3.7 RELATION BETWEEN INTERPLANAR DISTANCE AND CUBE EDGE

Interplanar distance is the distance between two adjacent parallel planes having Miller indices (hkl). In the Figure shown the interplanar distance between the planes ABC and A'B'C' is NM.

Consider the plane ABC as shown in Figure 3.23. The plane ABC belongs to a family of planes whose Miller indices are (hkl). The perpendicular ON from the origin to the plane represents the interplanar distance. Let this distance be d = ON. The distance d of this normal from the origin to the plane will also be the distance between adjacent planes. That is, the interplanar distance.

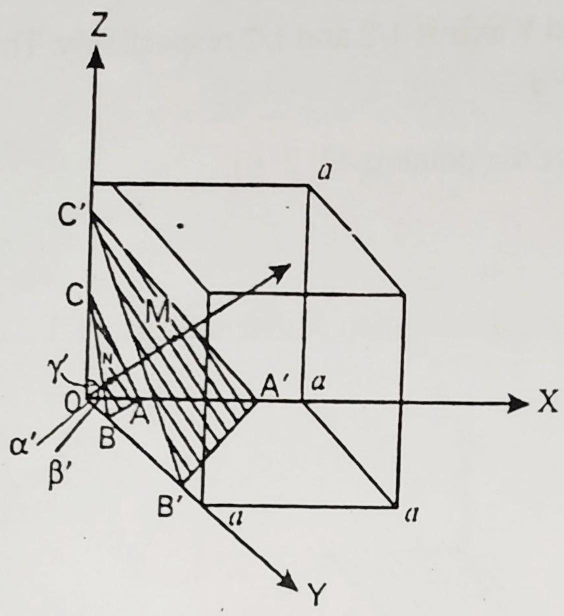


Figure 3.23: Interplanar spacing

Let ON make an angle α', β' and γ' (different from interfacial angles) with the X, Y and Z axes respectively.

The intercepts of the plane on the three axes are,

$$OA = pa, \quad OB = qa \quad \text{and} \quad OC = ra$$

But, $$p = \frac{1}{h}, \quad q = \frac{1}{k} \quad \text{and} \quad r = \frac{1}{l}$$

$$\therefore \quad OA = \frac{a}{h}, \; OB = \frac{a}{k} \text{ and } OC = \frac{a}{l}$$

where 'a' is the length of the cube edge.

$$\therefore \quad OA : OB : OC = \frac{a}{h} : \frac{a}{k} : \frac{a}{l}$$

From Figure 3.24, we have,

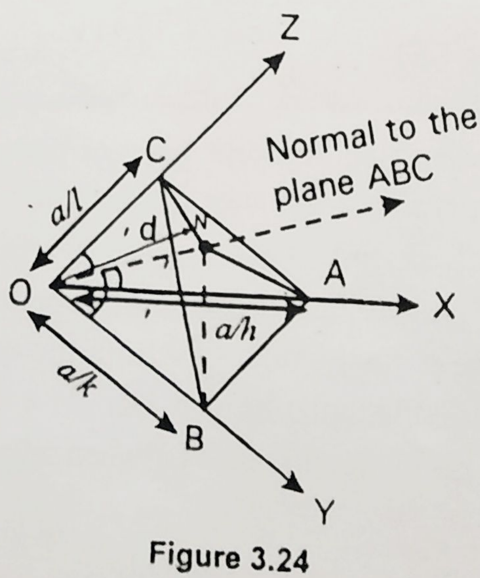


Figure 3.24

(From Δ NOA) $\cos\alpha' = \dfrac{d}{OA} = \dfrac{d}{\frac{a}{h}} = \dfrac{dh}{a}$

(From Δ NOB) $\cos\beta' = \dfrac{d}{OB} = \dfrac{d}{\frac{a}{k}} = \dfrac{dk}{a}$

(From Δ NOC) $\cos\gamma = \dfrac{d}{OC} = \dfrac{d}{\frac{a}{l}} = \dfrac{dl}{a}$

But, from the **direction of cosine's law**

$$\cos^2\alpha' + \cos^2\beta' + \cos^2\gamma = 1.$$

Hence substituting for $\cos\alpha'$, $\cos\beta'$, and $\cos\gamma$ in above equation,

$$\frac{d^2h^2}{a^2} + \frac{d^2k^2}{a^2} + \frac{d^2l^2}{a^2} = 1$$

$$\therefore \quad \frac{d^2}{a^2}(h^2 + k^2 + l^2) = 1$$

$$d^2 = \frac{a^2}{h^2 + k^2 + l^2}$$

or

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

This gives the relation between interplanar distance d and cubic edge a.

Note:

- Except for cubic and trigonal, for all other crystal systems the relation between the interplanar distance d and the axial length is given by

$$d_{hkl} = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$$

Example 3.3

Calculate the interplanar spacing for a (3 1 1) plane in a simple cubic lattice whose lattice constant is 2.109×10^{-10} m.

Solution:

Given, Miller indices (h k l) = (3 1 1)

Lattice constant $a = 2.109 \times 10^{-10}$ m

The interplanar distance is given by,

$$d = \frac{a}{\left(h^2 + k^2 + 1^2\right)^{1/2}} = \frac{2.109 \times 10^{-10}}{\left(3^2 + 1^2 + 1^2\right)^{1/2}}$$

$$\therefore \quad \mathbf{d = 6.358 \times 10^{-11}\ m.}$$

Example 3.4

The distance between the Miller indices (1 1 0) is 2.86 Å. Calculate the lattice constant.

