CONCEPTUAL QUESTIONS

Q 1. Why does the spectrum of hydrogen consists of many lines even though a hydrogen atom has only a single electron?

Ans: Spectrum of hydrogen contains many lines although it has single electron. It is because atom of hydrogen has many energy levels in which the electron can be excited. During de-excitation, it returns to ground state either directly or in several jumps into lower energy states. During each jump of de-excitation, a photon of a specific frequency and wavelength is emitted depending upon the difference of energy between corresponding levels. This is the reason that spectrum of hydrogen has more than one lines.

Q 2. Suppose that the electron in hydrogen atom obeyed classical mechanics rather quantum mechanics. Why would such a hypothetical atom emit a continuous spectrum rather than the observed line spectrum?

Ans: If electron of hydrogen obeyed classical mechanics, then according to classical electromagnetic theory, an electron in accelerated motion always emits electromagnetic radiation continuously during the course of acceleration. Since electron of hydrogen atom is in continuous accelerated motion when it revolves around nucleus (centripetal acceleration), so it should emit electromagnetic radiations continuously. Therefore the spectrum formed should be continuous, and not discrete lines.

Q 3. Can the electron in the ground state of hydrogen absorb a photon of energy (a) less than 13.6eV (b) greater than 13.6eV? Explain.

Ans: (a) Yes, electron of hydrogen atom in ground state can absorb a photon of energy less than 13.6eV but not all the photons. It can absorb only those photons of energy less than 13.6eV, which satisfy the following generalized energy equation of hydrogen atom given by

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

where n=integer.

Now if n = 2 => E_2 = -3.4 eV can be absorbed and if n=3 then E_3= -1.51 eV can also be absorbed but a photon having energy in between 1.51 eV and 3.4 eV will not be absorbed. For a photon to be absorbed, it is important to have energy, equal to the difference of energies between the two levels in which transition is desired.

In short, if a photon has energy less than 13.6 eV and it satisfies the quantized energy equation above, can be absorbed.

(b) If a photon carries energy more than 13.6 eV then it can also be absorbed but the electron of hydrogen will no more be its part i.e, this photon of energy more than 13.6 eV will ionize hydrogen atom because ionization energy of hydrogen atom is

13.6 eV. The electron of hydrogen atom will take 13.6 eV as its ionization energy to become free and rest of the energy will appear as its kinetic energy.

Q 4. Why do solids give rise to continuous spectrum while hot gases give rise to line spectrum?

Ans: In solids, the constituent atoms are so close to each other that their energy levels overlap to form an energy band. In this energy band, all transitions are possible. Each transition corresponds to a particular frequency and wavelength. Therefore in solids, the spectrum formed is continuous due to the fact that radiations of all wavelengths are emitted.

On the contrary, gas molecules are not as close to each other as the atoms in solids. The distance between molecules of a hot gas is larger as compared to their average size. Also the energy levels of gas molecules are discrete. Therefore, their spectrum is also discrete, containing lines of particular wavelength. Each line corresponds to a specific transition. Thus spectrum of solids is continuous while that of hot gases is discrete.

Q 5. Explain difference between laser light & light from an incandescent lamp.

- Incandescent lamp has light of all wavelengths while laser light has only a single wavelength (monochromatic).
- Light from incandescent lamp spreads equally in all directions but laser light travels only in one direction (parallel).
- Light of incandescent lamp is not coherent but laser light is coherent.
- Light of incandescent lamp is due to spontaneous emission while laser light is emitted due to stimulated emission.
- There is no need of optical pumping and metastable state for light of ordinary lamp but laser light requires both of these.
- Intensity of ordinary light is lesser than laser light.

Q 6. Why Bohr extends quantum theory to the structure of the atom?

Ans: Bohr extended quantum theory to the structure of atom because classical theory failed to explain many aspects of structure of atom for instance, an electron revolving around nucleus is in accelerated motion and hence by applying classical electromagnetic theory it should radiate electromagnetic waves but it does not radiate during its motion around nucleus. Electromagnetic radiation are emitted only when electron de-excites from higher to a lower energy level.

