithium

Answer: D

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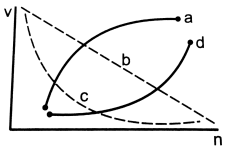
7. Which of the following cueve may repressent the speed of the electron in a hydrogen atom as afunction of the principal

quantum number n?



A.

B. 

C. 

D. 

Answer: C

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8. As one considers orbits with higher value of n in a hydrogen atom, the electron potential energy of the atom

A. a) decreases

B. b) increases

C. c) remain the same

D. d) does not increases

Answer: B

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9. The energy of an atom (or ion) in the ground state is $-54.4eV$ .It may be?

A. a) Hydrogen

B. b) Deuterium

C. c) He^{+}

D. d) Li^{++}

Answer: C

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10. The radius of the shortest orbit in a one electron system is 18pm it may be

A. Hydrogen

B. deuterium

C. He^+

D. Li^{++}

Answer: D

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11. A hydrogen atom in ground state absorbs $10.2eV$ of energy .The orbital angular momentum of the electron is increases by

A. $1.05 \times 10^{-34} Js$

B. $2.11 \times 10^{-34} Js$

C. $3.16 \times 10^{-34} Js$

D. $4.22 \times 10^{-34} Js$

Answer: A

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12. Which of the following parameters are the same for all hydrogen like atoms and ions in their ground state?

A. Radius of the orbit

B. Speed of the electron

C. Energy of the atom

D. Orbital angular momentum of the electron

Answer: D

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13. In a laser tube all the photons

A. have same wavelength

B. have same energy

C. move in same direction

D. move with same speed

Answer: D

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Obejective - II

1. In a laboratory experiment on emission from atomic hydrogen in a discharge tube only a small number of lines are observed whereas a large number of lines are pressent in the hydrogen spectrum of a star .This is because in a laboratory

A. the amount of hydrogen taken is smaller than that pressent in the star

B. the temperature of hydrogen is much smaller than that of the star

C. the pressure of hydrogen is much smaller than that of the star

D. the gravitational pull is much smaller than that of the star

Answer: B

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2. An electron with kinetic energy $5eV$ is incident on a hydrogen atom in its ground state.The collision

A. must be elastic

B. may be partially elastic

C. must be completely inelastic

D. may be completely inelastic

Answer: A

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3. Which of the following products in a hydrogen atom are independent of the principal quantum number n? The symbols have theirusual meanings

A. un

B. Er

C. E pi

D. ur

Answer: A::B

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4. Let A_0 be the area enclosed by the orbit in a hydrogen atom .The graph of $\ln(A_0 / A_1)$ against $\ln(n)$

A. will pass through the origin

B. will be a straigth line with slope 4

C. will be a monotonically increasing nonlinear curve

D. will be a circle

Answer: A::B

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5. Ionzation energy of a hydrogen like A is greater than that of another hydrogen like ion B Let r, u, E and L represent the radius of the orbit, speed of the electron energy of the atom and orbital angular momentum of the electron respectively, in ground state

A. $r_A > r_B$

B. $u_A > u_B$

C. $E_A > E_B$

D. $L_A > l_B$

Answer: B

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6. When a photon stimulates the emission of another photon the two photon have

A. same energy

B. same direction

C. same phase

D. same wavelength

Answer: A::B::C::D

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Exercises

1. The bohr radius is given by $a_0 = \frac{\varepsilon_0 h^2}{\pi m e^2}$ verify that the RHS has dimesions of length

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2. Find the wavelength of the radiation by hydrogen in the transition (a)n = 3 to n = 2, (b)n = 5 to n = 4 and(c) n = 10 to n = 9`

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3. Calculate the smaller wavelength of radiation that may be emitted by (a) hydrogen (b)He^{+} and (c) Li^{++}

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4. Evalute Rydberg constant by putting the value of the fundamental constants in its expression

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5. Find the binding energy of a hydrogen atom in the state $n = 2$

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6. Find the radius and energy of a He^{++} ion in the states (a) $n = 1, (b) n = 4$ and $(c) n = 10$ is

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7. A hydrogen atom emits ultraviolet of wavelength $102.5nm$ what are the quantum number of the state involved in the transition?