Solution:

Given,

Miller indices (h k l) = (1 1 0)

Distance between the Miller indices d = 2.86 Å

We know, $$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

Therefore, $$a = d \times \sqrt{h^2 + k^2 + l^2}$$

$$= 2.86 \times 10^{-10} \times \sqrt{1^2 + 1^2 + 0^2}$$

$$\boldsymbol{a = 4.044 \times 10^{-10}\ \mathrm{m}.}$$

Example 3.5

Show that $d_{101} : d_{100} : d_{001} :: \frac{a}{\sqrt{2}} : \frac{a}{\sqrt{1}} : \frac{a}{\sqrt{1}}$.

Solution:

We know, $$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$\therefore \quad d_{101} = \frac{a}{\sqrt{1^2 + 0^2 + 1^2}} = \frac{a}{\sqrt{2}}$$

and $$d_{100} = \frac{a}{\sqrt{1^2 + 0^2 + 0^2}} = \frac{a}{\sqrt{1}}$$

and $$d_{001} = \frac{a}{\sqrt{0^2 + 0^2 + 1^2}} = \frac{a}{\sqrt{1}}$$

$$\therefore \quad \mathbf{d_{101} : d_{100} : d_{001} :: \frac{a}{\sqrt{2}} : \frac{a}{\sqrt{1}} : \frac{a}{\sqrt{1}}.}$$

Example 3.6

In a simple cubic crystal, find the ratio of intercepts on the three axes by (1 1 1) plane.

Solution:

If a plane cut intercepts of lengths l_1, l_2 and l_3 along the three crystal axes then,

$$l_1 : l_2 : l_3 = pa : qb : rc$$

where a, b and c are primitive vectors of the unit cell and p, q and r are numbers related (i.e., intercept values) to the Miller indices (hkl) of the plane by relation,

$$\frac{1}{p} : \frac{1}{q} : \frac{1}{r} = h : k : l$$

Since, the crystal is simple cubic a = b = c and given that, h = 1, k = 1 and l = 1.

$$\therefore \quad p : q : r = h^{-1} : k^{-1} : l^{-1} = \frac{1}{1} : \frac{1}{1} : \frac{1}{1}$$

$$\therefore \quad p : q : r = 1 : 1 : 1$$

Similarly, $l_1 : l_2 : l_3 = 1a : 1a : 1a$

$$\therefore \quad \mathbf{l_1 : l_2 : l_3 = 1 : 1 : 1.}$$

Example 3.7

Calculate the interplanar spacing between (1 1 1), (2 0 0) and (2 2 0) planes in FCC crystal. Given the atomic radius 1.246 Å.

Solution:

Given, $r = 1.246$ Å $= 1.246 \times 10^{-10}$ m; a = ? and d = ?

In a FCC crystal, the lattice constant is

$$a = \frac{4r}{\sqrt{2}}$$

$$a = \frac{4 \times 1.2460 \times 10^{-10}}{\sqrt{2}} \text{ m}$$

$$\therefore \quad a = \mathbf{3.5242 \times 10^{-10} \ m.}$$

To find d:

$$\because \quad d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$\therefore \quad d_{111} = \frac{3.5242 \times 10^{-10}}{\sqrt{1^2 + 1^2 + 1^2}}$$

$$= \frac{3.5242 \times 10^{-10}}{\sqrt{3}}$$

$$d_{111} = \mathbf{2.034 \times 10^{-10} \ m.}$$

Similarly, $$d_{200} = \frac{3.5242\times10^{-10}}{\sqrt{2^2+0^2+0^2}} = \frac{3.5242\times10^{-10}}{2}$$

∴ $$d_{200} = 1.7621 \times 10^{-10} \text{ m.}$$

and $$d_{220} = \frac{3.5242\times10^{-10}}{\sqrt{2^2+0^2+0^2}} = \frac{3.5242\times10^{-10}}{\sqrt{8}}$$

∴ $$d_{220} = 1.246 \times 10^{-10} \text{ m.}$$

Example 3.8

Calculate the interplanar distance of three important planes (1 0 0), (1 1 0) and (1 1 1) of a simple cubic system.

Solution:

Formula: $$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

∴ $$d_{100} = \frac{a}{\sqrt{1^2+0^2+0^2}} = \frac{a}{\sqrt{1}}$$

$$d_{110} = \frac{a}{\sqrt{1^2+1^2+0^2}} = \frac{a}{\sqrt{2}}$$

$$d_{111} = \frac{a}{\sqrt{1^2+1^2+1^2}} = \frac{a}{\sqrt{3}}$$

Therefore, $$d_{100} : d_{110} : d_{111} = \frac{1}{\sqrt{1}} : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}.$$

Example 3.9

Find the Miller indices of a plane which intercepts at *a*, b/2 and 3c along X, Y and Z axes respectively in a simple cubic unit cell.

Solution:

Given, numerical intercept values $p = 1, q = 1/2$ and $r = 3$

∴ $$h = \frac{1}{p} = \frac{1}{1} = 1$$

∴ $$k = \frac{1}{q} = \frac{1}{1/2} = 2$$

and, $$l = \frac{1}{r} = \frac{1}{3}$$

Hence, $(h\ k\ l) = (1\ \ 2\ \ 1/3)$

The least common multiple is 3.

