CRYSTALLOGRAPHY
AND
DIFFRACTION

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X
RAY

The sudden arrest of motion of
swiftly moving electrons by atoms
of matter is accompanied by the gen-
eration of x-rays and since 1912 great
strides have been taken toward using
these rays to make a powerful analyti-
cal tool. The x-ray generator or tube
is an apparatus in which a vacuum is
maintained so that an electron stream
can gain sufficient velocity, due to de-
creased air resistance, before striking
against the target or anode. The
target suddenly stops the electron mo-
tion with the result that x-rays are
emitted. The accelerating force exerted
on the electrons is supplied by an in-
duction coil or transformer and the en-
ergy of the emitted x-ray is only
about one-thousandth of the energy
supplied to the x-ray tube.

For use in x-ray crystallography, the
material of the anode is usually
molybdenum, rhodium, palladium, cop-
pers, or substances of the same order of
atomic weights. The wave lengths in-
variably vary from about 0.3 to 2.5
Angstrom Units (one A.U. = 10^{-10}
centimeters). Since interatomic dis-
tances are of the order of two A.U., x-
rays are capable of resolving separate
atoms.

Most types of analysis employ one
or several of the following properties of
x-rays:
1. Invisible, and pass through space
   without transference of matter.
2. Propagated in straight lines.
3. Unaffected by electric and mag-
   netic fields.
4. Reflected, diffracted, refracted,
   and polarized just as it light.
5. Propagated with the same veloci-
   ty as light (thirty billion centi-
   meters per second).
6. Characterized by a wide range of
   wavelengths (approximately 0.01
to 1000 A.U.).
7. Capable of producing fluores-
   cent and phosphorescence in
   some substances.
8. Differentially absorbed by matter.
9. Diffracted by optical gratings and
totally reflected at very small
glancing angles.

When x-rays strike an amorphous
body, the scattering takes place all
around the body. The rays emanate
outward from each atom in the same
manner that waves of water radiate in
(Continued on page 20)
X-Rays (Continued from Fig. 1)

The X-rays are produced by a target composed of a large number of atoms, each of which has a unique atomic number. When bombarded with electrons, these atoms emit X-rays, which can be used to determine the atomic structure of the material. The wavelength of the X-rays is inversely proportional to the energy of the incident electrons.

FIGURE 2

The diagram illustrates the diffraction pattern produced by X-rays passing through a crystal. The crystal is composed of a large number of atoms, each of which has a unique atomic number. When bombarded with X-rays, these atoms emit a characteristic diffraction pattern, which can be used to determine the atomic structure of the material.

Other factors that can affect the diffraction pattern include the crystal's orientation, the temperature, and the intensity of the X-ray source. The diffraction pattern can be used to determine the atomic structure of the crystal, and this information can be used to identify the material and determine its properties.

The formula for calculating the wavelength of the X-rays is given by:

\[
\lambda = \frac{\hbar}{m_e E} \]

where \(\lambda\) is the wavelength, \(\hbar\) is Planck's constant, \(m_e\) is the mass of the electron, and \(E\) is the energy of the incident electrons.

The diffraction pattern can be analyzed to determine the atomic structure of the material. This information can be used to identify the material and determine its properties, such as its strength, hardness, and chemical composition. The diffraction pattern can also be used to determine the orientation of the crystal, which can be important for applications such as crystal growth and thin film deposition.
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X-RAYS

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3. Deduction of crystal unit (atom, ion, molecule), of size of unit, of type of bonding, and of general properties of solid to be expected.

4. Chemical identity, chemical and crystallographic changes and stability.

5. Allotropic modifications.

6. Type and mechanisms of alloy formation.

7. Single crystal or aggregate.

8. Crystallographic orientation of single crystal or of grains in aggregate.

9. Random or fibered aggregate and relative degree of preferred orientation in intermediate stages.

10. Grain size in an aggregate (particularly in cellular range).

11. Internal strain or distortion.

12. Extent of deformation and mechanism of fabrication in welding, drawing, etc.


14. Differentiation between surface and interior structure, and film structure.

15. Atomic distribution in liquids and gases.

The uses for x-rays have certainly broadened since 1912, but perhaps just as important is the accompanying technological advancement which makes access to such methods within the reach of all.

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