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8. Find the first excitation potential of He^+ ion (a)Find the ionization potential of Li^{++} ion

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9. A group of hydrogen atom are prepered in $n = 4$ states list the wavelength that are emitted as the atoms make transition and return to $n = 2$ states

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10. A positive ion having just one electron ejects it if a photon of wavelength 228Å or less is absorbed by it. Identify the ion

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11. Find the maximum coulomb force can act on the electron due to the nucleus in a hydrogen atom.

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12. A hydrogen atom in a having a binding of $0.85eV$makes transition to a state with excited energy $10.2eV$(a) identify the quantum number n of theupper and the lower energy state involved in the transition (b) Find the wavelength of the emitted radiation

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13. Whenever a photon is emitted by hydrogen in balmer series it is followed by another in

lyman series what wavelength does this latter photon correspond to?

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14. A hydrogen atom in state $n = 6$ makes two successive transition and reaches the ground state in the first transition a photon of $1.13eV$ is emitted (a) Find the energy of the photon emitted in the second transition (b) what is the value of n in the intermediate state?

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15. What is the energy of a hydrogen atom in the first excited state if the potential energy is taken to be zero in the ground state?

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16. A hot gas emites radition of wavelength $46.0nm, 82.8nm$ and $103.5nm$ only Assume that the atoms have only two excited state and the difference between consecutive energy levels decrease as energy is increased

Taking the energy of the higest energy state to be zero find the energies of the ground state and the first excited state

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17. A gas of hydrogen like ions is prepared in a particular excited state A. if emit photons having wavelength equal to the wavelength of the first line of the lyman series together with photons of five other wavelength identify the

gas and find the principal quantum number of the state A

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18. Find the maximum angular speed of the electron of a hydrogen atoms in a statoonary orbit

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19. A spectroscopic instrument can resolve two nearly wavelength λ and $\lambda + \Delta\lambda$ if $\lambda/\Delta\lambda$ is smaller than 8000 This is used to study the spectral lines of the balmer series of hydrogen Approximately how many lines will be resolved by the instrument?

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20. Suppose in certine condition only those transition are allowed to hydrogen atoms in

which the principal quantum number a changes by2 (a) Find the smaller wavelength emitted by hydrogen (b) list the wavelength emitted by hydrogen in the visible range $(380nm \rightarrow 780nm)$

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21. According to Maxwell's theory of electrodynamics, an electron going in a circle should emit radiation of frequency equal to the frequency of revolution what should be

the wavelength of the radiation emitted by a hydrogen atom in ground state if this rule is followed?

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22. The average kinetic energy of molecules in a gas at temperature T is $1.5KT$find the temperature at which the average kinetic energy of the molecules of hydrogen equals the binding energy of its atoms will hydrogen

remain in molecles form at this temperature ?

Take $k = 8.62 \times 10^{-5} eVK^{-1}$

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23. Find the temperature at which the everage thermal kinetic energy is equal to the energy needed to take a hydrogen atom from its ground state $n = 3$ state hydrogen can now emit rod light of wavelength $653.1nm$because of maxwellan distribution of speeds a hydrogen sample emits red light at

temperature much lower than that obtained from this problem Asuume that hydrogen that hydrogen molecules dissociate into atoms

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24. Avarage lifetime of a hydrogen atom excited to $n = 2$ state $10^{-6}s$ find the number of revolutions made by the electron on the avarage before it jump to the ground state

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25. calculate the magnetic dipolemoment corresponding to the motion of the electron in the ground state of a hydrogen atom

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26. Show that the ratio of the magnitic dipole moment to the angular momentum$(l = mvr)$ is a universal constant for hydrogen atom and ions find the value

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27. A beam of light having wavelength distributed uniformly between $450nm \rightarrow 550nm$ passes through a sample of hydrogen gas which wavelength will have the least intensity in the transition beam?

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28. Radiation coming from transition $n = 2 \rightarrow n = 1$ of hydrogen atoms falls on helium in $n = 1 \text{ and } n = 2$ state what are

the possible transition of helium ions as they absorb energy from the radiation?

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29. A hydrogen atom in ground state obsebe a photon of ultraviolet radition of wavelength $50nm$ Assuming that the entire photon energy is taken up by the electron with what kinetic energy will the up by the electron with what kinetic energy will the electron be ejected?