$\therefore$ $(h\ k\ l) = (3\ 6\ 1)$.

Example 3.10

Calculate the value of d-spacing for (1 0 0) planes in a rock salt crystal of $a = 2.814$ Å.

Solution:

Given, $a = 2.814$ Å ; $h = 1$; $k = 0$; $l = 0$; $d = ?$

Formula:
$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$= \frac{2.814 \times 10^{-10}}{\sqrt{1^2 + 0^2 + 0^2}} = 2.814 \text{ Å}$$

$\therefore$ **d = 2.814 Å.**

Example 3.11

The unit cell edges a, b and c of an orthorhombic crystal are 0.05 nm, 0.04 nm and 0.03 nm respectively. Of a family of parallel, equidistant planes, the one that is closest to the origin of the unit cell makes intercepts on the a, b and c edges at 0.025 nm, 0.02 nm and 0.01 nm respectively. Find the Miller indices of the set of parallel planes.

Solution:

Given, OA = 0.025 nm, OB = 0.02 nm and OC = 0.01 nm.

The unit cell edges are $a = 0.05$ nm, $b = 0.04$ nm and $c = 0.03$ nm.

We know OA = pa, OB = qb and OC = rc.

$$\therefore \quad p = \frac{OA}{a},\ q = \frac{OB}{b} \text{ and } r = \frac{OC}{c}$$

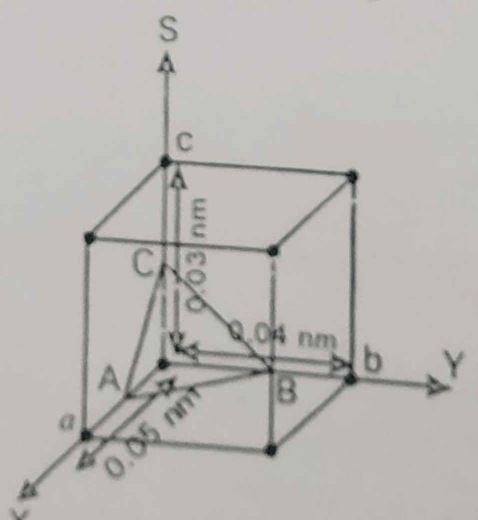


Figure 3.25

Therefore, the intercept along X-axis is $$p = \frac{0.025\,\text{nm}}{0.05\,\text{nm}} = 0.5 = \frac{1}{2}$$

The intercept along Y-axis is $$q = \frac{0.02\,\text{nm}}{0.04\,\text{nm}} = 0.5 = \frac{1}{2}$$

The intercept along Z-axis is $$r = \frac{0.01\,\text{nm}}{0.03\,\text{nm}} = \frac{1}{3}$$

Reciprocal of (p q r) = (2 2 3)

Hence, the Miller indices is (2 2 3).

Example 3.12

A certain orthorhombic crystal has axial units a : b : c of 0.424 : 1 : 0.367. Find the Miller indices of crystal face whose intercepts are (i) 0.212 : 1:0.183 (ii) 0.848 : 1:0.732 and (iii) 0.424 : ∞ : 0.123.

Solution:

Given, $$a : b : c = 0.424 : 1 : 0.367$$

$$(hkl) = ?$$

(i) Miller indices for intercepts 0.212 : 1 : 0.183

We know that $$OA : OB : OC = pa : qb : rc$$

$$0.212 : 1 : 0.183 = pa : qb : rc$$

$$\therefore \quad pa = 0.212 \quad \text{or } p = \frac{0.212}{a} = \frac{0.212}{0.424} = \frac{1}{2} \qquad [\because\ a = 0.424]$$

Similarly, qb = 1

$$\therefore \quad q = \frac{1}{b} = \frac{1}{1} = 1 \qquad [\because b = 1]$$

and, $$rc = 0.183 \quad \text{or } r = \frac{0.183}{c} = \frac{0.183}{0.367} = \frac{1}{2} \qquad [\because\ c = 0.367]$$

Hence, numerical parameter values are $\left(\frac{1}{2}\,1\,\frac{1}{2}\right)$.

Therefore, Miller indices are $\mathbf{\frac{1}{1/2}\ \frac{1}{1}\ \frac{1}{1/2}}$ **= (2 1 2).**

(ii) Miller indices for intercepts 0.848 : 1 : 0.732

$$\therefore \quad p = \frac{OA}{a} = \frac{0.848}{0.424} = 2$$

$$q = \frac{OB}{b} = \frac{1}{1} = 1$$

$$r = \frac{OC}{c} = \frac{0.732}{0.367} = 2$$

Hence, numerical parameters are (2 1 2).

Therefore, the Miller indices are $\left(\frac{1}{2}\,\frac{1}{1}\,\frac{1}{2}\right)$ **= (1 2 1).**

(iii) The Miller indices for intercepts 0.424 : ∞ : 0.123

$$p = \frac{OA}{a} = \frac{0.424}{0.424} = 1$$

$$q = \frac{OB}{b} = \frac{\infty}{1} = \infty$$

$$r = \frac{OC}{c} = \frac{0.123}{0.367} = \frac{1}{3}$$

Hence, the numerical parameters are (1 ∞ 1/3).

Therefore, the Miller indices are $\left(\frac{1}{2}\,\frac{1}{\infty}\,\frac{1}{\frac{1}{3}}\right)$ **= (1 0 3).**

Example 3.13

Find the Miller indices of a set of parallel planes which make intercepts in the ratio 2b : 7c, and are parallel to x-axis; *a*, b, and c being primitive vectors of the lattice.

