43. Bohr's Model and Physics of the Atom

Short Answer

Answer.1

We know from Rydberg's Equation, the wavelength λ of emission spectrum when electrons move from n_2 energy level to n_1 energy level is given by,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{{n_1}^2} - \frac{1}{{n^2}^2}\right)$$

where $R = 1.09677X10^7\ m^{-1}$ Z = Atomic Number

For Hydrogen atom, Z=1.

The wavelength range 380-780 nm lies in the Balmer Series.

Thus, n_1=2 for Balmer Series.

Substituting n_2=3, we get λ=656.3 nm

Substituting n_2=7, we get λ=397.0 nm

Thus, we get 5 wavelengths: n=3 to n=2; n=4 to n=2; n=5 to n=2; n=6 to n=2 and n=7 to n=2.

For other values of n_2, the range of 380-780nm is not possible.

The wavelength range 50-100 nm, within n=7 to n=2, lies in the Lyman Series.

Thus, n_1=1 for Lyman Series.

Substituting n_2=4, we get λ=97.3 nm

Substituting n_2=6, we get λ=93.8 nm

Thus, we get 3 wavelengths: n=4 to n=1; n=5 to n=1 and n=6 to n=1.

For other values of n_2 (within n=7 to n=2), the range of 50-100 nm is not possible.

Answer.2

We know that energy E of a hydrogen or hydrogen-like species is given by,

$$E = -13.6\frac{Z^2}{n^2}\ eV$$

where Z = Atomic Number and n = Principal Quantum Number

Now, for the ground state energy of hydrogen(Z=1), Z/n= 1. Thus, E=-13.6 eV.

Also, for the first excited energy of helium ion(Z=2), Z/n= 1. Thus, E=-13.6 eV.

Thus, we have seen that in all hydrogen like species where Z=n, E=-13.6 eV.

So, for the second excited state of lithium ion(Z=2), for the third excited state of beryllium ion(Z=3), so on, we have E=-13.6 eV.

Hence, there will always be an energy level of an hydrogen like species which will be same as the ground state energy of hydrogen.

Answer.3

We know, according to Bohr's Model, the energy ΔE released, when electrons move from n_2 energy level to n_1 energy level is given by,

$$\Delta E\ = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

Now, given that hydrogen is in its ground state. So n_1=1.

Substituting, n_2=2, we get ΔE=10.2 eV.

Thus, the electrons will be released from n=2 level to n=1 level.

Substituting, n_2=3, we get ΔE=12.08 eV.

Thus, the electrons will be released from n=3 level to n=1 level.

This, corresponds to the Lyman Series(infrared region).

Answer.4

We know, according to Bohr's Model, the energy ΔE released, when electrons move from n_2 energy level to n_1 energy level is given by,

$$\Delta E = 13.6 \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

At room temperature, all electrons in a hydrogen atom are in ground state. In order to excite them to n=2 level a minimum of 10.2 eV energy is needed. This is because,

$$\Delta E = 10.2eV = 13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right)\ eV$$

White light contains radiations of energy around 10.2eV. So, it excites electrons to n=2 level. During de-excitation, electrons move from n=2 level to n=1 level. This corresponds to the Lyman Series.

Thus, absorption lines are only observed in Lyman Series.

Answer.5

Balmer Series corresponds to the visible spectrum. So it is visible to the human eye.

Thus, it was observed and analyzed before the other series.

Answer.6

While deriving formula for energy for the Bohr's Model of an atom, we take the potential energy to be zero when the electron and proton are far apart (infinite distance). But, here the potential energy is not zero; it is 10 eV.

So the formula of energy will be modified as,

$$E = -\frac{13.6}{n^2} + 10\ eV$$

where n= Principal Quantum Number.

For the first excited state, n=2. Therefore,

$$E = -\frac{13.6}{2^2} + 10\ eV = 6.6\ eV$$

The formula of radius of orbit remains unchanged as it does not involve any concept of potential energy and can be derived just by taking into consideration the Quantization Rule and Coloumb's Law.

Answer.7

We know from Rydberg's equation for a hydrogen atom (Z=1) the wavelength λ of emission spectrum, when electrons move from n_2 energy level to n_1 energy level, is given by,

$$\frac{1}{\lambda} = R\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

where $\mathrm{R} = 1.09777\mathrm{X}10^7\ \mathrm{m}^{-1}$

For the difference in the series limit (last line) of Lyman series and Balmer series.

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right) - R\left(\frac{1}{2^2} - \frac{1}{\infty}\right) = R\left(1 - \frac{1}{4}\right)$$

This is because n_1=1 when we are considering Lyman Series and n_1=2 when we are considering Balmer Series.

For the first line of Lyman Series,

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{(1+1)^2}\right) = R\left(1 - \frac{1}{4}\right)$$

Thus, we can see in both cases the value of 1/λ is same. So frequency (c/λ, c=speed of light=constant) will also be same for both cases.

Answer.8

We know that energy has dimension of

$$Energy = Charge\ X\ Potential$$

In the unit 'eV', the charge part is not multiplied with potential. The charge is kept as 'e' and its value is not incorporated. As a result, energy has the same value of potential, because only the value of potential is used and not charge when we use the unit 'eV'. Thus, energy has the same value of potential.

This is not true when we use other units of energy like joule, where the value of charge is substituted and multiplied.

Answer.9

We do have stimulated absorption where atoms absorb energy and move to the excited state when electromagnetic wave of suitable frequency is incident on it.

However, there is nothing called spontaneous absorption. This is because for absorption to take place electromagnetic radiation has to be incident. Absorption is not possible without any incident of radiation, as if there is no incident energy, there is nothing for the atoms to absorb.

Answer.10

In case of stimulated emission, atoms come to ground state if there is a stimulated radiation present. In that case, it also depends on the wavelength of radiation. Only a radiation of suitable wavelength can stimulate atoms for emission.

However in case of spontaneous emission, atoms come to the ground state spontaneously. Thus, it does not depend on the presence of radiation or its wavelength.

Objective I

Answer.1

According to Bohr's quantization rule, orbital angular momentum

(L) of an electron is given by,

$$L = n\frac{h}{2\pi}$$

Now here, n=1,2,3… and h is the Planck’s Constant. Note that the minimum value of n is 1.

Thus, the minimum orbital angular momentum is $L = \frac{h}{2\pi}$.

Hence, option (c) is the correct answer.

Answer.2

We know, according to Bohr's Model, the energy ΔE released, when electrons move from n_2 energy level to n_1 energy level is given by,

$$\Delta E = 13.6 \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

Now, the photons having energies can be due to the following transitions:

From n=3 to n=1: $13.6\left(\frac{1}{1^2} - \frac{1}{3^2}\right) eV = 12.1\ eV$

From n=3 to n=2: $13.6\ \left(\frac{1}{2^2} - \frac{1}{3^2}\right) eV = 1.9\ eV$

From n=2 to n=1: $13.6\ \left(\frac{1}{1^2} - \frac{1}{2^2}\right) eV = 10.2\ eV$

Now, an excited electron always comes to its ground state. Since there is only one electron in hydrogen atom, it can make transitions from n=3 to n=1 directly or from n=3 to n=2 and then finally from n=2 to n=1.

