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Chapter = 20

ATOMIC SPECTRA

What is Spectroscopy?

"The branch of Physics which deals with investigation of wavelength and intensities of electromagnetic radiations emitted or absorbed by atoms is called spectroscopy".

Define the Types of spectra?

There are following three types of spectra

i. Continuous spectra
ii. Band spectra
iii. Discrete or line spectra

Continuous spectrum:

A spectrum which consists of continuously frequency region without broken up in lines or band is called continuous spectrum.

For example:

Black body radiation spectrum.

What is Band spectrum: A spectrum that appears as a number of bands of emitted or absorption radiations is called band spectrum. For example Molecular spectrum

Line or discrete spectrum: A spectrum which consists of discrete lines corresponding to single wavelength of emitted radiations is called line spectrum. For example **atomic spectra of hydrogen atom.**

Atomic spectrum

A spectrum of radiations due to transition b/w energy levels in an atom is called atomic spectrum.

Spectral series: The spectrum of an element contains certain wavelengths that show definite regularities into certain groups called spectral series General formula for spectral series $\frac{1}{\lambda}=R_H\left(\frac{1}{p^2}-\frac{1}{n^2}\right)$.

R_H= Rydberg constant=1.0974*10^7 m^{-1}

Name of series	Formula	n=	Region in which lies	Range of wavelength
Lyman series	$\frac{1}{\lambda}=R_H\left(\frac{1}{l^2}-\frac{1}{n^2}\right)$	2, 3,4,..	Ultraviolet Region	91 nm to 122 nm
Balmer Series In 1896	$\frac{1}{\lambda}=R_H\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$	3, 4,5,..	Visible region	365 nm to 656 nm
Paschen series	$\frac{1}{\lambda}=R_H\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$	4, 5,6,..	Infrared region	820 nm to ownward…
Bracket series	$\frac{1}{\lambda}=R_H\left(\frac{1}{4^2}-\frac{1}{n^2}\right)$	5, 6,7,…	Infrared region	…….
Pfund series	$\frac{1}{\lambda}=R_H\left(\frac{1}{5^2}-\frac{1}{n^2}\right)$	6, 7,8,…	Infrared region	…….

Explain postulates of Bohr Model Of Hydrogen Atom and de-Broglie interpretation of Bohr postulate.

Bohr devised a model of hydrogen atom in 1913

First postulate: Electrons are moving around the nucleus in circular orbit.

Stationary state of atom: When an electron remains in any of allowed orbit, no energy is radiated, these orbit are quantized stationary state of atom.

2nd postulate: Only those orbits are allowed in which angular momentum of electron is integral multiple of h/2π.

$$mvr = n\frac{h}{2\pi}.$$

3rd postulate: When an electron jump from a high energy state En to Ep, a photon of energy hf s emitted such that

$$En - Ep = hf\ .$$

De-Broglie interpretation of Bohr Postulate

Consider a string of length l, in stationary wave set on

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$l = n\lambda \quad l = 2\pi r$ circumference of circle

$2\pi r = n\lambda = --$

$$\lambda = \frac{2\pi r}{n} - (1$$

$$\lambda = \frac{h}{mv} ---------(2$$

comparing both eq $mvr = n\frac{h}{2\pi}$

Write General formula for radius, velocity and energy of hydrogen atom

Quantized Radii: $r_n = n^2 \times 0.053nm$

Quantized energy: $En = -\frac{Eo}{n^2}, \quad Eo = 13.6eV$

Velocity of electron $V_n = \frac{2\pi Ke^2}{nh}$ **in first Bohr orbit v is $2.18*10^6$ m/s.**

Define Ground state?When the electron is in its lowest energy state, it is said to be in its ground state.
DefineExcited state?When the electron is in the higher orbit, it is said to be in excited state
DefineExcitation potential?The potential which require to raise an atom from normal state to higher state is called excitation potential. As excitation potential b/w 2nd and 3rd state is 10.2 V.
Defineionization?The removal of an electron from the atom is called ionization.
Defineionization energy?The amount of energy required to remove an electron from the ground state of an atom completely is called ionization energy. Ionization energy for H-atom is 13.6 eV.
Defineionization potential? The potential which is required to remove an electron from ground state is called excitation potential which 13.6V.

Write formula for Rydberg constant and value. $R_H = \frac{E_o}{hc} = \frac{13.6*1.6*10^{-19}}{6.63*10^{-34}*3*10^8} = 1.09*10^7\, m^{-1}$

Find the speed of the electron in the first Bohr orbit.

