CHAPTER

INTRODUCTION
The phenomenon of luminescence has been known for a very long time. It is well known to us by its applications in fluorescent lighting, fluorescent paints and pigments, electroluminescent panels, radar, C.R. tube screens, radiation detectors, nuclear scintillation counters and lasers.

The study of luminescence provides one with a tool in understanding the phenomena exhibited by electronically active solids.

Luminescence is closely connected with the problem of imperfections of the crystal lattice. The investigation of luminescence of solids provides information on band structure and energy levels of impurities and imperfections. The optical absorption or excitation spectra involve electronic states of the system with equilibrium nuclear coordinates characteristic of the ground state. Luminescent emission spectra involve electronic states with equilibrium nuclear coordinates of the emptying state. On the other hand, detailed theoretical knowledge of band structure and of impurities and imperfections obtained from semiconductor and photoconductor research provides a basis for understanding the luminescence of these materials.

Study of luminescence has led to the realization of the extreme importance of small concentrations of impurities on the detailed electronic processes taking place in solids and throws light on related phenomena such as photoconduction and colour centres.
Although a number of important advances have been made during the last few decades in the field of luminescence, the present knowledge of the phenomenon is far from satisfactory and further investigations are essential to account for the known properties and nature of luminescence, in terms of a single unified theory.

1.2 Definitions of terms commonly used in Luminescence:

(a) **Luminescence** - When a substance absorbs energy in some form or the other, a fraction of the absorbed energy may be re-emitted in the form of electromagnetic radiation in the visible or near visible region. This phenomenon is known as "Luminescence." It is distinguished from thermal radiation in that it does not follow Kirchoff's law. A time delay in emission of the order of $10^{-9}$ sec. distinguishes it from the Raman and Compton effects which are completed in a time of about $10^{-14}$ sec. or less.

The term luminescence is further categorised according to modes of excitation as follows:

(i) **Photoluminescence** - that produced by absorption of photons of energies from a few to several electron volts;

(ii) **Radioluminescence** - that produced by bombardment with high energy radiations such as X-rays, or Y-rays as well as particles such as α and β particles, protons etc.;
(iii) Cathodoluminescence — that produced by bombardment of the phosphor with high energy electrons or cathode rays i.e., a specific case of radioluminescence;

(iv) Electroluminescence — that produced by an electric field;

(v) Triboluminescence — that produced by a substance subjected to mechanical forces;

(vi) Chemiluminescence and Bioluminescence — emission produced by chemical or biological reactions;

(vii) Sonoluminescence — emission produced by ultrasonic waves.

(b) Fluorescence and Phosphorescence — A distinction between the two has been made on the basis of physical processes involved. According to Curie and others fluorescence is the luminescence emission during excitation, whereas phosphorescence is the emission after $10^{-3}$ sec. of removing the excitation. Some authors also define fluorescence as emission of light for which decay time is temperature independent and phosphorescence as the temperature dependent part. Moreover fluorescence is produced due to transitions between excited and ground states of an activator whereas phosphorescence is due to delayed return of electrons from a metastable level via the excited state (Fig. 1.1).
FIG 1.1 - SCHEMATIC DIAGRAM OF THE PROCESSES OF PHOSPHORESCENCE (HET₁S₁L) & FLUORESCENCE (HES₁L)

C - CONDUCTION BAND, F - FILLED BAND
H - HOLE, E - ELECTRON
T₁ - ELECTRON TRAPS, T₂ - HOLE TRAPS
S₁ - EXCITED STATE, S₂ - GROUND STATE
L - LUMINESCENCE CENTRE
(c) Thermoluminescence - Thermoluminescence is defined as thermally stimulated release of energy (in the form of optical radiation) stored in a material by previous excitation. The excitation is achieved by any conventional agent like ionising radiations, UV rays, mechanical vibrations, stress, chemical reactions and so on. 9 Laverenz suggested a more appropriate term "Thermostimulation" for the phenomenon because the term thermoluminescence is misleading as heat is not the primary excitant. It is a type of activation by thermal energy of electrons lying in metastable states.

(d) Phosphors - These are structure and impurity sensitive solid crystalline materials capable of absorbing energy from various sources at certain frequencies and re-emitting it as visible or near visible radiation of other frequency during or after cessation of excitation. 10,11 These are strongly influenced by chemical composition, crystal structure, presence of impurities in small amounts and other physical conditions such as temperature and type of excitation.