This is not possible for a single atom as only one transition is allowed. So option (a) is wrong.

This is possible for two atoms where one atom makes n=3 to n=1 transition and the other makes n=3 to n=2 and then to n=1 transitions.

This is also possible for three atoms where all the three atoms make three different transitions.

Here, only one option is correct. So among (b), (c) and (d) options, we choose (d) as it includes all the cases.

Hence, option (d) is the correct answer.

Answer.3

Here, from Bohr's quantization rule, we know angular momentum (L) is given by,

$$L = n\frac{h}{2\pi}$$

Where n=0,1,2….. and h=Planck's Constant.

Now, the initial angular momentum is $L_3 = \frac{3h}{2\pi}$

And, the final angular momentum is $L_2 = \frac{2h}{2\pi}$

Now from the relation between angular momentum(L) and torque(τ), we have

$$\tau = \frac{dL}{dt}$$

$$= \frac{\frac{2h}{2\pi} - \frac{3h}{2\pi}}{10^{-8}}\ Nm$$

Putting $h = 6.625\ X\ 10^{-34}\ Js$

$\tau \sim 10^{-24}\ Nm$

Hence, option (b) is the correct answer.

Answer.4

We know from Rydberg's equation the wavelength λ of emission spectrum when electrons move from n_2 energy level to n_1 energy level, is given by,

$$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

where $R = 1.09677 X 10^7 m^{-1}$ Z = Atomic Number

For option (a), we have $\frac{1}{\lambda} = RZ^2 \left(\frac{1}{4^2} - \frac{1}{5^2}\right) = \frac{RZ^2 9}{400}$

For option (b), we have $\frac{1}{\lambda} = RZ^2 \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{RZ^2 7}{144}$

For option (c), we have $\frac{1}{\lambda} = RZ^2 \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{RZ^2 5}{36}$

For option (d), we have $\frac{1}{\lambda} = RZ^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{RZ^2 3}{4}$

Thus, in option (d) 1/λ has the maximum value and thus λ is minimum.

Hence, option (d) is the correct answer.

Answer.5

We know that the radius (r) of an orbit of an atom of atomic number Z, according to Bohr's Model is:

$$r = 0.529\frac{n^2}{Z}\ A^{\circ}$$

Where, n= Principal Quantum number and Z= Atomic Number.

Thus, for a fixed n (n=1), the radius of an orbit is inversely proportional to Z.

Among the options, lithium ion has the highest atomic number, Z=3.

Hence, option (d) is the correct answer.

In which of the following systems will the wavelength corresponding to n = 2 to n = 1 be minimum?

A. Hydrogen atom

B. Deuterium atom

C. Singly ionized helium

D. Doubly ionized lithium

Answer.6

We know from Rydberg's equation, the wavelength λ of emission spectrum when electrons move from n_2 energy level to n_1 energy level, is given by,

$$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

where $R = 1.09677X10^7 m^{-1}$ Z = Atomic Number

Now, here n_1=1 and n_2=2 are fixed. So wavelength is inversely proportional to Z^2.

Among the options, lithium ion has the highest atomic number, Z=3.

Hence, option (d) is the correct answer.

Answer.7

The speed of an electron (v) is inversely proportional to the principal quantum number (n). Thus the v-n graph should be rectangular hyperbola.

Hence, option (c) is the correct answer.

B. increases

C. remains the same

D. does not increase

Answer.8

We know that the electric potential energy (U) of an electron of an atom of atomic number Z is given by,

$$U = -27.2\frac{Z^2}{n^2}$$

where n = Principal Quantum Number

For hydrogen atom, Z=1 is fixed. Thus, with increase in 'n', 'U' becomes less negative, which means it increases.

Hence, option (b) is the correct answer.

Answer.9

We know the energy (E) of an electron according to Bohr's Model of an atom of atomic number Z is given by,

$$E = -13.6\frac{Z^2}{n^2}\ eV$$

where n= Principal Quantum Number

For ground state, n=1 is fixed.

For hydrogen, Z=1. So E=-13.6 eV. So, option (a) is wrong.

For deuterium, Z=1. So E =-13.6 eV. So, option (b) is wrong.

For helium ion, Z=2. So E=-54.4 eV. So, option (c) maybe correct. Let's check option (d).

For lithium ion, Z=3. So E=-122.4 eV. So, option (d) is wrong.

Hence, option (c) is the correct answer.

Answer.10

We know that the radius (r) of an orbit according to Bohr's Model of an atom of atomic number Z is given by,

$$r = 0.529\frac{n^2}{Z}\ A°$$

where n= Principal Quantum Number

For shortest orbit, n=1 which means it is fixed.

For hydrogen, Z=1. So, r=0.529 A°. So, option (a) is wrong.

For deuterium, Z=1. So, r=0.529 A°. So, option (b) is wrong.

For helium ion, Z=2. So, r=0.2645 A°. So, option (c) is wrong.

For lithium ion, Z=3. So, r=0.176 A° ~ 18pm. So, option (d) is right.

Hence, option (d) is the correct answer.

Answer.11

We know, according to Bohr's Model, the energy ΔE released, when electrons move from n_2 energy level to n_1 energy level is given by,

$$\Delta E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$$

For hydrogen atom, Z=1 and given ΔE=10.2 and n_1=1. Let n_2=n (say).

Thus,

$$1 - \frac{1}{n^2} = \frac{10.2}{13.6}$$

$$or\ n = 2$$

Thus, the increase in angular momentum is given by,

$$\Delta L = \frac{2h}{2\pi} - \frac{h}{2\pi}$$

Or $L = \frac{h}{2\pi} = \frac{6.625X10^{-34}}{2\pi} = 1.05X10^{-34}\ Js$

Hence, option (a) is the correct answer.

Answer.12

It is only angular momentum of an electron which does not depend on atomic number Z.

According to Bohr's quantization rule angular momentum (L) is,

$$L = n\frac{h}{2\pi}$$

Where n=0,1,2,3… and h= Planck's constant.

For ground state, even n=1 is fixed. Thus, L is same for hydrogen and all hydrogen like species.

Hence, option (d) is the correct answer.

Answer.13

In Laser light, photons, that is the basic quantum of light energy, travel with the same speed, which is the speed of light. It may have different wavelengths, energies and directions. But the speed of all the photons is the same and constant.

Hence, option (d) is the correct answer.

Objective II

Answer.1

A material shows radiation lines when it is heated. Thus, when hydrogen gas is heated inside a discharge tube, only a small amount of radiations is observed because temperature inside the laboratory can be increased to a certain limit. As star (e.g. sun) exhibits a huge temperature, thus hydrogen emits more number of wavelengths in a star as compared to that in laboratory.

Option A. is not correct as spectral lines never depend upon the amount of material taken.

Option C. is not correct as spectral line emission is independent of pressure

Option D. is not correct as spectral lines is also independent of gravitational pull.