Solution:

Given, OB = 2b and OC = 7c and OA = ∞

(hkl) = ?

The numerical value of intercepts along the three axis are (∞, 2, 7)

Therefore, Miller indices are $\left(\frac{1}{\infty}\,\frac{1}{2}\,\frac{1}{7}\right)$ = (0 7 2).

X-RAYS

X-radiation (composed of **X-rays**) is a form of electromagnetic radiation. X-rays have a wavelength in the range of 0.01 to 10 nanometers, corresponding to frequencies in the range 30 petahertz to 30 exahertz (3×10^{16} Hz to 3×10^{19} Hz) and energies in the range 120 eV to 120 keV. They are shorter in wavelength than UV rays and longer than gamma rays. In many languages, X-radiation is called **Röntgen radiation**, after Wilhelm Conrad Röntgen, who is usually credited as its discoverer, and who had named it X-radiation to signify an unknown type of radiation.

X-rays from about 0.12 to 12 keV (10 to 0.10 nm wavelength) are classified as "soft" X-rays, and from about 12 to 120 keV (0.10 to 0.01 nm wavelength) as "hard" X-rays, due to their penetrating abilities.

Hard X-rays can penetrate solid objects, and their most common use is to take images of the inside of objects in diagnostic radiography and crystallography. As a result, the term *X-ray* is metonymically used to refer to a radiographic image produced using this method, in addition to the method itself. By contrast, soft X-rays hardly penetrate matter at all; the attenuation length of 600 eV (~2 nm) X-rays in water is less than 1 micrometer.

The distinction between X-rays and gamma rays has changed in recent decades. Originally, the electromagnetic radiation emitted by X-ray tubes had a longer wavelength than the radiation emitted by radioactive nuclei (gamma rays). Older literature distinguished between X- and gamma radiation on the basis of wavelength, with radiation shorter than some arbitrary wavelength, such as 10^{-11} m, defined as gamma rays. However, as shorter wavelength continuous spectrum "X-ray" sources such as linear accelerators and longer wavelength "gamma ray" emitters were discovered, the wavelength bands largely overlapped. The two types of radiation are now usually distinguished by their origin: X-rays are emitted by electrons outside the nucleus, while gamma rays are emitted by the nucleus.

Characteristics of X-Rays

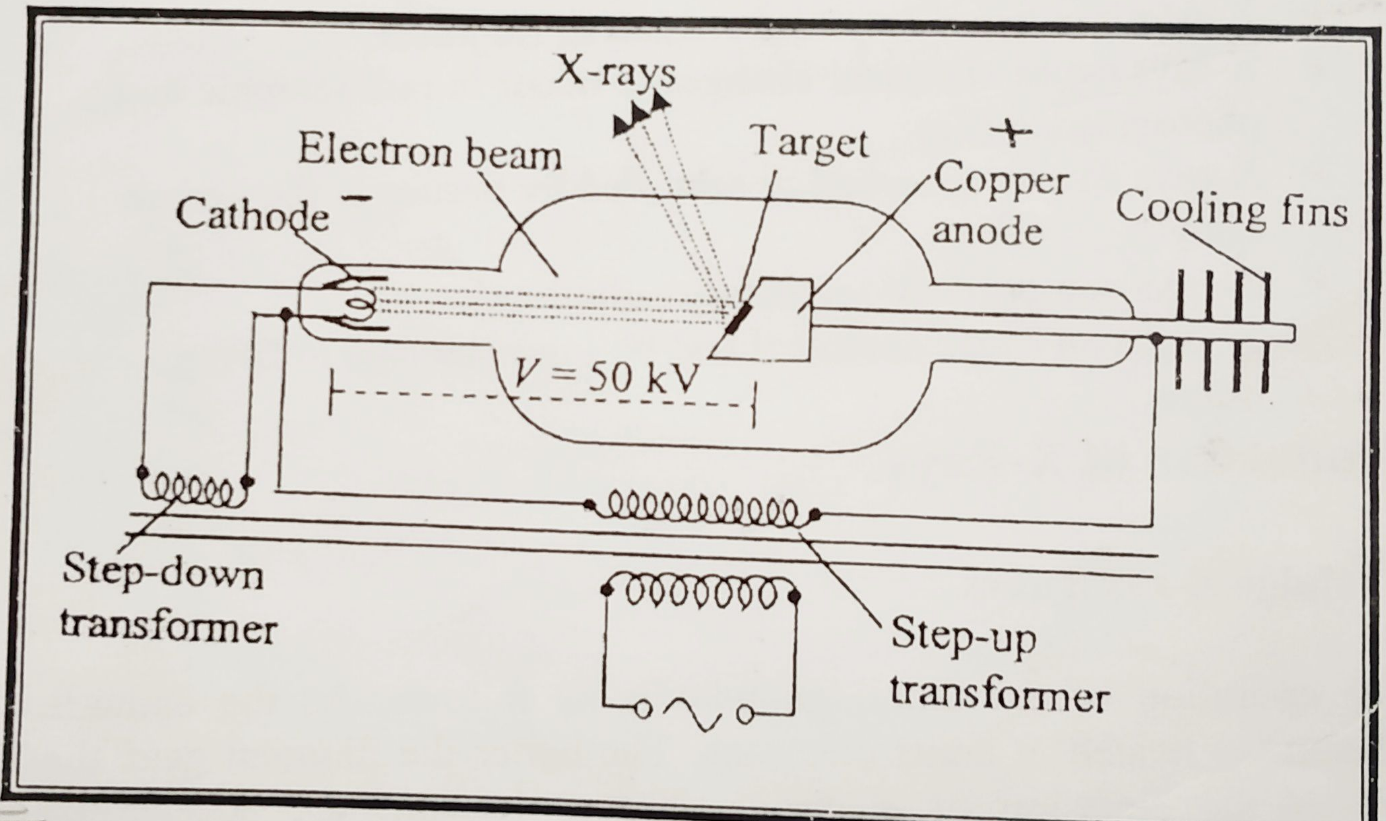
- X-rays are invisible.
- X-rays are electrically neutral. They have neither a positive nor a negative charge.
- They cannot be accelerated or made to change direction by a magnet or electrical field.
- X-rays have no mass.
- X-rays travel at the speed of light in a vacuum.
- X-rays cannot be optically focused.
- X-rays form a polyenergetic or heterogenous beam.
- The x-ray beam used in diagnostic radiography comprises many photons that have much different energy.
- X-rays travel in straight lines.
- X-rays can cause some substances to fluoresce.
- X-rays cause chemical changes to occur in radiographic and photographic film.
- X-rays can be absorbed or scattered by tissues in the human body.
- X-rays can produce secondary radiation.
- X-rays can cause chemical and biologic damage to living tissue.