Another point of failure of classical theory is that in classical theory, electron in an atom can occupy any energy state but once again, it is not true in reality as an electron can only occupy those energy states in which its angular momentum is an integral multiply of Planck's constant. Due to these reasons, Bohr extended quantum theory to the structure of the atom.

Q 7. Why $_2He^4$ has larger ionization energy than H?

Ans: In order to ionize an atom, we must provide it an energy that overcomes the electrostatic force of attraction between positively charged nucleus and negatively charged electron. Now helium "He" nucleus has two protons while hydrogen H has only one proton. This clearly indicates that Columbic attractive force between nucleus and electron of He atom is greater than that for H atom. Hence electron of He atom is more tightly bound to the nucleus than electron of H atom. So more energy is required to overcome the Columbic attractive force of He atom and lesser for H-atom. Therefore, we can say He has larger ionization energy than hydrogen.

Q 8. X-rays can emit eléctrons from metal surface and X-rays can be diffracted. Comment?

Ans: We know that matter and energy both have dual nature i.e, particle as well as wave nature but we cannot observe both aspects at a single time. Whenever X-rays have got energy lesser than 0.5MeV, they can emit electrons from metal surface on which they are incident. In this case, they behave as particles, called X-ray photons.

When the same X-rays fall on a crystal, they are diffracted because their wavelength and interatomic distance in crystals are of the same order (A°). In this case, X-rays behave like waves.

In short, X-rays are electromagnetic radiations which have particle as well as wave behavior depending upon the type of experiment.

Q 9. Why X-rays have different properties from light even though both originate from orbital transition of electrons in excited atoms?

Ans: Innermost electrons of heavy atoms are very tightly bound to the nucleus and when they are knocked out, the X-rays are emitted which have very high energy and high penetrating power. They are capable of ionizing a gas through which they pass. On the other hand, ordinary light is also produced due to the atomic transition but electrons involved in this case are outermost shell electrons that make transition and emit the light. Outer shell electrons are loosely bound to the nucleus. So light emitted from them does not have same properties as that of X-rays.

Due to this reason, we can say that X-rays have different properties than light despite the fact that both originate from atomic transition of electrons in excited atoms.

Q 10. What is meant by the statement that a laser beam is coherent, monochromatic and parallel?

Ans: A laser beam is coherent means that all the waves emitted from a laser light have same phase difference which does not change at all.

A laser beam is monochromatic means that all the waves carried by laser light beam have a single wavelength or single color.

A laser beam is parallel means that light from a laser source always travels in a straight line.

Q 11. What are laser knives?

Ans: Laser beam is very thin as well as intense and it can be used to cut a thin material or sheet. Due to this fine cutting property, these are also called laser knives. Laser cutting is one of the neatest and fastest cutting process available today. It is readily used in industries for cutting die boards, thin metal sheets and paper sheets. Another wide area of the laser knives is in medicine where surgery of a particular area of body is carried and infected region is cut quite efficiently than a finest scalpel.

Q 12. Why we cannot see atom?

Ans: Size of the atom is so small that it cannot be seen even by high resolution microscopes available. Size of the atom is of the order of angstrom and there is no such microscope that can resolve an object of this size. In order to see the atom we need a microscope which uses light of wavelength, smaller than size of the atom but it is not available till yet. That is why we cannot see the atom.

13. What meant by braking radiation?

Ans: Whenever an electron moving with very high kinetic energy, approaches a heavy nucleus, its kinetic energy is lost because of the interaction of electron with the heavy nucleus. As a result, the electron suddenly slows down in which its kinetic energy appears as photons in the X-rays region. These are continuous X-rays and are also called Bremsstrahlung (braking radiations). These braking radiations are electromagnetic in nature.

14. What is optical pumping?

Ans: Optical pumping is the process in which a photon hits the electron of an atom in order to excite it from lower energy state to a higher energy state. This process is required by laser to produce laser beam. The lasing medium also called the active medium is supplied with photons to raise its electrons to excited state. Once the electrons are in excited state and population inversion is achieved, a high intensity, monochromatic and coherent laser beam is emitted by stimulated emission.