Answer.2

This is because we know from the special condition of elastic collision that when an object having a lesser mass strikes with an object with larger mass, the collision is elastic and the object with lesser mass moves in opposite direction with opposite velocity. Thus here the mass of electron is less as compared to that of the hydrogen and thus the collision will be elastic.

Again the energy of the first excited state of the hydrogen atom is 3.4eV and that at the ground state is 13. 6eV.So the difference becomes 10.2eV which is larger than the energy of the electron(5eV). Thus its kinetic energy remains conserved and the photon does not get absorbed.

Option B is not correct because the electron with the kinetic energy of 5eV will exchange the energy with that of the heavier mass hydrogen and thus the collision will be completely elastic.

Option C is not correct as the collision cannot be inelastic

Option D will also be not correct as the collision is not going to be inelastic.

Answer.3

The correct answers are A. and B.

We know that,

The velocity of the electrons is given by , $v\alpha \frac{Z}{n}$ so,$vn\ \alpha\ Z$

The energy is,$E\ \alpha \frac{z^2}{n^2}$ and radius as $r\alpha \frac{n^2}{Z}$ so,$Er\ \alpha\ Z$ (α=proportionality sign)

And all the rest of the options depends on the quantum number n.

Answer.4

As A_n denoted the area of the nth orbit and A_1 denotes the area of the first orbit.So,area of the nth orbit will be $A_n = \pi r_n^2$ and that of the first orbit is

$A_1 = \pi r_1^2$

Thus,

$$\frac{A_n}{A_1} = \frac{\pi r_n^2}{\pi r_1^2}$$

Now, the nth radius is given by,

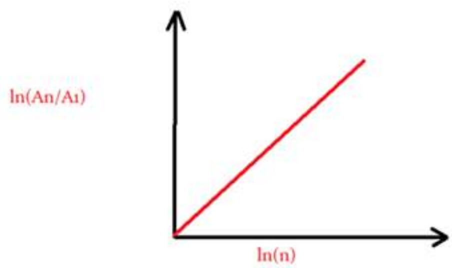
$r_n \propto n^2$

Therefore, $\frac{A_n}{A_1} = \frac{\pi r_n^2}{\pi r_1^2} = \frac{n^4}{1} = n^4$

So, $\ln(A_n/A_1) = 4\ln(n)$

On comparing the above with y=mx+c, we get

$$y = \frac{A_n}{A_1}, m = 4 \; and \; x = \ln(n)$$



Thus, Hence , we obtain that the graph will be a straight line passing through the origin with a slope of 4.

Therefore, option A and B are correct.

Answer.5

As ionisation energy is the energy needed to detach an electron from the atom, thus the electrons will gain some speed when detached from the atom and therefore ionisation energy will directly depend upon the speed of the electron

Thus, option B. will be the correct answer.

Option A. is not correct as ionisation energy does not depend upon the radius of the atom

Option C. is not correct as ionisation energy is independent of the atom energy and depends upon the energy supplied to detach the electron.

Option D. is not correct as ionisation energy is independent of angular momentum.

Answer.6

As the photon that stimulates another photon are identical, so they will have same energy, direction, phase and wavelength.

Exercises

Answer.1

We know that the dimensions of the following are,

$\varepsilon_0 = A^2T^2$

$h = ML^2T^{-1}$

$\pi = L^2MLT^{-2}$

$e = AT$

Thus we obtain the Bohr's radius as,

$$a_0 = \frac{A^2T^2(ML^2T^{-1})^2}{L^2MLT^{-2}M(AT)^2}$$

$$a_0 = \frac{M^2L^4T^{-2}}{M^2L^3T^{-2}}$$

Therefore, a_0 = L, which is in the dimension of length.

Answer.2

We know that the wavelength is given by,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$$

As the atom is hydrogen atom, so Z=1.

A. Here, n=2 and m=3.Thus,

$$\frac{1}{\lambda} = 1.1 \times 10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda} = 1.1 \times 10^7\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$Therefore, \lambda = \frac{36}{5 \times 1.1 \times 10^7} = 6.54 \times 10^{-7} = 654nm$$

B. Here, n=4, m=5.Thus,

$$\lambda = \frac{400}{1.1 \times 10^7 \times 9} = 40.404 \times 10^{-7} = 4040.4nm$$

C. Here, n=9, m=10. Thus,

$$\lambda = \frac{8100}{1.1 \times 10^7 \times 19} = 387.5598 \times 10^{-7} = 38755.9nm$$

Answer.3

When it is referred to as the smallest wavelength, it means longest energy as because energy is inversely proportional to wavelength.

Thus, the electron will jump from ground state to the state where energy is maximum(i.e.∞)

So, the ground state is n=1 and the state of higher energy is m=∞

A. we know that,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$$

$Thus, for\ hydrogen\ Z = 1$

Therefore, we obtain,

$$\frac{1}{\lambda} = 1.1 \times 10^7\left(\frac{1}{1} - \frac{1}{\infty}\right), R = 1.1 \times 10^7$$

$$Thus, \lambda = \frac{1}{1.1 \times 10^7} = 0.909 \times 10^{-7} = 90.9 \times 10^{-9} \approx 91nm$$

B. As He has an atomic number 2, so Z=2.

Thus,$\frac{1}{\lambda} = 1.1 \times 10^7 \times Z^2\left(\frac{1}{1} - \frac{1}{\infty}\right)$

Therefore, we obtain,

$$\lambda = \frac{1}{1.1 \times 10^7 \times 4} = 23nm$$

C. As lithium has an atomic number of 3, so Z=3

Thus,$\frac{1}{\lambda} = 1.1 \times 10^7 \times Z^2\left(\frac{1}{1} - \frac{1}{\infty}\right)$

Therefore, we obtain,

$$\lambda = \frac{1}{1.1 \times 10^7 \times 9} = 10nm$$

Answer.4

Rydberg constant is given by,

$$R = \frac{me^4}{8\varepsilon_0^2 h^3 c}$$

As we know that R is associated with electronic transition, so all values of the fundamentals will be w.r.t the electrons.

We know,

Mass of electron,$m = 9.1 \times 10^{-31}$kg,

charge of electron, e=$1.6 \times 10^{-19} C$

Planks constant, h=$6.63 \times 10^{-34} J - s$

Velocity of light, c=$3 \times 10^{8} m/s$

Permittivity,$\varepsilon_0 = 8.85 \times 10^{-12}$

Putting all these above values, we obtain the Rydberg constant to be,

$$R = \frac{9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^4}{8 \times (6.63 \times 10^{-34})^3 \times 3 \times 10^8 \times (8.85 \times 10^{-12})^2}$$

$$R = 1.097 \times 10^7$$

Answer.5

As we know that binding energy is defined as the energy released when its constituents are brought from infinity to from the system. Thus here the initial sta

te will be m=2 and this state is reached after bringing the constituent from infinity, so n=∞.