Production of X-Rays

Coolidge X-ray Tubes

The operation of the Coolidge tube is as follows. As the cathode filament is heated, it emits electrons. The hotter the filament gets, the greater the emission of electrons. These electrons are accelerated towards the positively charged anode and when the electrons strike the anode, they change direction and emit bremsstrahlung, i.e., x-rays with a continuous range of energies. The maximum energy of the x-rays is the same as the kinetic energy of the electrons striking the anode. In addition to the x-rays produced at the focal spot of the anode, some undesirable X-rays (stray radiation) are produced by electrons striking other tube components.

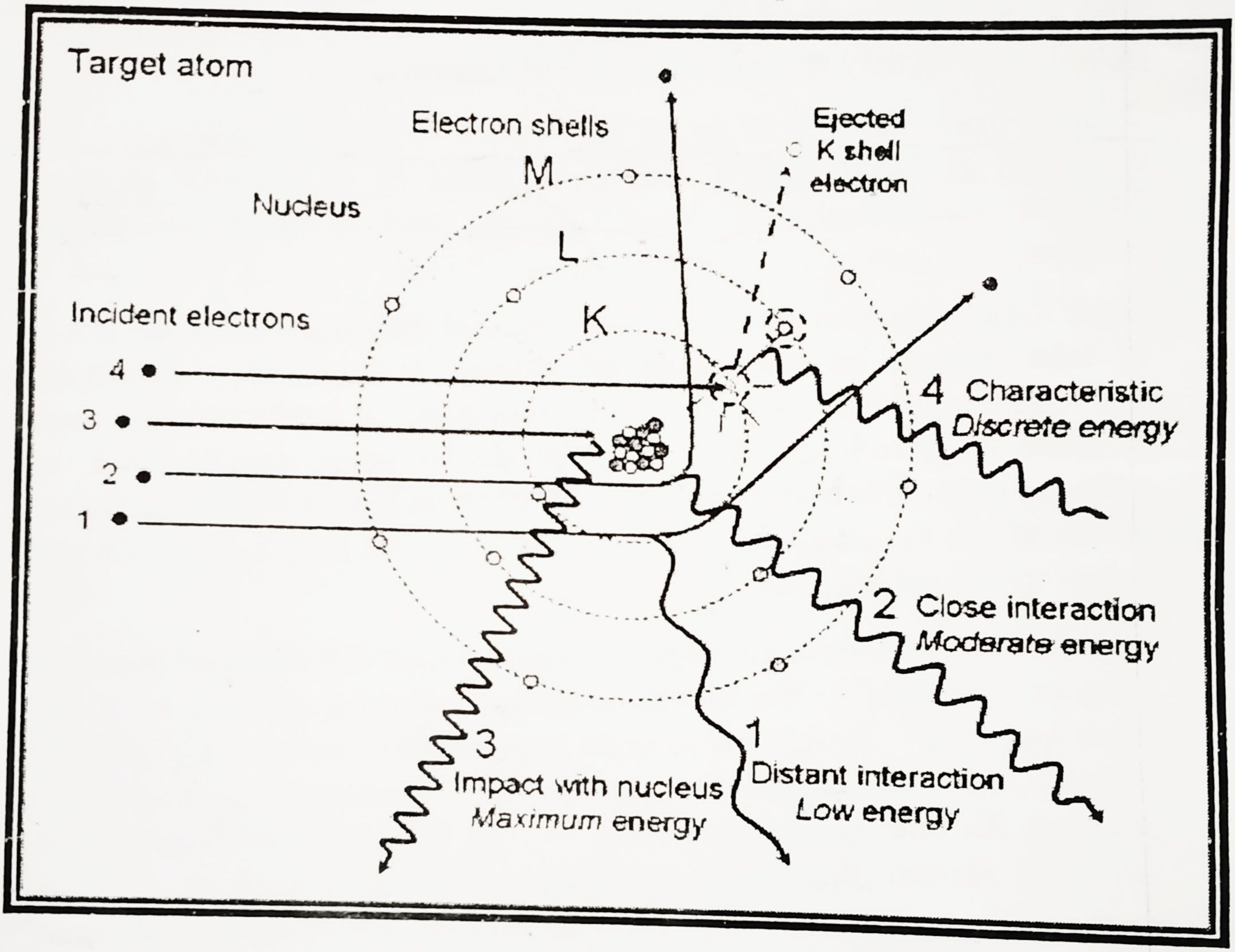
The key advantages of the Coolidge tube are its stability, and the fact that the intensity and energy of the x-rays can be controlled independently. Increasing the current to the cathode increases its temperature. This increases the number of electrons emitted by the cathode, and as a result, the intensity of the x-rays. Increasing the high voltage potential difference between the anode and the cathode increases the velocity of the electrons striking the anode, and this increases the energy of the emitted x-rays. Decreasing the current or the high voltage would have the opposite effects. The high degree of control over the tube output meant that the early radiologists could do with one Coolidge tube what before had required a stable of finicky cold cathode tubes. As a bonus, the Coolidge tube could function almost indefinitely unless broken or badly abused.