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30. A parallel beam of light of wavelength $100nm$ passes through a sample of atomic hydrogengas in ground state (a)Assume that when a photon suppose some of its energy to a hydrogen atom the rest of the energy appears as another photon moving in the same direction as the incident photon Neglecting the light emitted by the excited hydrogen ato in the direction of the incident beam, ? (b) A radiation detector is placed near

the gas to detect radiation coming perpenducular to the incident beam find the wevelength of radiation that may be detected by the detector

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31. A beam of momechromatic light of wavelength λ ejectes photonelectrons from a cesium $(\phi = 1.9eV)$ these photonelectron are mde to collide with h-atom in ground state . find the maximum value of λ for which (a)

hydrogen atoms may be ionised (b) hydrogen may get excited from the ground state to the first excited state and (c) the excited hydrogen atoms may emit visible light

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32. Electron are emited from an electron gun at almost zero velocity and are accelerated by an electric field E through a distance of $1.0m$ The electron are now scatteared by an atomic hydrogen sample in ground state what should

be the minimum value of E so that red light of wavelength $656.5nm$ may be emitted by the hydrogen?

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33. A neutron having kinetic energy $12.5eV$ collides with a hydrogen atom at rest negect the difference in mass between the neutron and the hydrogen atom and assume that the neutron does not leave its of motion find the

posible kinetic energy of the neutron after the event

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34. A hydrogen atom moving at speed v collides with another hydrogen atom kept at rest .Find the minimum value of u for which one of the atoms may get ionized the mass of a hydrogen atom $= 1.67 \times 10^{-27} kg$

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35. A neutron moving with a speed u strikes a hydrogen atom in ground state in ground toward it with the same speed Find the minimum speed of the neutron for which ineleastic (completely or perially) collision may take place .The mass of neutron = mass of hydrogen $= 1.67 \times 10^{-27} kg$

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36. When a photon is emited by a hydrogen atom , the photon carries a momentum with it

(a) calculate the momentum carreied by the photon when a hydrogen atom emits light of wavelength $656.3nm$(b) with what speed does the atoms recoil during this transition? Take the mass of the hydrogen atom $= 1.67 \times 10^{-27} kg$ (c) Find the kinetic energy of recoil of the atom

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37. When a photon is emitted from an atom , the atom recils The kinetic energy of recoils

and the energy of the photon come from the difference in energy between the state involved in the transition suppose a hydrogen atom change its state from $n = 3 \rightarrow n = 2$ calculate the fractional change in the wavelength of light emitted , due to the recoil

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38. The light emitted in the transition $n = 3 \rightarrow n = 2$ in hydrogen is called H_α light .Find the maximum work fonction a metel one

have so that H_{α} light can emit photoelectrons from it

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39. Light from balmer series of hydrogen is able to eject photoelectron from a metal what can be the maximum work function of the metal?

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40. Radiation from hydrogen discharge tube falls on a cesium plate. Find the maximum possible kinetic energy of the photoelectron. work function of cesium is $1.9ev$

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41. A filter transition only the radiationof wavelength greater than 440 nm. Radiation from a hydrogen discharge tube goes through such a filter and is incident on a metel of work

function 2.0eV . Find the stopping potential which can stop the photoelectrons.

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42. The earth revolves round the sun due to gravitatinal attraction. Suppose that the sun and the earth are point particle with their existing masses and that Bhor's quantization rule for angular monentum is valid in the case of gravitation (a) Calculate the minimum radius the earth can have for its orbit. (b)

What is the value of the principle quantum number n for the present radius ? Mass of the earth = 6.0×10^{24} kg, mass of the sun = 2.0×10^{30} kg, earth-sun distance = $1.5 \times 10^{11} m$.

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43. Consider a neutrom and an electron bound to each other due to gravitational force. Assuming Bohr's quantization rule angular momentum to be valid in this case, derive an

expression for the energy of the neutron-electron system.

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44. A uniform magnetic field B exists in a region. An electrons projected perpendicular to the field goes in a circle. Assuming Bohr's quantization rule for angular momentum, calculate (a) the smallest possible radius of the electrons (b) the radius of the nth orbit

and (c) the minimum possible speed of the electron.

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45. Suppose in an imginary world the angular momentum is quantized to be even integral multiples of $h/2\pi$. What is the longest possible wavelenght emitted by hydrogen atoms in visible range in such a world according to Bohr's model?

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46. Consider an excited hydrogen atom in state n moving with a velocity $v(v << c)$. It emits a photon in the direction of its motion and changes its state to a lower state m. Apply momentum and energy conservation principle to calculate the frequency v of the emitted radiation, compare this with the frequency v_0 emitted if the atom were at rest.

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