Now, the energy of hydrogen atom is given by,

$$E = \frac{-13.6}{n^2} eV$$

Where 13.6 is the binding energy of the hydrogen atom

So, if we consider transition state from infinity to n=2, we have

$$E = \frac{-13.6}{n^2} - \left(\frac{-13.6}{m^2}\right)$$

$$or\ E = 13.6\left(\frac{1}{\infty^2} - \frac{1}{2^2}\right)$$

$$or\ E = -13.6 \times \frac{1}{4} = -3.4eV$$

Answer.6

As we know that radius of an atomic orbit is given by,

$$r = \frac{n^2 a_0}{Z}, here\ a_0 = 0.053nm$$

$$or\ r = \frac{0.053 \times n^2}{Z}$$

Again, the energy of the atomic orbit is given as,

$$E = \frac{-13.6 \times Z^2}{n^2}$$

Here Z is the atomic number of the atom. Thus Z for $He^+$is 2.

A. Here, n=1 and thus the radius and energy becomes,

$$r = \frac{0.053 \times 1^2}{2} = 0.265Å$$

And energy,$E = \frac{-13.6 \times 2^2}{1^2} = -54.4eV$

B. here n=4 and thus the radius and energy is,

$$r = \frac{0.053 \times 4^2}{2} = 4.24Å$$

And energy, $E = \frac{-13.6 \times 2^2}{4^2} = -3.4eV$

C. here n=10 and thus the radius and energy becomes,

$$r = \frac{0.053 \times 10^2}{2} = 26.5Å$$

And energy is, $E = \frac{-13.6\times2^2}{10^2} = -0.544eV$

Answer.7

As we consider ground state to be n=1, so the transition involved will be from n=1 to m = (TO BE DETERMINED).

As we know from the topic of hydrogen spectra,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$$

Here, λ=102.5nm and Z=1(as atomic number of hydrogen is 1), n=1

Thus, $\frac{1}{102.5\times10^{-9}} = 1.1\times10^7\left(\frac{1}{1^2} - \frac{1}{m^2}\right)$

$$or, \frac{10^9}{102.5} = 1.1\times10^7\left(\frac{1}{1^2} - \frac{1}{m^2}\right)$$

$$or, \frac{10^9}{102.5\times1.1\times10^7} = 1 - \frac{1}{m^2}$$

$$or, \frac{1}{m^2} = \frac{1-100}{102.5\times1.1}$$

$$or, m = 2.97 \approx 3$$

Answer.8

We know the formula for energy calculation is,

$$E = \frac{-13.6\times Z^2}{n^2}$$

So, as the He^+makes first transition,so n=1 and m=2.Thus we will obtain 2 energies at state 1 and state 2.The difference of the 2 energies will give us the excitation potential.

A.

Thus, $E_1 = \frac{-13.6\times2^2}{1^2} = -54.4eV$

$$and\ , E_2 = \frac{-13.6 \times 2^2}{2^2} = -13.6eV$$

Therefore, the excitation energy of $He^+$is,

$$E = E_2 - E_1 = -13.6 - (-54.4) = 40.8V$$

B. Ionisation potential is defined as the energy required to ionise an atom(i.e.to remove one or more electron from the valence shell).The ionisation potential of hydrogen is 13.6eV.Thus,for any other atom it will be 13.6×Z^2

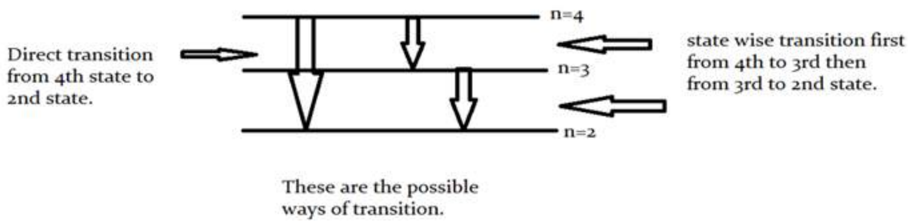
Thus, for Li^{++},we have atomic number,Z=3.

So ionisation potential =13.6×9=122.4 V

Answer.9

As the atom is in n=4 state, so while making a transition from n=4 to n=2 state, the transitions it will undergo are

In the first case, n=4→3→2



Thus, for the first case,

n=3 and m=4 (as the atom first makes transition from 4^{th} state to 3^{rd} state)

Thus the wavelength will be, $\frac{1}{\lambda} = RZ^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$

$$or, \frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{1}{9} - \frac{1}{16}\right)$$

$$or, \frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{16-9}{144}\right) = 0.0537 \times 10^7$$

$$or, \lambda = 1910nm$$

Second case is when the atom makes transition from n=3 to m=2.

Thus,

$$\frac{1}{\lambda} = 1.1 \times 10^7 \times (\frac{1}{2^2} - \frac{1}{3^2})$$

$$or, \frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{1}{4} - \frac{1}{9}\right) = 1.1 \times 10^7 \times \left(\frac{9-4}{36}\right) =$$

$$or, \lambda = \frac{36 \times 10^{-7}}{5 \times 1.1} = 654nm$$

Third case is when the atom will make the transition from 4^{th} state to directly to 3^{rd} state. At that time, n=4 and m=2,

$$\frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{1}{4} - \frac{1}{16}\right)$$

$$or, \lambda = 4.87nm$$

Answer.10

As the electron is ejected, so it makes a transition from its ground state n=1 to the immediate excited state m=2.

Thus the energy associated will be,

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{228} = 0.0872 \times 10^{-16} eV$$

The energy is in this term because the question says that the electron ejects when a photon of frequency 228Å is applied.

Now comparing this energy with that of the orbital energy, we get,

$$-13.6 \times Z^2 \left(\frac{1}{2^2} - \frac{1}{1^2}\right) = 0.0872 \times 10^{-16}$$

$$or, -13.6 \times Z^2 \left(\frac{1-4}{4}\right) = 0.0872 \times 10^{-16} \times 1.6 \times 10^{-19}$$

1.6×10^{-19} is multiplied as because the energy of the photon is in electron-volt.So we multiplied the charge of the electron.

$$or, Z^2 = 5.3$$

$$or, Z = \sqrt{5.3} \approx 2.3$$

Hence, the ion may be He^+

Answer.11

Since, hydrogen atom has only one electron in its outermost shell. Thus, the distance between the nucleus and the outer electron will be the Bohr radius.

We know that the columbic force is given by,$F = \frac{q_1 \times q_2}{4\pi\varepsilon_0 r^2}$,where q1 and q2 are the magnitude of charges,r=radius(in this case is Bohr radius)

The value of $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ and the value of Bohr's radius is r=0.053Å.

The charges of proton and electron are the same but opposite in sign(i.e. 1.6×10^{-19}).But as we are taking the magnitude of the charges, so we don't require the sign involved.

Therefore, we obtain the force to be,

$$F = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(0.053 \times 10^{-10})^2} = 82.02 \times 10^{-9}$$

$$or\ , F = 8.2 \times 10^{-8} N$$

Answer.12

A. We know that the binding energy is given by,

$$E = \frac{13.6 \times Z^2}{n^2} = \frac{13.6}{n_1^2}$$

Now, energy in the first state is given as, E=0.85eV

So,$E = \frac{13.6}{n_1^2} \Rightarrow 0.85 = \frac{13.6}{n_1^2} \Rightarrow n_1^2 = \frac{0.85}{13.6} = 16 \Rightarrow n_1 = 4$

Again,$10.2 = \frac{13.6}{n_2^2} \Rightarrow n_2^2 = \frac{10.2}{13.6} = 4 \Rightarrow n_2 = 2$

Thus, the states are 4 and 2.

