PHYSICS

BOOKS - VIKRAM PUBLICATION (ANDHRA PUBLICATION)

ATOMS

Textual Examples

1. In the Rutherford's nuclear model of the atom, the nucleus (radius about $10^{-15} m$) is analogous to the sun about which the electron move in orbit (radius= $10^{-10} m$) like the earth orbits around the sun. If the dimensions of the solar system had the same proportions as those of the atom, would the earth be closer to or farther away from the sun than actually it is ? The radius of earth's orbit is about $1.5 \times 10^{11} m$. The radius of sun is taken as $7 \times 10^{8} m$.

2. In a geiger - marsden experiment. Find the distance of closest approach to the nucleus of a 7.7 me v α- particle before it comes momentarily to rest and reverses its direction. (z for gold nucleus = 79) .

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3. It is found experimentally that $13.6eV$ energy is required to separated a hydrogen atom into a proton and an electron. Compute the orbital radius and velocity of electron in a hydrogen atom.

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4. According to the classical electromagnetic theory, calculate the initial frequency of the light emitted by the electron revolving around a proton in hydrogen atom.

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5. A 10 kg satellite circles earth once every 2 h in an orbit having a radius of `8000 km. Assuming that Bohr's angular momentum postulate applies to satellites just as it does to an electron in the hydrogen atom, find the quantum number of the orbit of the satellite.

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6. Using the Rydberg formula, calculate the wavelengths of the first four spectral lines in the Lyman series of the hydrogen spectrum.

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Vert Short Answer Questions

1. What is the angular momentum of electron in the second orbit of Bohr's model of hydrogen atom ?

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2. Calculate the value of 'fine structure constant'

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3. What is the physical meaning of 'negative energy of an electron' ?

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4. Sharp lines are present in the spectrum of a gas. What does this indicate ?

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5. Name a physical quantity whose dimensions are the same as those of angular momentum.

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6. What is the difference between α - particle and helium atom ?

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7. How is impact parameter related to the scattering angle?

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8. Among alpha, beta and gamma radiations, which get affected by the electric field ?

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9. What do you understand by the 'phrase ground state atom' ?

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10. Why does the mass of the nucleus not have any significance in scattering in Rutherford's experiment ?

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11. The Lyman series of hydrogen spectrum lies in the ultraviolet region. Why?

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12. Write down a table giving longest and shortest wavelengths of different spectral series.

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13. The wavelengths of some of the spectral lines obtained in hydrogen spectrum are 1216Å, 6463Å and 9546Å. Which one of these wavelengths belongs to the Paschen series ?

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14. Give two drawbacks of Rutherford's atomic model.

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15. If the kinetic of revolving electron in an orbit is K, what is its potential energy and total energy ?

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Short Answer Question

1. How is impact parameter related to the scattering angle?

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2. Derive an expression for the potential energy and kinetic energy of an electron in any orbit of a hydrogen atom, according to Bohr's atomic model. How does P.E. change with increasing n?

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3. What are the limitations of Bohr's theory of hydrogen atom?

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4. Explain distance of closest approach and impact parameter with illustrations.

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5. Give a brief account of Thomson model of-atom. What are its limitations ?

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6. Describe Rutherford atom model. What are the draw backs of this model.

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7. Distinguish between excitation potential and ionization potential.

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8. Explain the different types of spectral series· in hydrogen atom.

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9. Write a short note on Debroglie's explanation of Bohr's second postulate of quantization.

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Long Answer Questions

1. Draw a schematic arrangement of the Geiger Marsden experiment. How did the scattering of α particles by a thin foil of gold provide an important way to determine an upper limit on the size of nucleus? Explain briefly.

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2. Discuss Bohr's theory of the spectrum of hydrogen atom.

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3. State the basic postulates of Bohr's theory of atomic spectra. Hence obtain an expression for the radius of orbit and the energy of orbital electron in a hydrogen atom.

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Textual Exercises

1. The radius of the first electron orbit of a hydrogen atom is $5.3 \times 10^{-11} m$. What is the radius of the second orbit ?

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2. Determine the radius of the first orbit of the hydrogen atom. What would be the velocity and frequency of the electron in the first orbit ? Given :

$h = 6.62 \times 10^{-34} Js, m = 9.1 \times 10^{-31} kg, e = 1.6 \times 10^{-19} C, k = 9 \times 10^{9}$

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3. The total energy of an electron in the first excited state of the hydrogen atom is -3.4eV. What is the potential energy of the electron in this state ?

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4. The total energy of an electron in the first excited state of hydrogen atom is -3.4eV. What is the kinetic energy of the electron in this state ?

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5. Find the radius of the hydrogen atom in its ground state. Also calculate the velocity of the electron in n = 1 orbit. Given

$h = 6.63 \times 10^{-34} Js, m = 9.1 \times 10^{-31} kg,$

$e = 1.6 \times 10^{-19} C, K = 9 \times 10^{9} Nm^{2} C^{-2}$

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6. Prove that the ionisation energy of hydrogen atom is 13.6 eV.

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7. Calculate the ionization energy for a lithium atom.

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8. The wavelength of the first member of Lyman series is 1216Å. Calculate the wavelength of second member of Balmer series.

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9. The wavelength of first member of Balmer series is 6563Å. Calculate the wavelength of second member of Lyman series.

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10. The second member of Lyman series in hydrogen spectrum has wavelength 5400Å. Find the wavelength of first member.

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11. Calculate the shortest wavelength of Balmer series. Or Calculate the wavelength of the Balmer series limit. Given : $R = 10970000m^{-1}$.

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12. Using the Rydberg formula, calculate the wavelength of the first four spectral lines in the Balmer series of the hydrogen spectrum.