Phosphor materials may be divided into two classes: -

(i) Pure state phosphors: Those which luminesce in the pure state, such as zinc borates, zinc oxide, tungstates, molybdates, diamond, radium halides, uranyl salts, platinocyanides and salts of rare earths. 12-15
Luminescence in these materials may be due to native defects.

(ii) Impurity activated phosphors: These are phosphors in which an activating impurity is responsible for luminescence. Mott and Gurney divide the phosphors into two classes on the basis of the physical process involved.

(a) Non photoconducting phosphors: In this category of phosphors, under usual conditions of luminescence excitation, photoconductivity is negligible i.e., the electrons are not raised into the conduction band. Hence the emitting system is quasi-atomic. KCl : Tl is a typical example of this class.

(b) Photoconducting phosphors: In this case luminescence excitation raises electrons from the valence band or from the luminescence centres into the conduction band. Thus a marked photoconductivity arises. Examples are ZnS : Cu, CdS : Ag etc.

According to Leverenz phosphors can be classified into three main groups on the basis of the site occupied by the activator atoms:

(i) phosphors in which activator atoms occupy substitutional sites and exhibit exponential decay predominantly. Examples are ZnS : Mn, ZnF$_2$ : Mn etc.
(ii) Phosphors in which activator atoms occupy interstitial sites and exhibit power law decay predominantly.

(iii) Phosphors in which foreign atoms occupy both substitutional as well as interstitial sites. In these cases initial exponential decay is followed by a strong power law decay.

(e) Centers — Lattice defects, impurities and other perturbations of the ideal crystal configuration give rise to localized energy levels in the forbidden gap. These energy levels are responsible for different centers which are classified as follows:

(i) **Luminescence centres** \(^6,19\): those localized levels which are responsible for the luminescence emission, are termed as "Luminescence centres". Such levels have high electron capture cross-section and greater probability for radiative transitions than for non-radiative ones;

(ii) **Killer centres** \(^18\): those discrete energy levels which have large electron capture cross-section but a low probability for radiative transitions;

(iii) **Traps** : these are metastable levels responsible for phosphorescence and thermoluminescence. \(^19\) Trap is a restricted region in the crystal where an electron or hole may be captured and is no longer free to move through the crystal unless an optimum quantity of optical or
thermal energy is supplied which is necessary to release it. After liberation from the trap the electron or hole may migrate through the crystal to recombine with the luminescent centre or killer centre or may be retrapped.

(iv) Donor and Acceptor : A normally occupied "electron trap" is called a "donor" level while a normally occupied "hole trap" is known as an "acceptor" level.

1.3 Theories of Luminescence :

In order to explain the mechanism of luminescence, different workers have proposed different models. A short resume of these models is given below.

(A) Configurational Coordinate Model

The one dimensional configuration coordinate model for a localized centre first introduced by von Hippel \(^21\) and applied to problems of luminescence by Seitz \(^22\) and others, \(^23\)–\(^26\) is shown in Fig. (1.2). The ordinate represents the total energy of the ground and excited states of the luminescence centre (including both ionic and electronic terms). The abscissa represents the "configuration coordinate" of the ions around the centre. Electronic transitions may be represented by vertical lines according to Frank-Condon principle since they occur in a
FIG. 1.2 - CONFIGURATION COORDINATE MODEL
time short compared with the time necessary for an ion to move
appreciably. When a centre absorbs a requisite amount of
energy (h\nu), it is raised from the equilibrium position of
ground state A to the excited state B; then the ions of the
system adjust until a new equilibrium is reached at C, the
energy difference between B and C is given off as phonons.
From C the centre may return to the ground state D by the
emission of light energy (h\nu'). The centre relaxes from D to
A by again giving up phonons. The energy of emitted photon
(h\nu') is less than that of the absorbed photon (h\nu) because
of the energy transferred to lattice vibrations. This shift is
known as "Stokes' shift".

The classical configuration coordinate model explains the
sudden decrease in luminescence efficiency of a centre at higher
temperatures as observed in KCl : Tl phosphors. Gurney and
Mott pointed out that if a system is given adequate thermal
energy when it is at C, it may reach the point E in the excited
state at some higher vibrational level and make the non-radiative
transition to the ground state there. Hence thermal quenching of
luminescence results.

The non-radiative transitions from excited state to the
ground state of the centre can be explained by two other mechanisms
using configuration coordinate model. Fig. (1.3) gives the Seitz
model (for exciton). In this model the system after excitation
relaxes to such an extent that its minimum (A) lies outside the
ground state curve and this increases the probability of non-radiative transition. The other model was proposed by Dexter et al., 25 Fig. (1.4). In this model the energy dissipated during relaxation is less than that according to the Seitz model and the system comes quite close to the ground state from where the radiative return is not probable.