B. If we take n_1 as n and n_2 as m and thus calculate the wavelength as follows,

$$\frac{1}{\lambda} = 1.1 \times 10^7 \left(\frac{1}{4} - \frac{1}{16}\right) = 1.1 \times 10^7 \left(\frac{3}{16}\right)$$

or, λ=487nm

Answer.13

It is said that the photon is emitted in Balmer series and then next in Lyman series. Balmer series correspond to n=2 state and Lyman series corresponds to n=1 state. If we take n=1 and m=2, then we obtain the wavelength as,

$$\frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{1}{1} - \frac{1}{4}\right) = 1.1 \times 10^7 \times \frac{3}{4}$$

$$or, \lambda = 1.215 \times 10^{-7} = 121.5 \times 10^{-9} = 122nm$$

Answer.14

As the hydrogen atom reaches the ground state from n=6, thus,

A. Energy at n=6, $E = \frac{-13.6 \times Z^2}{n^2} = \frac{-13.6 \times 1^2}{6^2} = -0.3777777$

Again, energy in the ground state is, $E = -13.6$ (for hydrogen atom)

Since the atom makes 2 successive transitions, so the energy in the second transition can be found out by subtracting the energy in the ground state and energy in the 6^{th} state and adding up the first transition energy.

So, $E = -13.6 - 0.3777777 + 1.13 = -12.09 = -12.1eV$

$$or, E = 12.1eV$$

(The negative sign shows that energy is being given for making the transitions from 6^{th} state to the ground state)

B. Energy in the intermediate state is given as=1.13+0.3777777=1.507eV

Thus, to calculate the n, we have, $E = \frac{13.6 \times Z^2}{n^2} = 13.6 \times \frac{1^2}{n^2}$

$$or, 1.507 = 13.6 \times \frac{1}{n^2}$$

$$or, n^2 = \frac{1.507}{13.6} = 3.03$$

$$or, n \approx 3$$

Answer.15

The energy needed to take the hydrogen atom from ground state to the excited state is called excitation energy and hydrogen requires 10.2 eV of energy to get excited from the ground state. As the energy of hydrogen atom in the ground state is 13.6 eV. So, the energy needed to make the hydrogen atom reach the first excited state is,

$$E = 13.6 + 10.2 = 23.8eV$$

Answer.16

As the atom has only 2 excited states, thus it makes transition to n=2 from ground state. The question asks to take higher energy state to be zero, so n=2 is zero in terms of energy.

So energy of the ground state will be,

$$E = \frac{hc}{\lambda_1} = \frac{6.634 \times 10^{34} \times 3 \times 10^8}{46 \times 10^{-9}} = \frac{1242}{46} = 27eV$$

And that of the first excited state is,

$$E = \frac{hc}{\lambda_2} = \frac{6.634 \times 10^{34} \times 3 \times 10^8}{103.5 \times 10^{-9}} = 12eV$$

Answer.17

The gas emits total of 6 wavelengths. Thus,

$from\ this\ formula, we\ obtain,$

$$\frac{n(n-1)}{2} = 6 \Rightarrow n = 4$$

Thus the gas is in the 4th state. Since the gas is hydrogen like ion and in the 4th excited state, thus the gas is He^+.

Answer.18

We know,

$$mvr = \frac{nh}{2\pi}$$

Where v is the velocity is the radius and m being the mass

For angular velocity i.e. ω, we know that v=ωr.

Thus, $m\omega r^2 = \frac{nh}{2\pi} \Rightarrow \omega = \frac{nh}{2\pi mr^2} = \frac{1\times6.634\times10^{34}}{2\times3.14\times9.1\times10^{-31}\times(0.053\times10^{-10})^2}$

$$or, \omega = 4.13 \times 10^{17} rad/sec$$

Answer.19

The range of Balmer series is from 656.3nm to 365 nm. If the instrument can resolve up to 80000, then,

$$No. of\ wavelengths\ in\ the\ range = \frac{656.3 - 365}{8000}$$

or, No. of wavelengths = 36

Answer.20

(a)Given: Quantum number n changes by 2.

And as we know that for minimum wavelength $n1 = 1$ and from given condition $n2 = 3$.

Now as per Einstein-Planck equation,

$E = \frac{hc}{\lambda}$ where $E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$ and λ is wavelength.

$$\Rightarrow 13.6\left(\frac{1}{1} - \frac{1}{9}\right) eV = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} eV$$

$$\Rightarrow 13.6\left(\frac{1}{1} - \frac{1}{9}\right) eV = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{\lambda} eV$$

$$\Rightarrow \lambda = 1.027 \times 10^{-7} m = 103 nm$$

(b)Since the obtained wavelength does not lie in visible range so we will take another transition possible that is from $n = 2$ to $n = 4$.

Again using,

$E = \frac{hc}{\lambda}$ where $E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)$

$$\Rightarrow 13.6\left(\frac{1}{4} - \frac{1}{16}\right) eV = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} eV$$

$$\Rightarrow \lambda = 487 nm$$

Since this wavelength lies in the range between 380nm to 780nm so this is the wavelength emitted by hydrogen in the visible range.

Answer.21

Frequency of radiation emitted by hydrogen atom in ground state is $f = \frac{c}{\lambda}$ where c is speed and λ denotes the wavelength.

Now, if Maxwell's theory of electrodynamics is true then this frequency is equal to the frequency due to revolution in the ground state by hydrogen atom which is given as-

$f = \frac{V}{2\pi r}$ where v represents the velocity in ground state and r denotes radius in ground state of hydrogen atom.

Equating both the equations,

$$\frac{c}{\lambda} = \frac{V}{2\pi r}$$

$$\Rightarrow \lambda = \frac{2c\pi r}{V}$$

$$\Rightarrow \lambda = \frac{2 \times 3 \times 10^{8} \times 3.14 \times 0.53 \times 10^{-10}}{2187 \times 10^{3}} m = 45.686nm$$

Answer.22

As we know Binding energy of a system is defined as the energy released when its constituents are brought from infinity to form the system.

So,

Binding energy $= E = -13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = -13.6\left(\frac{1}{\infty} - \frac{1}{1}\right) = 13.6\ eV$

According to this question the binding energy is equal to the average kinetic energy of the molecules.

So,

$$\frac{3}{2}KT = 13.6\ eV$$

$$\Rightarrow T = \frac{13.6}{1.5 \times 8.62 \times 10^{-5}} = 1.05 \times 10^{5}\ K$$

No, it is not possible because according to question positive ion of hydrogen molecules exists which is practically impossible.

distribution of speeds, a hydrogen sample emits red light at temperatures much lower than that obtained from this problem. Assume that hydrogen molecules dissociate into atoms.

Answer.23

Energy needed to take hydrogen atom from ground to second exited state is given by

$$E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)eV = 13.6\left(\frac{1}{1} - \frac{1}{9}\right)eV = 12.08\ eV$$

This energy is equal to the average thermal kinetic energy.