X-ray production by energy conversion.

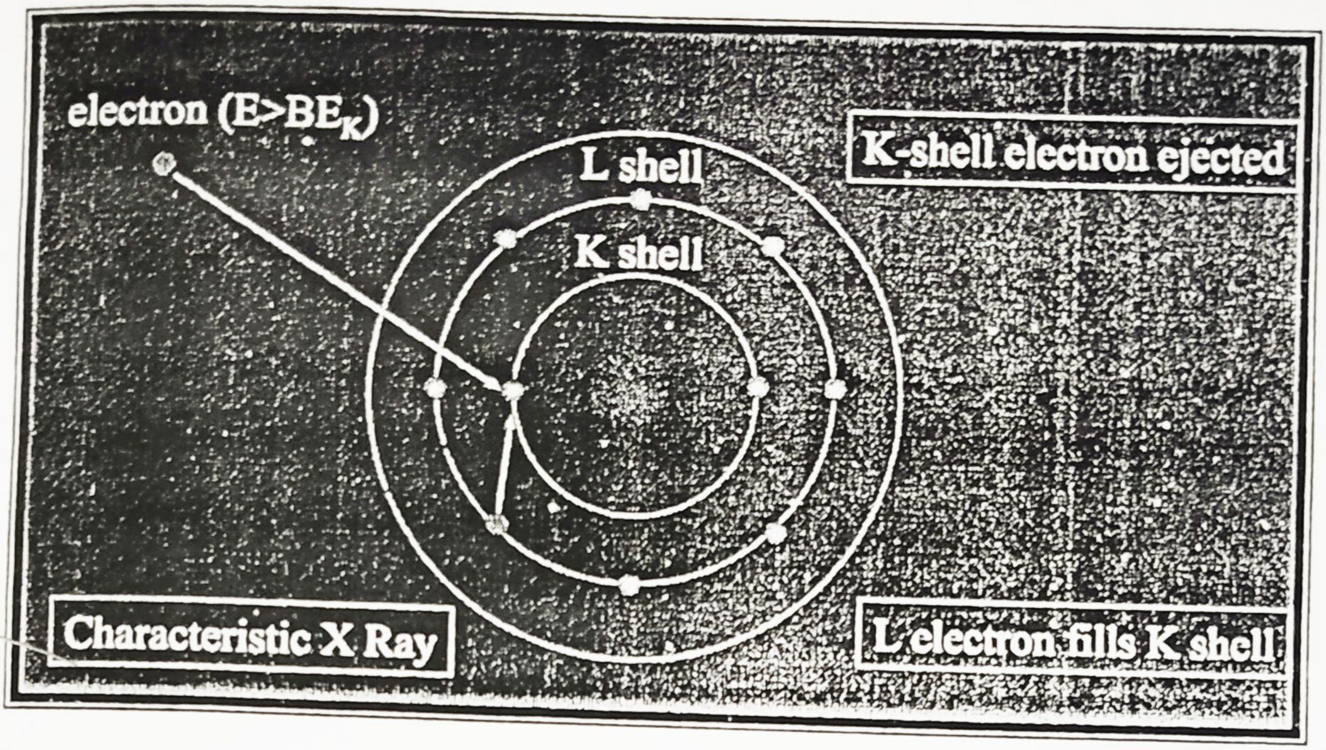
Events 1, 2, and 3 depict incident electrons interacting in the vicinity of the target nucleus, resulting in bremsstrahlung production caused by the deceleration and change of momentum, with the emission of a continuous energy spectrum of x-ray photons.

Event 4 demonstrates characteristic radiation emission, where an incident electron with energy greater than the K-shell binding energy collides with and ejects the inner electron creating an unstable vacancy. An outer shell electron transitions to the inner shell and emits an x-ray with energy equal to the difference in binding energies of the outer electron shell and K shell that are "characteristie" of tungsten.