Given Data : Bohr orbit = n = 1 speed = v = ?

$$v = \frac{2\pi Ke^2}{nh} = \frac{2*3.14*9*10^9*(1.6*10-19)^2}{1*6.63*10^{-34}} = 2.18*10^6\, m/s$$

Multiple choice questions

1	If an electron jump from nth orbit of energy En to pth(lower) orbit of Energy Ep and a photon of frequency f and wavelength λ is thus emitted than	fλ=En-Ep	**hc/λ=En-Ep**	hf=Ep-En	hλ=Ep-En
2	SI unit of Rydberg constant is	m^{-2}	ms	**m^{-1}**	ms^{-1}
3	If one or more electrons are completely removed from an atom then atom is to be	Excited	**Ionized**	Polarized	Stabilized
4	The numerical value of ground state energy for hydrogen atom in eV is	-10	13.6	10	**-13.6**
5	The value of Rydberg constant is – m^{-1}	**$1.09x10^7$**	$1.07x10^8$	$1.07x10^9$	$6.63x10^{-34}$
6	In electronic transition atom cannot emit	**Gamma rays**	Infra red rays	Visible light	UV rays
7	The energy in the 4th orbit of hydrogen atom is	-2.51eV	-3.50eV	-3.4eV	**-0.85eV**

8	The relation between Rydberg constant RH and ground state energy Eo is	**R_H=Eo/hc**	RH=hc/Eo	Eo=RH/hc	$RH=E_o hC$
9	Balmer series lies in the	UV region	Far UV region	Infrared region	**Visible region**
10	The radius of 2nd orbit by a factor of	2	**4**	3	9
11	The radius of 10th Bohr orbit in hydrogen atom is	0.053nm	0.053nm	**5.3nm**	53nm
12	Which is an example of continuous spectra	**Black body radiation spectrum**	Molecular spectra	Atomic spectra	None of these
13	Atomic spectra are the example of spectra	Continuous spectra	**Line**	Band	Mix
14	The radius of 3rdbohr orbit in hydrogen atom is greater then the radius of 1st orbit by a factor	2	3	4	**9**
15	Which of the following series H-spectrum lies in UV region	**Lyman series**	Balmer series	Pachen series	Bracket series
16	Joule second is the unit of	Energy	Heat	**Plank constant**	Work
17	Which of the following is an example of continuous spectra	**BB radiation spectrum**	Molecular spectrum	Atomic spectra	None
18	In the spectrum of which of the following will you find Balmer series	Oxygen	Nitrogen	**Hydrogen**	All of these
19	The radius of 3rdbohr orbit is	0.159nm	**0.477 nm**	0.53nm	1.59nm
20	The total energy of electron in the state n=infinity of hydrogen atom is	**Zero**	3.2 eV	10.2eV	13.6eV
21	Bohr second postulate was justified by	Bohr himself	**De-Broglie**	Plank	Davisson and Germer
22	The total number of spectral lines for an electron transition from n=5 to n=1 is	1	**5**	7	10
23	Orbital angular momentum in the allowed stationary orbit of H atom is given by	2π/nh	**nh/ 2π**	2h/n π	None
24	When an electron absorb energy it jumps to	Lower energy state	**Higher energy state**	Ground state	Remains in same state
25	Paschen series is obtained when all the transition of electron starts on	2nd orbit	**3rd orbit**	4th orbit	5th orbit
26	Quantized radius of first Bohr orbit in hydrogen atom is	**0.053nm**	0.0053nm	0.0053nm	0.53nm

27	In one or more electrons are completely removed from an atom then atom is said to be	Excited	Polarized	Stabilized	**Ionized**
28	In Balmer series the shortest wavelength radiations have wavelength equal to	$\left(\frac{R_H}{4}\right)m$	$\left(\frac{4}{R_H}\right)m$	$\left(\frac{R_H}{9}\right)m$	$(9R_H)\,m$
29	The longest wavelength radiations in Braket series have wavelength equal to	$-\frac{25}{16}R_H$	$\frac{16}{25}R_H$	$\frac{135}{27R_H}$	**None of these**
30	Which was identified in sun by using spectroscopy	Hydrogen	**Helium**	Oxygen	Uranium
31	Which series lies in visible region of spectrum	**Balmer**	Paschen	Pfund	Bracket

WHAT ARE X-RAYS? EXPLAIN PRODUCTION OF X-RAYS?

X-rays discoveredGerman Physicist by Dr. RontgenIn 1895.

X-rays: Such type of electromagnetic radiations of short wavelength 10A° to 0.5A° are called X-rays.They lie in visible, infrared and ultraviolet region due to small energy differences.