$\frac{3}{2}KT = 12.08\ eV$ where value of K=$8.62 \times 10^{-5} eV/k$

$$\Rightarrow T = \frac{12.08}{1.5 \times 8.62 \times 10^{-5}} = 9.4 \times 10^4\ kelvin$$

Answer.24

As we know that number of revolution is equal to average lifetime divided by time period. So first we calculate time period.

Now, from Bohr's model we can say that

$$frequency = \frac{me^4}{4\varepsilon^2 n^3 h^3}$$

Where n=2, m=$9.1 \times 10^{-31} kg$ and h= 6.63×10^{-34}

Time period $= \frac{1}{f} = \frac{4\varepsilon^2 n^3 h^3}{me^4}$

$$\Rightarrow \frac{4 \times 8.85^2 \times 2^3 \times 6.63^3}{9.1 \times 1.6^4} \times 10^{-19} sec$$

$$\Rightarrow 1.224 \times 10^{-15} sec$$

Number of revolution $= \frac{Average\ lifetime}{Time\ period}$

$$= \frac{10^{-8}}{1.224 \times 10^{-15}} = 8.16 \times 10^6\ revolutions$$

Answer.25

We know that dipole moment $\mu = niA$

As hydrogen atom is in ground state, so $n = 1$.

And we know that $i = \frac{q}{t}$ $and\ t = \frac{1}{f}$

Adding both the equations we get

$i = qf$

Hence, $\mu = niA = qfA$

Now from Bohr's model

$$f = \frac{me^4}{4\varepsilon^2 n^3 h^3}$$

And area is equal to $\pi r^2 n^2$.

So, $\mu = qfA = e \times \frac{me^4}{4\varepsilon^2 n^3 h^3} \times \pi r^2 n^2$

$$= \frac{9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^5 \times 3.14 \times (0.53 \times 10^{-10})^2}{4 \times (8.85 \times 10^{-12})^2 \times (6.64 \times 10^{-34})^3 \times 1}$$

$$= 9.17 \times 10^{-24} A/m^2$$

Answer.26

We know that magnetic dipole moment is $\mu = niA$

And we know that $i = \frac{q}{t}$ $and\ t = \frac{1}{f}$

Adding both the equations we get

$i = qf$

Hence, $\mu = niA = qfA$

Now from Bohr's model

$$f = \frac{me^4}{4\varepsilon^2 n^3 h^3}$$

And area is equal to $\pi r^2 n^2$.

So, $\mu = qfA = e \times \frac{me^4}{4\varepsilon^2 n^3 h^3} \times \pi r^2 n^2$

Now, angular momentum $l = mvr = \frac{nh}{2\pi}$

Now $\frac{\mu}{l} = e \times \frac{me^4}{4\varepsilon^2 n^3 h^3} \times \pi r^2 n^2 \times \frac{2\pi}{nh}$

$$= \frac{9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^5 \times 3.14^2 \times (0.53 \times 10^{-10})^2}{2 \times (8.85 \times 10^{-12})^2 \times (6.64 \times 10^{-34})^4 \times 1^2}$$

$= 8.73 \times 10^{10}\ C/kg$

Since this term is independent of Z so it is universal constant.

Answer.27

As we know that energy associated with a wavelength λ

Is equal to $\frac{1242}{\lambda}\ eV$ where λ is in nm and this is derived from $E = hc/\lambda$.

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV \text{ where } \lambda \text{ is in nm.}$$

So,

Energy associated with 450nm wavelength $= \frac{1242}{450}\ eV = 2.76eV$

Energy associated with 550nm wavelength $= \frac{1242}{550}\ eV = 2.26eV$

Since the light is coming in the visible region.

So, we have n1=2 and n2=3,4,5,6….and so on.

Now energy corresponding to change in these transition state is

E_2-E_3= $13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) eV = 13.6\left(\frac{1}{4} - \frac{1}{9}\right) = 1.9eV$

E_2-E_4= $13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) eV = 13.6\left(\frac{1}{4} - \frac{1}{16}\right) = 2.55eV$

E_2-E_5= $13.6\left(\frac{1}{{n_1}^2}-\frac{1}{{n_2}^2}\right)eV = 13.6\left(\frac{1}{4}-\frac{1}{25}\right) = 2.85eV$

As E_2-E_4 is in range between the two energy produced by two given wavelengths so wavelength corresponding to this energy is absorbs.

$$E = \frac{1242}{\lambda} eV \; where \; \lambda \; is \; in \; nm.$$

$$\lambda = \frac{1242}{2.55} nm = 487.05nm$$

Answer.28

Radiation coming from change in transition state of hydrogen atom

$$E = 13.6\left(\frac{1}{{n_1}^2}-\frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{1}-\frac{1}{4}\right) = 10.2eV$$

Now we have to check transition possible for n=1 and n=2 states separately.

From n = 1 to 2 for helium ions(Z=2).

$$E1 = Z^2 \times 13.6\left(\frac{1}{{n_1}^2}-\frac{1}{{n_2}^2}\right) = 4 \times 13.6\left(\frac{1}{1}-\frac{1}{4}\right) = 40.8eV$$

It is not possible as it is greater than E.

From n=1 to 3

$$E2 = Z^2 \times 13.6\left(\frac{1}{{n_1}^2}-\frac{1}{{n_2}^2}\right) = 4 \times 13.6\left(\frac{1}{1}-\frac{1}{9}\right) = 48.3eV$$

It is also not possible.

Now as we can see energy is increasing (E2>E1) we can say that no transition is possible from n=1.

From n=2 to 3

$$E3 = Z^2 \times 13.6\left(\frac{1}{{n_1}^2}-\frac{1}{{n_2}^2}\right) = 4 \times 13.6\left(\frac{1}{4}-\frac{1}{9}\right) = 7.56eV$$

This is possible as E3<E.

From n=2 to 4

$$E4 = Z^2 \times 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 4 \times 13.6\left(\frac{1}{4} - \frac{1}{16}\right) = 10.2eV$$

It is also possible as E4=E.

Now as energy reached maximum limit so no further transition changes is possible.

Hence E3(n=2 to 3) and E4(n=2 to 4) are only possible transition change.

Answer.29

According to the question

Work function=Energy required to remove electron from ground state to n=∞

Work function = w

$$= E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{1} - \frac{1}{\infty}\right) = 13.6eV$$

Now applying photoelectric effect.

$$\frac{hc}{\lambda} = w + KE$$

And

$$\frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} eV$$

$$= \frac{1242}{\lambda} eV \text{ where } \lambda \text{ is in nm.}$$

$$KE = \frac{hc}{\lambda} - w = \frac{1242}{50} - 13.6 = 24.84 - 13.6 = 11.24eV$$

Answer.30

Given: wavelength=100nm

Energy associated with this wavelength

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV \ where\ \lambda\ is\ in\ nm.$$

$E = \frac{1242}{\lambda(nm)}$ (substituting the vaue of c and plank's constant)

$= 12.42eV$

(a)Suppose E_n be the energy in the nth orbit. Let consider all possible change in transitions state.