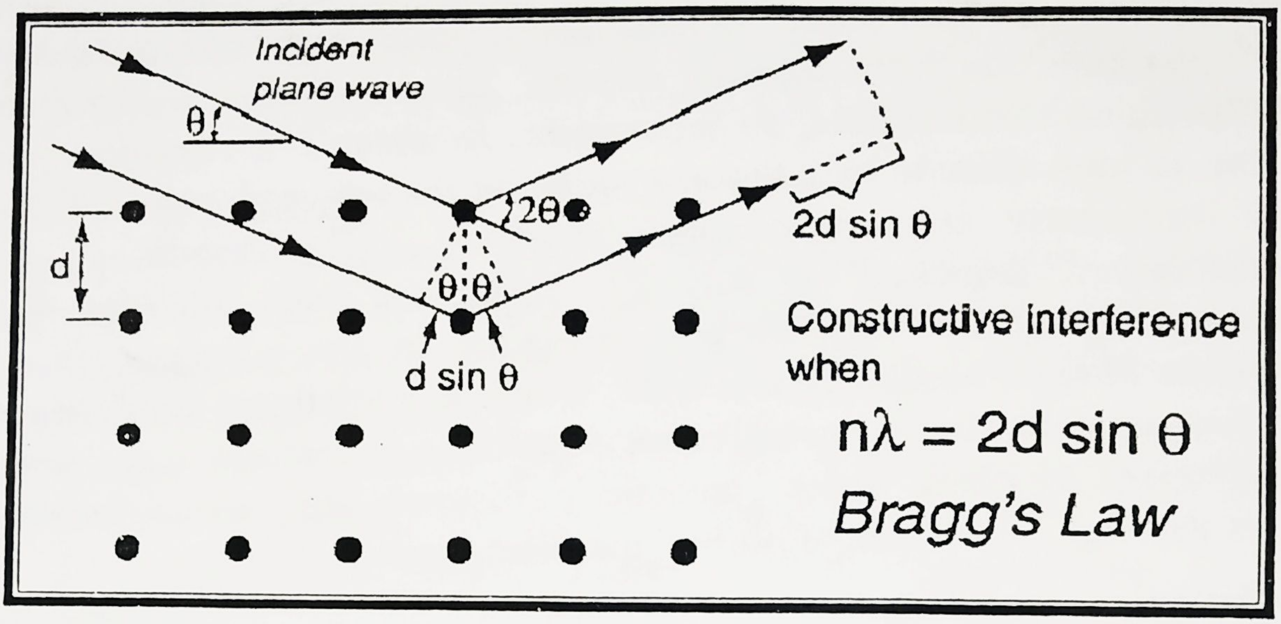
- ➢ When an electron hits the target its entire kinetic energy is converted into a photon.

- The work done on each electron when it is accelerated onto the anode is eV. Hence $hf = eV$ and the maximum frequency *i.e.* $f_{max} = \frac{eV}{h} \Rightarrow \lambda_{min} = \frac{hc}{eV}$



Characteristic x-rays are used for the investigation of crystal structure by x-ray diffraction. Crystal lattice dimensions may be determined with the use of Bragg's law in a Bragg spectrometer. Bragg diffraction occurs when electromagnetic radiation or subatomic particle waves with wavelength comparable to atomic spacings are incident upon a crystalline sample, are scattered in a specular fashion by the atoms in the system, and undergo constructive interference in accordance to Bragg's law. For a crystalline solid, the waves are scattered from lattice planes separated by the interplanar distance d. Where the scattered waves interfere constructively, they remain in phase since the path length of each wave is equal to an integer multiple of the wavelength. The path difference between two waves undergoing constructive interference is given by $2d\sin\theta$, where θ is the scattering angle. This leads to **Bragg's law**, which describes the condition for constructive interference from successive crystallographic (h, k, and l) of the crystalline lattice: $2d\sin\theta = n\lambda$

Where, n is an integer determined by the order given, and λ is the wavelength. A diffraction pattern is obtained by measuring the intensity of scattered waves as a function of scattering angle. Very strong intensities known as Bragg peaks are obtained in the diffraction pattern when scattered waves satisfy the Bragg condition.



When x-rays are scattered from a crystal lattice, peaks of scattered intensity are observed which correspond to the following conditions:

1. The angle of incidence = angle of scattering.
2. The pathlength difference is equal to an integer number of wavelengths.

The condition for maximum intensity contained in Bragg's law above allow us to calculate details about the crystal structure, or if the crystal structure is known, to determine the wavelength of the x-rays incident upon the crystal.

APPLICATIONS OF X-RAYS

X-ray crystallography

It is a method of determining the arrangement of atoms within a crystal, in which a beam of X-rays strikes a crystal and diffracts into many specific directions. From the angles and intensities of these diffracted beams, a crystallographer can produce a three-dimensional picture of the density of electrons within the crystal. From this electron density, the mean positions of the atoms in the crystal can be determined, as well as their chemical bonds, their disorder and various other information.

X-ray astronomy

It is an observational branch of astronomy, which deals with the study of X-ray emission from celestial objects. X-ray radiation is absorbed by the Earth's atmosphere, so instruments to observe X-rays must be taken to high altitude by balloons, sounding rockets, and satellites. X-ray astronomy is part of space research. The Chandra X-ray Observatory, launched on July 23, 1999, has been allowing the exploration of the very violent processes in the universe which produce X-rays. Unlike visible light, which is a relatively stable view of the universe, the X-ray universe is unstable, it features stars being torn apart by black holes, galactic collisions, and novas, neutron stars that build up layers of plasma that then explode into space

X-ray microscope

It uses electromagnetic radiation in the soft X-ray band to produce images of very small objects. Unlike visible light, X-rays do not reflect or refract easily, and they are invisible to the human eye. Therefore the basic process of an X-ray microscope is to expose film or use a charge-coupled device (CCD) detector to detect X-rays that pass through the specimen. It is a contrast imaging technology using the difference in absorption of soft x-ray in the water window region (wavelength region: 2.3 - 4.4 nm, photon energy region: 0.28 - 0.53 keV) by the carbon atom (main element composing the living cell) and the oxygen atom (main element for water).