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Additional Exercises

1. Choose the correct alternative form the clues given at the end of each statement:

(a) The size of the atom in Thomson's model is .... the atomic size in Rutherford's model (much greater than/no different form/much less than)

(b) In the ground state of ...., electrons are in stable equilibrium, while in.......... electrons always experience a net force (Thomson's model/Rutherford's model).

(c) A classical atom based on .... is doomed to collapse (Thomson's model/Rutherford's model).

(d) An atom has a nearly continuous mass distribution in .... but has highly non uniform mass distribution in....... (Thomson's model/Rutherford's model).

(e) The positively charge part of the atom possesses most of the mass of the atom in .... (Rutherford's ,model /both the models).

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2. Suppose you are given a chance to repeat the alpha - particle scattering experiment using a thin sheet of solid hydrogen in place of the gold foil. (Hydrogen is a solid at temperatures below 14 K.) What results do you expect ?

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3. What is the shortest wavelength present in the Paschen series of spectral lines ?

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4. A difference of 2.3 eV separates two energy levels in an atom. What is the frequency of m radiation emitted when the atom make a transition from the upper level to the lower level ?

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5. The ground state energy of hydrogen atom is-13.6 eV. What are the kinetic and potential energies of the electron in this state ?

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6. A hydrogen atom initially in the ground level absorbs a photon, which excites it to the n = 4 level. Determine the wavelength and frequency of photon.

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7. a) Using the Bohr's model calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels.

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8. (a) Using the Bohr's model, calculate the speed of the electron in a hydrogen atom in the n=1,2 and 3 levels. (b) Calculate the orbital period in each of these levels.

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9. The radius of the innermost electron orbit of a hydrogen atom is $5.3 \times 10^{-11} m$. What are the radii of the n = 2 and n = 3 orbits ?

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10. A $12.5 eV$ electron beam is used to bombard gaseous hydrogen at room temperature. What serious of wavelength will be emitted?

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11. In accordance with the Bohr's model, find the quantum number that characterises the earth's revolution-around the sun in an orbit of radius $1.5 \times 10^{11} m$ with orbital speed $3 \times 10^{4} m/s$. (Mass of earth $= 6.0 \times 10^{24} kg$.)

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12. Answer the following questions, which help you understand the difference between Thomson's model and Rutherford's model better.

Is the average angle of deflection of $alph$ - particles by a thin gold foil predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?

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13. Is the probability of backward scattering (i.e. scattering of a-particals at angle greater than 90^0) predicated by Thomson's model much less, about the same , or much greater than less, about the same , or much greater than that predicted by Ruthorford's model ?

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14. Answer the following questions, which help you understand the difference between Thomson's model and Rutherford's model better.

Keeping other factors fixed, it is found experimentally that for small thickness t, the number of α- particles scattered at moderate angles is proportional to t. What clue does this linear dependence on t provide ?

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15. Answer the following questions, which help you understand the difference between Thomson's model and Rutherford's model better.

(a) Is the average angle of deflection of -particles by a thin gold foil predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?

(b) Is the probability of backward scattering (i.e., scattering of α-particles at angles greater than 90°) predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?

(c) Keeping other factors fixed, it is found experimentally that for small thickness t, the number of α-particles scattered at moderate angles is proportional to t. What clue does this linear dependence on t provide?

(d) In which model is it completely wrong to ignore multiple scattering for the calculation of average angle of scattering of α -particles by a thin foil?

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16. The gravitational attraction between electron and proton in a hydrogen atom is weaker than the coulomb attraction by a factor of about 10^{-40}. An alternative way of looking at this fact is to estimate the radius of the first Bohr orbit of a hydrogen atom if the electron and proton were bound by gravitational attraction. You will find the answer interesting.

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17. Obtain an expression for the frequency of radiations emitted when a hydrogen atom de-excites from level n to level (n-1). for larger n, show that the frequency equals the classical frequency of revolution of the electron in the orbit.

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18. Classically, an electron can be in any orbit around the nucleus of an atom. Then what determines the typical atomic size? Why is an atom not, say, thousand times bigger than its typical size? The question had greatly puzzled Bohr before he arrived at his famous model of the atom that you have learnt in the text. To simulate what he might well have done before his discovery, let us play as follows with the basic constants of nature and see if we can get a quantity with the dimensions of length that is roughly equal to the known size of an atom $\left(\sim 10^{-10} m\right)$.

(a) Construct a quantity with the dimensions of length from the fundamental constants e, m_e, and c. Determine its numerical value.

(b) You will find that the length obtained in (a) is many orders of magnitude smaller than the atomic dimensions. Further, it involves c. But energies of atoms are mostly in non-relativistic domain where c is not expected to play any role. This is what may have suggested Bohr to discard c and look for 'something else' to get the right atomic size. Now, the Planck's constant h had already made its appearance elsewhere. Bohr's great insight lay in recognising that h, m_e, and e will yield the right atomic size. Construct a quantity with the dimension of length from h, m_e, and e and confirm that its numerical value has indeed the correct order of magnitude.

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20. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV.

What is the kinetic energy of the electron in this state ?

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21. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV.

What is the potential energy of the electron in this state ?

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22. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV.

Which of the answers above would change if the choice of the zero of potential energy is changed?

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23. If Bohr's quantisation postulate (angular momentum = $nh/2\pi$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why then do we never speak of quantisation of orbits of planets around the sun?

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24. Obtain the first Bohr radius and the ground state energy of a muonic hydrogen atom (i.e., an atom in which a negatively charged muon (μ) of mass about $207m_e$ revolves around a proton).