Although the classical configuration coordinate model is successful in explaining the Stokes' shift, the phenomenon of thermal quenching at high temperatures and the accompanying decrease of decay time, it fails to describe adequately the variation in the width of the absorption and emission bands with temperature at low temperatures. It cannot be applied to the processes occurring between absorption and emission e.g., photoconductivity. In the quantum mechanical modification of the model the centre is considered as a simple harmonic oscillator with quantized vibrational energy levels. The zero point energy of the oscillator provides an explanation for the fact that emission bands do not sharpen into lines at low temperatures. 27 The problem of obtaining the shape of the absorption and emission bands for the quantum mechanical case was solved by Williams and Hebb. 29 They treated the initial and final states of the centre quantum mechanically. The model leads to a low temperature spectrum consisting of a large number of closely spaced lines. In most cases there appears to be enough broadening of the levels so that this fine structure is not observed.
FIG. 1.3 - SEITZ MODEL

FIG. 1.4 - MODEL OF DEXTER, Klick AND RUSSEL.
Some workers have made successful attempts to calculate configuration coordinate curves for a luminescence centre in the case of various photoconducting phosphors. The work of Williams is particularly noteworthy on KCl-Te. These curves have also been applied to explain the phenomenon of sensitization in doubly activated phosphors. The disagreement between theory and experiment in the prediction of activation energy for non-radiative transitions was accounted for by introducing multidimensional models in place of the one-dimensional model.

(B) Continuous Dielectric Model

In the previous model the interaction of a centre with the lattice is restricted to the first and second nearest neighbours. Huang and Rhys have proposed a theory in which they ignore these short range forces and compute the interaction of a centre with the phonon field of the lattice. They consider the lattice as a continuous dielectric in which the centre is embedded. In absorption the centre experiences a difference in charge distribution when the system jumps from the ground to excited state. This re-arrangement in charge induces a change in lattice polarization which is accompanied by the creation of lattice phonons. Extensions and refinements of this work have been made by Lax, O'Rourke and Meyer. Hung and Rhys have also investigated the probability of multiphonon transition between electronic states using the continuous dielectric model. These
ideas helped to understand edge emission.

(C) Energy Band Model

The "collective electron model" for a perfect crystal lattice proposed by Bloch has been extended by Mott and Gurney and Seitz to explain the luminescence mechanism of phosphors. The energy states of an electron in a crystal may be derived from the states of the individual atoms and ions which compose the crystal. The discrete energy levels in atoms and ions are broadened into bands due to interaction with the crystal lattice. These allowed energy bands are separated by forbidden regions and they are either filled or unoccupied.

The highest filled band $F$, occupied by valence electrons of the crystal atoms, is called the valence band and the first unoccupied band $G$ above it, is known as the conduction band. However the periodicity of the crystal lattice is destroyed by the presence of impurities and lattice defects. This gives rise to discrete localized levels in the forbidden gap. The discrete localized levels just above the valence band in the forbidden gap function as luminescence centres ($L$). The ground state of each $L$ centre is occupied. Other unoccupied levels near the conduction band, known as traps in which excited electrons can be trapped are produced by other impurities, vacant lattice sites or lattice defects.

When the matrix lattice absorbs a photon of energy equal to
FIG: 1.5 - ENERGY BAND MODEL.

FIG: 1.6 - SCHÖN-KLASENS MODEL.
or greater than the band gap, an electron is raised to the conduction band and a positive ion vacancy known as a hole is created in the valence band. Both are free to move through the crystal under the influence of an applied electric field. The wavelength corresponding to the band gap energy is known as absorption edge $A$. Radiation of less energy may be absorbed by the impurity centres, the resulting electron transition may then be either into an excited state of the centre or into the conduction levels. Thus additional absorption bands due to impurities are expected. These bands will lie to the long wavelength side of the fundamental absorption band. If the electron transition is into the excited state of the centre, no photoconduction and electron trapping is found. The absorption of energy may also result in transition $E$, from the filled band directly into the trapping states, the positive holes then migrate to the luminescence centres and empty them. The trapped electrons may be raised by optical stimulation into the conduction band giving rise to an absorption band in the long wavelength region. Similarly electrons may be raised into empty emission centres from the filled band (valence band) with the absorption of low energy radiation. Hence such centres are no longer available for recombination with conduction electrons and hence this leads to quenching of emission.

