



# PHYSICS

## NCERT - NCERT PHYSICS(ENGLISH)

### ATOMS

#### Solved Examples

1. In Rutherford's nuclear model of the atom, the nucleus (radius about  $10^{-15}m$ ) is analogous to the sun about which the

electron moves in orbit (radius about  $10^{-10}m$ ) 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 further 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 the sun is taken as  $7 \times 10^8m$ .



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2. In the original experiment, Geiger and Marsden calculated the distance of closest approach to the gold nucleus ( $Z=79$ )- of a  $7.7\text{MeV } \alpha$  particle before it comes momentarily to rest and reverses its direction. What is its value?



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3. It is found experimentally that  $13.6\text{eV}$  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 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  $10\text{kg}$  satellite circles earth once every  $2\text{hr}$  in an orbit having a radius of  $8000\text{km}$ . 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 wavelength of the first four spectral lines in the Lyman series of the hydrogen spectrum.



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## Exercise

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 radiation emitted when the atom transits from the upper level to the lower level.



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5. The energy of the electron in the ground state of hydrogen atom is  $-13.6\text{eV}$ . Find the

kinetic energy and potential energy of electron in this state.



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6. A hydrogen atom initially in the ground level absorbs a photon, Which excites it to  $n=4$  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. (b) Calculate the orbital period in each of these levels.



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



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9. A  $12.5\text{eV}$  electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted?



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



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**11.** 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  $\alpha$ -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  $\alpha$ -particles at angles greater than  $90^\circ$ ) 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  $\alpha$ -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  $\alpha$  -particles by a thin foil?



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12. 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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**13.** 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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**14.** 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 ( $\sim 10^{-10}m$ ).

(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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**15.** The total energy of an electron in the first excited state of hydrogen atom is  $-3.4$  eV.

(a) What is kinetic energy of electron in this

state?

(ii) What is potential energy of electron in this state?

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



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**16.** If Bohr's quantisation postulate (angular momentum =  $n\hbar / 2\pi$ ) 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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**17.** 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 ( $\mu$ ) of mass about  $207m_e$  revolves around a proton).



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