Energy absorbed in transition state in n=1 to n=2

$$E = 13.6\left(\frac{1}{1} - \frac{1}{4}\right) = 10.2eV$$

Energy left$= 12.42eV - 10.2eV = 2.22eV$

Energy left$= \frac{1242}{\lambda(nm)}$ as we know that

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV \ where\ \lambda\ is\ in\ nm.$$

$$So, 2.22eV = \frac{1242}{\lambda(nm)}$$

$\Rightarrow \lambda = 560nm$

Energy absorbed in transition state in n=1 to n=3

$$E = 13.6\left(\frac{1}{1} - \frac{1}{9}\right) = 12.1eV$$

Energy left$= 12.42eV - 12.1eV = 0.32eV$

Energy left$= \frac{1242}{\lambda(nm)}$

$$\Rightarrow 0.32eV = \frac{1242}{\lambda(nm)}$$

$\Rightarrow \lambda = 3880nm$

Energy absorbed in transition state in n=3 to n=4

$$E = 13.6\left(\frac{1}{9} - \frac{1}{16}\right) = 0.65eV$$

Energy left$= 12.42eV - 0.65eV = 11.77eV$

Energy left$= \frac{hc}{\lambda}$

$$\Rightarrow 11.77eV = \frac{1242}{\lambda(nm)}$$

$$\Rightarrow \lambda = 105nm$$

(b)According to the question if hydrogen atom is radiated perpendicularly then only absorbed energy to change the transition state is taken into consideration.

For n=1 to n=2

$$E = 10.2eV$$

And

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV \text{ where } \lambda \text{ is in } nm.$$

$$\Rightarrow \frac{1242}{\lambda(nm)} = 10.2eV$$

$$\Rightarrow \frac{1242}{\lambda} = 10.2$$

$$\Rightarrow \lambda = 121nm$$

For n=1 to n=3

$$E = 12.1eV$$

$$\Rightarrow \frac{1242}{\lambda(nm)} = 12.1eV$$

$$\Rightarrow \frac{1242}{\lambda} = 12.1$$

$$\Rightarrow \lambda = 103nm$$

For n=3 to n=4

$$E = 0.65eV$$

$$\Rightarrow \frac{1242}{\lambda(nm)} = 0.65eV$$

$$\Rightarrow \frac{1242}{\lambda} = 0.65$$

$$\Rightarrow \lambda = 1911nm$$

Hence three wavelength obtained are 103nm,121nm,1911nm.

Answer.31

Since we have to find maximum λ so energy of ionization should be maximum.

So n_1=1 and n_2=∞

$E = 13.6\left(\frac{1}{1} - \frac{1}{\infty}\right) = 13.6eV$ and we know that

$$\frac{hc}{\lambda} - work\ function = E$$

$$\frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV\ where\ \lambda\ is\ in\ nm.$$

$$\frac{1242}{\lambda(nm)} - 1.9 = 13.6\text{eV}$$

$$\Rightarrow \frac{1242}{\lambda} = (1.9 + 13.6)\ \text{eV}$$

$$\Rightarrow \lambda = 80\text{nm}$$

(b)To change the transition state from n=1 to n=2

$$E = 13.6\left(\frac{1}{1} - \frac{1}{4}\right) = 10.2eV$$

$$\frac{1242}{\lambda(nm)} - 1.9 = 10.2\text{eV}$$

$$\Rightarrow \frac{1242}{\lambda} = (1.9 + 10.2)\text{ eV}$$

$$\Rightarrow \lambda = 102\text{ nm}$$

(c) To get the light in visible region the change in transition state should be in Balmer series (n=2 to n=3)

But here atom is in ground state.

So, n=1 to n=3

Hence,

$$E = 13.6\left(\frac{1}{1} - \frac{1}{9}\right) = 12.09eV$$

$$\frac{1242}{\lambda(nm)} - 1.9 = 12.09\text{eV}$$

$$\Rightarrow \frac{1242}{\lambda} = (1.9 + 12.09)\text{ eV}$$

$$\Rightarrow \lambda = 89\text{ nm}$$

Answer.32

As the red light has wavelength 656.3nm which is in Balmer Series so for minimum energy change in state should be from n=2 to n=3. But right now hydrogen atom is in ground state.

Hence n=1 to n=3

So

$$E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{1} - \frac{1}{9}\right) = 12.09eV$$

Hence minimum electric field required = 12.09 v/m

Answer.33

According to the question as masses of hydrogen atom and neutron are equal and line of motion does not change, hence this is a type of elastic collision in one line/dimension.

Hence the velocity of two particles interchanged as per elastic collision principle.

So neutron will come to rest. Hence its kinetic energy is zero.

Answer.34

According to problem this is a type of collision so we can conserve momentum and energy.

Let take v_1 and v_2 be two velocity of hydrogen after collision.

From conservation of momentum we have

$$mv = mv1 + mv2$$

$$\Rightarrow v = v1 + v2$$

From conservation of energy

$$\frac{1}{2}mv^2 = \frac{1}{2}m{v_1}^2 + \frac{1}{2}m{v_2}^2 + E$$

Where E is ionization energy and is equal to 13.6eV.

Solving this equation

$$v^2 = {v_1}^2 + {v_2}^2 + \frac{2E}{m}$$

Putting value of $v = v1 + v2$

$$(v1 + v2)^2 = {v_1}^2 + {v_2}^2 + \frac{2E}{m}$$

$$v_1 v_2 = \frac{E}{m}$$

And we know that

$$(v_1 + v_2)^2 = (v1 + v2)^2 - 4v_1 v_2$$

Substituting $v_1 v_2$ and v from above expressions.

$$(v_1 + v_2)^2 = v^2 - 4\frac{E}{m}$$

Now for minimum v, $v_1 = v_2$

Then

$$v^2 = 4\frac{E}{m}$$

$$v = \sqrt{4\frac{E}{m}}$$

$$= \sqrt{\frac{4\times13.6\times1.6\times10^{-19}}{1.67\times10^{-27}}}\text{m/s}$$

$$= 7.2 \times 10^4 \text{m/s}$$

Answer.35

For inelastic collision to take place between neutron and hydrogen of same mass the sum of initial kinetic energy should be greater than or equal to amount of energy absorbed for change in transition to first exited state.