In the case of alkali halide crystals, absorption occurs to the long wavelength side of the fundamental absorption band but no photoconduction is observed, though absorption is in the matrix.
This is explained by assuming that the excited electron and hole are moving in one another's field with no net charge. These bound electron hole pairs are known as "excitons". 44-48

It is difficult to depict the dynamic processes involved in luminescence by means of static diagrams and a good deal of imagination is necessary to take into account temporary changes in atomic configurations, atomic motions, spin and spin-orbit interactions, spatial distributions and densities of electron clouds. The simple configurational coordinate model for example is not capable of dealing with photoconductivity while the energy band model does not deal with Stokes' shift. Also a specific diagram can represent only a given centre while a real crystal is an ensemble of systems having statistical deviations from the mean. Nonetheless even two dimensional energy state diagrams offer considerable promise as a graphic means of correlating empirical data and simplifying the task of visualising the electronic transitions, processes of transmission and temporary storage of energy in real solids.

1.4 Emission Processes in Simple Centres

Luminescent systems have been divided into the following three categories:

(A) Systems in which transfer of energy is predominantly by movement of charge carriers.
(B) Systems in which absorption is in one centre and emission is in another centre, the transfer of energy from absorbing to the emitting centre taking place without movement of charge carriers.

(C) Systems in which the absorption and emission of energy take place in the same centre.

(A) Luminescence involving movement of charge carriers (Photoconducting phosphors).

The most common form involving transport of charge is that in which electrons and holes recombine at an imperfection. Three types of models have been proposed to explain the luminescence phenomena in these phosphors.

(i) Schön-Klasens Model — This model was proposed by Schön and subsequently elaborated by Klasens and his associates. 49-53

Fig. (1.6) represents the Schön-Klasens model. The sequence of events proposed is as follows:

(a) light is absorbed in the fundamental absorption band producing a free electron and a hole leading to photoconductivity;
(b) the hole migrates towards the impurity centre; (if for example, the centre is due to Ag⁺ substituted for Cd⁺⁺ in CdS, the centre has a net negative charge and attracts the hole with a coulomb like force).
(c) the hole is captured by the impurity centre giving off a small amount of energy as infra-red radiation or as vibrational quanta. This leaves the luminescence centre vacant for an electron;

(d) the conduction electron migrates through the lattice until it finally comes near the centre;

(e) the electron is captured by the centre where it recombines with the captured hole and energy is given off as luminescent radiation.

The cycle is now completed and the centre is thus re-set for the next cycle.

By extending this model to two impurity atoms Schön and Klasens were able to explain the effect of poisons, variation of luminescence colour with temperature of some phosphores, the non linear relationship between luminescence output and exciting intensity.

A serious objection to the theory is that the rate of luminescence decay would be of the same order as for photoconductivity but this is not always the case as pointed out by Bube. A reasonable explanation of this feature has been given by the model of Lambe and Klick.

(ii) Lambe and Klick Model — The model proposed by Lambe and Klick is a modified form of the Schön-Klasens model as shown in Fig. 1.7. The main
FIG. 1.7 - LAMBE AND KLICK MODEL.

FIG. 1.8 - WILLIAMS AND PRENER'S MODEL.
features of this model are that the trapping of the hole by the centre is considered to be a large energy transition and is assumed to give rise to luminescence. The localized level is situated slightly below the conduction band and is filled when the cycle starts.

The sequence of events in this case is as follows:

(a) light is absorbed in the fundamental absorption band producing a free hole and electron, leading to conductivity;

(b) the hole and electron move about in their respective bands, and eventually the hole migrates near the impurity centre;

(c) the hole is captured by the impurity centre and luminescent emission occurs, leaving the centre effectively neutral in charge;

(d) the electron wanders through the lattice until it finally comes near the centre;

(e) the electron is finally captured by the centre with a small amount of energy emission as infra-red radiation or as lattice phonons.

In the Lambe-Klick model the luminescent act occurs first and should occur much more rapidly than decay of photoconductivity. This is verified experimentally. Independent photoconductivity experiments show that holes are trapped in sulphides much more rapidly than electrons.
(iii) Williams and Prener Model (donor acceptor model)

Another model was proposed by Williams, Prener and coworkers \(^ {39-52}\) and is shown in Fig. (1.8). Originally the model was applied to ZnS : Cu, Cl phosphor where chlorine was taken as flux. In such a phosphor copper produces an acceptor level I near the valence band and chlorine a donor level II near the conduction band. Level I has high capture probability for holes whereas level II has a high capture probability for electrons.