Characteristics X-rays: Such type of X-rays consist of series of specific wavelengths or frequencies are called characteristic X-rays.

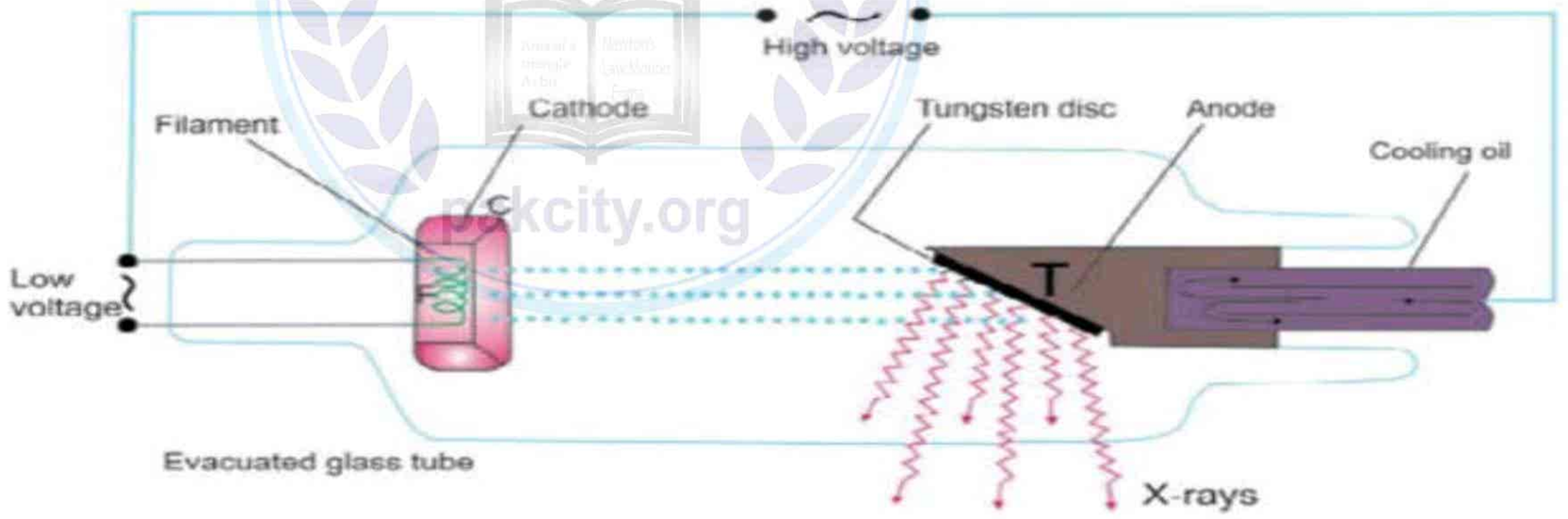
Study of characteristic X-ray spectra is important: Because it has important role in the study of atomic structure and periodic table of elements.

Production of X-rays: For production of X-rays take experimental setup which consists of a high vacuum tube, when cathode is heated by a filament, it emits the electrons which accelerated towards the anode. If Vo is the potential applied then K.E of electrons with which they collide the target is K.E=eVo

Production of X-rays is reverse process of photoelectric effect.

Kα X-rays: When electron from K shell of atom is removed, it produces a vacancy of electron or hole in K shell. The electron from L shell jumps to occupy the hole and emitting a photon of energy $hf_{K\alpha}$ called Kα Xrays. $hf_{K\alpha}=E_L-E_K$.

K_β X-rays: When electron from K shell of atom is removed, it produces a vacancy of electron or hole in K shell. The electron from M shell jumps to occupy the hole and emitting a photon of energy $hf_{K\beta}$ called K_βXrays. $hf_{K\beta}=E_L-E_K$.



Continuous X-rays: Such type of X-rays with a continuous range of frequencies is called continuous X-rays. This is obtained due to deceleration of impacting electrons. This effect is also known as brehmstrahlung or breaking radiations.

Applications of X-rays: There are following applications of X-rays

1. X-rays have many applications in medicines and industry because they penetrate several cm into a solid matter so they can be visualizes the interior of material.
2. They are used in CAT scanner

CAT scanner: CAT stands for computerized axial tomography. It is special technique developed on X-rays and corresponding instrument is called CAT scanner. Density difference of the order of one percent can be detected by CAT scanner such tumors etc.

Biological effects of X-rays: X-rays are ionization radiations. They may cause damage to living tissues. As X-rays useful for selective destruction of cancer cells. X-rays can cause cancer by excessive use. X-rays photons are absorbed in tissues and break the molecular bonds create highly reactive free radicals.