Energy for first exited state $E = 13.6\left(\frac{1}{1} - \frac{1}{4}\right) = 10.2eV$

Sum of kinetic energy= K.E of neutron+ K.E of hydrogen atom

$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ (as both has same velocity)

$$= mv^2$$

So for minimum speed

$$mv^2 = E$$

$$v = \sqrt{\frac{E}{m}}$$

$$= \sqrt{\frac{10.2\times1.6\times10^{-19}}{1.67\times10^{-27}}}\text{m/s}$$

$= 3.13 \times 10^4 \text{m/s}$

Answer.36

(a)As per $P = \frac{h}{\lambda}$

$= \frac{6.63 \times 10^{-34}}{656.3 \times 10^{-9}} = 10^{-27} \text{kgm/s}$

(b)As $P = mv$

$10^{-27} = 1.67 \times 10^{-27} \times v$

$v = 0.6 \text{m/s}$

(c) K.E$= \frac{1}{2} m v^2$

$= \frac{1}{2} \times 1.67 \times 10^{-27} \times 0.6^2$ J

$= 0.3 \times 10^{-27} J = 1.9 \times 10^{-9} eV$

Answer.37

Let E be the energy due to change in transition state and E_r be the recoil energy, $\Delta\lambda = \lambda' - \lambda$ *be change in wavelength.*

So, $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

And similarly from question $\lambda' = \frac{hc}{E - E_r}$

And $E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{4} - \frac{1}{9}\right) = 1.89eV = 3.024 \times 10^{-19}J$

$$E_r = E - \frac{1}{2}mv^2$$

$$E_r = 3.024 \times 10^{-19}J - \frac{1}{2} \times 9.1 \times 10^{-31}\left[\left(\frac{2.18}{2}\right)^2 - \left(\frac{2.18}{3}\right)^2\right] \times 10^{12}\,J$$

$$E_r = 3.024 \times 10^{-19}J - 3.0225 \times 10^{-19}J$$

Fractional change in wavelength

$\frac{\Delta\lambda}{\lambda} = \frac{\lambda' - \lambda}{\lambda} = \frac{E_r}{E - E_r} = 10^{-9}$ (after substituting the values and considering approximation.)

Answer.38

Maximum work function of a metal so that it can emit H_α light will be equal to energy absorbed by these H_α light to change the transition state from n=1 to n=2

$$E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{4} - \frac{1}{9}\right) = 1.89eV$$

So maximum work function can be $1.89eV$.

Answer.39

Maximum work function of the metal will be equal to the maximum energy liberated in Balmer Series to change the transition state.

And for maximum energy in Balmer Series

$$n_1 = 2 \text{ and } n_2 = \infty$$

$$E = 13.6\left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right) = 13.6\left(\frac{1}{4} - \frac{1}{\infty}\right) = 3.4eV$$

So maximum work function can be $3.4eV$.

Answer.40

Given: Work function of cesium is 1.9 eV.

Radiation from hydrogen discharge tube is equal to the photon energy in ground state and is equal to 13.6eV.

Now applying photoelectric effect.

Maximum K.E = Energy of photon – Work function

$= 13.6eV - 1.9eV$

$= 11.7eV$

Answer.41

Given: Threshold wavelength $\lambda = 440\text{nm}$

Work function $\phi = 2eV$

Applying photoelectric effect equation

$E - \phi = \text{K.E} = eV_0$

$and\ we\ know\ that\ E = \frac{1242}{\lambda} eV\ where\ \lambda\ is\ in\ nm$ from

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$
$$= \frac{1242}{\lambda} eV\ where\ \lambda\ is\ in\ nm.$$

$$\Rightarrow \left(\frac{1242}{440} - 2\right) eV = eV_0$$

$V_0 = 0.82volt$

Answer.42

Given: Mass of the earth = m_e = 6.0 × 10^{24} kg

Mass of the sun = m_s = 2.0 × 10^{30} kg

earth-sun distance = r =1.5 × 10^{11} m

Applying Bohr's quantization rule for angular momentum

$$m_e v r = \frac{nh}{2\pi}$$

And due to gravitational force balancing centripetal force.

$$\frac{G m_s m_e}{r^2} = \frac{m_e v^2}{r}$$

Using both the equations we get

$$r = \frac{n^2 h^2}{4\pi^2 G m_s^{\,2} m_e^{\,2}}$$

And $v = \frac{2\pi G m_s m_e}{nh}$

(a) For minimum value of r, n=1

$$r = \frac{1^2 \times (6.63 \times 10^{-34})^2}{4 \times 3.14^2 \times 6.67 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}} = 2.3 \times 10^{-138} m$$

(b) For present radius

$$n = \sqrt{\frac{4\pi^2 r G m_s^{\,2} m_e^{\,2}}{h^2}}$$

After substituting the values as above

$$n = 2.5 \times 10^{74}$$

Answer.43

Applying Bohr's quantization rule for angular momentum

$$m_e v r = \frac{nh}{2\pi}$$

And due to gravitational force balancing centripetal force.

$$\frac{G m_s m_e}{r^2} = \frac{m_e v^2}{r}$$

Using both the equations we get

$$r = \frac{n^2 h^2}{4\pi^2 G {m_s}^2 {m_e}^2}$$

And $v = \frac{2\pi G m_s m_e}{nh}$

Now substituting these values in

$$K.E = \frac{1}{2} m_e v^2 = \frac{1}{2} m_e \left(\frac{2\pi G m_s m_e}{nh}\right)^2 = \frac{2\pi^2 G^2 {m_s}^2 {m_e}^2}{n^2 h^2}$$

$$P.E = -\frac{G m_s m_e}{r} = -\frac{4\pi^2 G^2 {m_s}^2 {m_e}^2}{n^2 h^2}$$

Total energy = K.E + P.E

$$= -\frac{2\pi^2 G^2 {m_s}^2 {m_e}^2}{n^2 h^2}$$

Answer.44

Applying Bohr's quantization rule

$$mvr = \frac{nh}{2\pi}$$

And as electron is projected perpendicular to the magnetic field it will follow

$r = \frac{mv}{qB}$

Using both the equations and q=e

$eBr^2 = \frac{nh}{2\pi}$

$r = \sqrt{\frac{nh}{2\pi eB}}$

(a)Smallest possible radius is when n=1

$r = \sqrt{\frac{h}{2\pi eB}}$

(b)Radius in nth orbit

$r = \sqrt{\frac{nh}{2\pi eB}}$

(c)Using $mvr = \frac{nh}{2\pi}$ again and substituting the value of r from above

$v = \sqrt{\frac{nheB}{2\pi m^2}}$

For minimum possible value n=1

$v = \sqrt{\frac{heB}{2\pi m^2}}$

Answer.45

According to question if even quantum numbers are only allowed as there is even multiple of $h/2\pi$ then longest wavelength is possible for n=2 to n=4

Energy in this path

$E = 13.6\left(\frac{1}{4} - \frac{1}{16}\right) = 2.55eV$

and we know that

$$E = \frac{hc}{\lambda} = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} J = \frac{6.64 \times 10^{-34} \times 3 \times 10^{8}}{\lambda \times 1.6 \times 10^{-19}} eV$$

$$= \frac{1242}{\lambda} eV \text{ where } \lambda \text{ is in } nm.$$

$$\frac{1242}{\lambda} = 2.55$$

$$\lambda = 487 nm$$

Answer.46

As per the question v is frequency of emitted radiation and

v_0 is frequency if atom is at rest and velocity of photon is u.

But as u << c so velocity of emitted photon is same as that of

Hydrogen atom =u.

Now applying Doppler's effect formula

$$v = v_0 \left(\frac{1 + \frac{u}{c}}{1 - \frac{u}{c}} \right)$$

As u << c $\Rightarrow \frac{u}{c} \ll c$

Hence

$$v = v_0 \left(1 + \frac{u}{c}\right)$$