X-ray fluorescence (XRF)

It is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used fore elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry, forensic science and archaeology.

Industrial Radiography

It is the use of ionizing radiations to view objects in a way that can't be seen otherwise. It is not to be confused with the use of ionizing radiation to change or modify objects; radiography's purpose is strictly for viewing. Industrial radiography has grown out of engineering, and is a major element of nondestructive testing (NDT). It is a method of inspecting materials for hidden flaws by using the ability of short X-rays and Gamma rays to penetrate various materials.

Airport security

It refers to the techniques and methods used in protecting airports and aircraft from crime. Large numbers of people pass through airports. Such gatherings present a target for terrorism and other forms of crime due to the number of people located in a small area. Similarly, the high concentration of people on large airliners, the potential high lethality rate of attacks on aircraft, and the ability to use a hijacked airplane as a lethal weapon provide an alluring target for terrorism. Airport security provides defense by attempting to stop would-be attackers from bringing weapons or bombs into the airport. If they can succeed in this, then the chances of these devices getting on to aircraft are greatly reduced. As such, airport security serves two purposes: To protect the airport from attacks and crime and to protect the aircraft from attack

X-ray photoelectron spectroscopy (XPS)

It is a quantitative spectroscopic technique that measures the elemental composition, empirical formula,chemical state and electronic state of the elements that exist within a material. XPS spectra are obtained by irradiating a material with a beam of X-rays while simultaneously measuring the kinetic energy (KE) and number ofelectrons that escape from the top 1 to 10 nm of the material being analyzed. XPS requires ultra high vacuum (UHV) conditions.

X-ray Welding

It is an experimental welding process that uses a high powered X-ray source to provide thermal energy required to weldmaterials. Many advances in welding technology have resulted from the introduction of new sources of the thermal energy required for localised melting. These advances include the introduction of modern techniques such as gas tungsten arc, gas-metal arc, submerged-arc, electron beam, andlaser beam welding processes. However, whilst these processes were able to improve stability, reproducibility, and accuracy of welding, they share a common limitation - the energy does not fully penetrate the material to be welded, resulting in the formation of a melt pool on the surface of the material.

Hard x-ray nanoprobe

It is being built for the Center for Nanoscale Materials (CNM), Argonne National Lab will advance the state of the art by providing a hard X-ray microscopy beamline with the highest spatial resolution in the world. It will provide for fluorescence, diffraction, and transmission imaging with hard X-rays at a spatial resolution of 30 nm or better. A dedicated source, beamline, and optics will form the basis for these capabilities. This unique instrument will not only be key to the specific research areas of the CNM; it will also be of general utility to the broader nanoscience community in studying nanomaterials and nanostructures, particularly for embedded structures.

X-ray markers

It is also known as Pb markers, lead markers, x-ray lead markers, or radiographic film identification markers which are used to mark x-ray films, both in hospitals and in industrial workplaces (such as on airplane parts and motors). Most x-ray markers consist of a right and a left letter with the technologist's initials.

X-ray absorption spectroscopy (XAS)

It is a widely-used technique for determining the local geometric and/or electronic structure of matter. The experiment is usually performed at synchrotron radiation sources, which provide intense and tunable X-ray beams. Samples can be in the gas-phase, solution, or condensed matter (ie. solids).

Small-angle X-ray scattering (SAXS)

It is a small-angle scattering (SAS) technique where the elastic scattering of X-rays (wavelength 0.1 ... 0.2 nm) by a sample which has inhomogeneities in the nm-range, is recorded at very low angles (typically 0.1 - 10°). This angular range contains information about the shape and size of macromolecules, characteristic distances of partially ordered materials, pore sizes, and other data. SAXS is capable of delivering structural information of macromolecules between 5 and 25 nm, of repeat distances in partially ordered systems of up to 150 nm.[1] USAXS (ultra-small angle X-ray scattering) can resolve even larger dimensions.

Image intensification

X-rays are also used in "real-time" procedures such as angiography or contrast studies of the hollow organs (e.g. barium enema of the small or large intestine) using fluoroscopy acquired using an X-ray image intensifier. Angioplasty, medical interventions of the arterial system, rely heavily on X-ray-sensitive contrast to identify potentially treatable lesions.

X- Ray painting

Paintings are often X-rayed to reveal the under drawing and alterations in the course of painting, or by later restorers. Many pigments such as lead white show well in X-ray photographs.

Medical applications

X-rays are especially useful in the detection of pathology of the skeletal system, but are also useful for detecting some disease processes in soft tissue. Some notable examples are the very common chest X-ray, which can be used to identify lung diseases such as pneumonia, lung cancer or pulmonary edema, and the abdominal X-ray, which can detect intestinal obstruction, free air (from visceral perforations) and free fluid (in ascites). X-rays may also be used to detect pathology such as gallstones (which are rarely radiopaque) or kidney stones (which are often visible, but not always). Traditional plain X-rays are less useful in the imaging of soft tissues such as the brain or muscle. Imaging alternatives for soft tissues are computed axial tomography (CAT or CT scanning), magnetic resonance imaging (MRI) or ultrasound.

****

****