Why electron cannot exist inside the nucleus?

Electron cannot exist inside the nucleus because according to uncertainty principle if electron is to be confined in nucleus its speed would be greater than speed of light which is not possible.

Lets consider if electron can exist inside the nucleus then size of nucleus $\Delta x = 10^{-14}$ m, using uncertainty principle

$$\Delta V = \frac{h}{m\Delta\Delta} = \frac{6.63*10^{-34}}{9.1*10^{-31}*10^{-14}} = 7.3*10^{10}\ \text{m/s}$$ This is not possible as speed can not be greater than speed of ligth.

Now consider electron outside the nucleus then radius of H - atom is $\Delta x = 5*10^{-11}$ m

$$\Delta V = \frac{h}{m\Delta\Delta} = \frac{6.63*10^{-34}}{9.1*10^{-31}*5*10^{-11}} = 1.46*10^{7}\ \text{m/s}$$, this is possible as speed of electron is less than speed of light

WHAT IS LASER? EXPLAIN ITS PRINCIPLE AND WORKING.

LASER stands for light amplification by stimulated emission of radiation

Laser: It is a device which produce very narrow beam of radiations having following properties

i) intense ii) unidirectional iii) coherent iv) monochromatic is called laser.

Kinds of transitions occurs during the process of laser: There are following types of transition occur in laser.

i. **Stimulate absorption**: if the atom is initially in lower state E_1, it can raised to E_2 by absorbing a photon of energy E_2-E_1=hf is called induced absorption of stimulated absorption.
ii. **Spontaneous emission**: if the atom is initially in excited state E2, it can drop to E1 by emitting photon of energy hf, this is called spontaneous emission. 10-8 sec time is required for it.
iii. **Stimulated emission**: the process in which de-excitation of an atom is caused by an incident photon with emission of second photon of same energy is called stimulated emission.

Life time for excited and metastable state: Excited state= 10^{-8} sec metastable state= 10^{-3} sec

Meta stable state: Long lived state than excited state is metastable state, its life time is 10^{-3} sec.

Normal population: A normal population of atomic energy state with more atoms in the lower energy state E_1 than in the excited state E_2.

Population inversion: A population inversion in which high energy state has greater population then lower energy state

WHAT IS He-Ne laser? WRITE ITS USES.

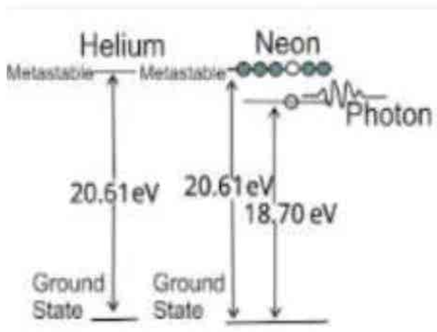
It is most common type of laser which consist of discharge tube filled with 15% neon gas and 85% helium gas.

i. Neon is the lasing or active medium in tube
ii. Helium and neon have nearly identical metastable state
iii. Helium is located at 20.61 eV
iv. Neon is located at 20.66eV

Uses of He-Ne laser: There are following uses of laser

i. It is used to diagnose disease of eye
ii. The use of laser technology in the field of ophthalmology is widespread

Population inversion occur in neon: It is achieved by direct collision with same energy electrons of helium atoms.



Uses of laser: There are following uses of Laser

i. Laser beam is used as surgical tool for welding detached retinas
ii. It is used to diagnose the disease of eye
iii. It is used to destroy cancerous, pre-cancerous cells
iv. It is potential energy source for inducing fusion reaction
v. It can be used for telecommunication in optical fiber
vi. It can be used to generate three dimensional image of object

WHAT IS Holography?Such a process in which three dimensional image of objects is generated by using the laser beam is called holography

Difference b/w orbital and free electrons: The orbital electrons have specific amount of energies whereas free electrons may have any amount of energy.

Multiple choice questions

1	X-rays are	High energy electrons	**High energy photons**	High energy protons	High energy neutrons
2	Which one of the following is not characteristic of laser	High intensity	High directivity	**Incoherence**	Monochromatic
3	Laser can only be produced if an atom is in its	Normal state	**Excited state**	Ionized state	De-excited state
4	X-ray photon moves with a velocity of	Less than light	**Light**	Greater than light	Sound
5	Helium Neon laser discharge tube contain neon	82%	**15%**	25%	85%
6	X-rays are EM radiations having wavelength in the range of	10^{-12} m	**10^{-10} m**	10^{-8} m	10^{-6} m
7	X-rays production is reverse phenomenon of	Compton effect	**Photo electric effect**	Pair production	Annihilation of matter
8	X-rays can be	Reflected	Diffracted	Polarized	**All of these**
9	After the emission of X-rays the atom of the target is	Doubly ionized	Single ionized	In the excited state	**In the ground state**
10	What is color of light emitted from He-Ne laser	Blue	Green	**Red**	Yellow
11	Electron can reside in excited state for about	10^{-3} sec	10^{-5} sec	**10^{-8} sec**	10^{-11} sec
12	For holography we use a beam of	Gamma rays	X-rays	Beta rays	**Laser**
13	Which of the following requires a material medium for their propagation	Heat waves	X-rays	**Sound waves**	UV rays
14	Joule second is the unit of	Energy	Heat	**Plank constant**	Work
15	Which is not true for X-rays	Not deflected by E	**Are polarized**	Consist of EM waves	Can be diffracted by grating
16	The diameter of an atom is of the order	10^{-12} m	**10^{-10}m**	10^{-4} m	10^{-5} m
17	Helium neon laser contain helium	25%	**85%**	15%	80%
18	Laser light has the property of	**Coherent waves**	Non coherent waves	Sound waves	Water waves

19	Production of X-rays is reverse process of	Pair production	Compton effect	**Photoelectric effect**	Annihilation of matter
20	X rays diffraction reveals that these are	Particle type	**Wave type**	Dual type	None
21	In CAT scanning a---- array of X-rays beam is directed through patient	Skin out	**Fanned out**	Normal out	Fitted
22	He-Ne laser is being used to diagnose diseases of	**Eye**	Brain	Skull	Skin

EXERCISE SHORT QUESTIONS

1. **Bohr's theory of hydrogen atom is based upon several assumptions. Do any of these postulate contradict classical physics?

Yes, Bohr's first postulate contradicts classical physics. According to this postulate: An electron in an orbit revolving around the nucleus doesn't radiate energy by radiation. But according to the classical physics, an accelerated electron radiates energy due to its circular motion around nucleus

2. **What is meant by a line spectrum? Explain, how line spectrum can be used for the identification of elements?

A spectrum which consists of isolated sharp parallel lines, in which each line corresponds to a definite frequency and wavelength, is called line spectra. Each element gives its own characteristic lines of definite wavelengths. So, elements can be easily identified by observing its spectrum.

3. **Can the electron in the ground state of hydrogen absorb a photon of energy 13.6 eV and greater than 13.6 eV?

Yes it can absorb a photon of energy 13.6 eV and greater than 13.6 eV. Since the ionization energy of the electron in the ground state of hydrogen atom is 13.6 eV. So by absorbing a photon having energy greater than 13.6 eV, ionization of H-atom will take place and the surplus energy of photon is taken away by electron as kinetic energy.

4. **How can the spectrum of hydrogen contain so many lines when hydrogen contains one electron?

When H-atom de-excites, the electron will come from higher energy level to ground level by several jumps. As the result, photons of different wavelengths are emitted. That's why the spectrum of hydrogen contains so many lines.

5. **Is energy conserved when an atom emits a photon of light?

Yes, energy is conserved when an atom emits a photon of light. Because the energy emitted during de-excitation is exactly equal to the energy absorbed by the atom during excitations. So the energy is conserved in this process.

6. Explain why a glowing gas gives only certain wavelengths of light and why that gas is capable of absorbing the same wavelengths? Give a reason why it is transparent to other wavelengths?

When white light is passed through gas, it absorbs only those photons which have the energy equal to the difference of energy levels in atoms of the gas. All other photons pass through the gas un-absorbed. In other words, gas is transparent for those photons

7. **What do we mean when we say that the atom is excited?

When certain amount of energy is supplied to the electrons of an atom by an external source, it will be raised up to one of the higher allowed states by absorption of energy. Then the atom is said to be in excited state.

8. **Can X-rays be reflected, refracted, diffracted and polarized just like any other waves? Explain.

Yes, X-rays can be reflected, refracted, diffracted and polarized as they are also electromagnetic waves of higher frequency and smaller wavelength.

9. **What are the advantages of lasers over ordinary light?

Advantages of laser over ordinary light

i. It is intense beam of light
ii. It is monochromatic

iii. It is unidirectional
iv. It is coherent

10. **Explain why laser action could not occur without population inversion between atomic levels?In population inversion, more than 50% vacancies in the meta-stable states become filled. Then all the electrons in the meta-stable state simultaneously jump to the ground level, thereby producing a pulse of coherent beam without population inversion, laser action could not occur.