The sequence of events is:

(a) the excitation produces a free electron and a free hole as before giving rise to conductivity;

(b) hole and electron captures now occur respectively in levels I and II with release of relatively small amounts of energy either as infra-red radiation or lattice phonons;

(c) transition of electrons from level II to level I occurs giving luminescence emission.

In this model the probability of radiative emission is much greater than that associated with the previous two models, provided the temperature is not too high. At relatively high temperatures electrons from level II are raised into the conduction band before radiative emission. This explains the quenching of emission.
There are three main criteria which have been used to identify the donor-acceptor emission.  

(a) Absence of photoconductivity effects connected with luminescence.  

(b) The radiation energy obeys Williams' formula for sharp line emission i.e.,

\[ E_r = E_g - \left( E_D + E_A \right) + \frac{e^2}{K_0 r_{DA}} \]  

where \( E_g \) is the band gap, \( E_D \) and \( E_A \) are respectively donor and acceptor binding energies. \( K_0 \) is the static dielectric constant of the medium and \( r_{DA} \) is the distance between donor and acceptor emitting radiation.  

(c) Agreement with the kinetic analysis based on donor acceptor hypothesis and other reasonable assumptions.  

This model of luminescence transition is consistent with the results of measurements on the temperature dependence of emissionspectrum, the decay of luminescence and some other related properties. Birman has reported a new approach for the copper levels in ZnS : Cu and has given some general discussion of the donor acceptor model. The radiative transitions so far calculated and observed in donor acceptor model are reviewed by Williams.  

Birman has observed that the shift of the peak or broadening of the envelope (distinct from broadening of the
individual "D. A. lines" is not in agreement with the D. A. hypothesis of isolated D. A. pairs.

(B) **Luminescence without movement of charge carriers**

In the case of sensitized phosphors the transfer of energy does not involve movement of charge and the energy absorbed by sensitizer may be transferred to the emitter by one of the following mechanisms:

(i) **Cascade mechanism** — This mechanism refers to radiative transfer of energy between two centres involving emission and reabsorption of photons. Here one centre on absorbing excitation energy emits radiation (primary emission) which on being absorbed by a second centre emits luminescence (secondary emission). The conditions for cascade mechanism are:

(a) The first absorbing species must be a reasonably efficient activator in the system.

(b) The second absorbing species must have its absorption band overlapping significantly with the primary emission band of the first.

(c) The absorption band associated with the centres due to second absorber must have an appreciable intensity.

(d) The second centre should show secondary emission if it is not a quencher.
(ii) Resonance transfer and concentration quenching - According to this mechanism, after the absorption of energy by the sensitizer it is transferred to the emitter which cannot be directly excited because of its small or unfavourable absorption range. Hence transfer of energy takes place by exchange in a non-radiative manner. This phenomenon is observed when the excitation levels of two centres overlap. From various considerations, resonance transfer of energy appears to be the most probable mechanism of sensitized luminescence. It becomes especially marked at low temperatures because of the freezing of charge carriers in traps.

Theory of resonance transfer of energy between molecules with allowed transitions has been given by Förster and then by Dexter. According to this theory the excited states of sensitizer and activator must have the same or nearly same energy values. The excited and unexcited molecules, e.g., sensitizer and emitter should be close enough for interaction of their dipole fields to permit energy transfer. This distance of closeness is called critical distance.

The theory of resonance transfer also explains concentration quenching and absence of luminescence in pure crystals.

It is observed that the luminescence efficiency of a phosphor decreases if the concentration of activator is increased beyond a certain value. Some workers assumed that quenching occurs at the centre which absorbs the emitting energy
initially. It is also assumed that the proximity of a given activator to another activator or certain types of lattice defects increase the probability of radiationless transition in the activator. Quenching is assumed to involve the resonance transfer of energy from activator to activator until it arrives at an activator near one of the energy sinks. 75

(iv) Exciton migration — It has been assumed by various workers that the energy can be transferred from the point where it is absorbed to the radiating centre in a crystal by an exciton. 79–80 This process being sensitive to the presence of surface states, exciton migration over a large distance is possible only in the case of pure and defect free crystals. 81–83 Host sensitization can also be considered from the point of view of the propagation of an exciton through the lattice. 84,85

(C) Luminescence systems in which the absorption and emission of energy both take place in the same centre

Such systems are best treated by the configurational coordinate model and continuous dielectric model. The process of luminescence involves three stages viz., (i) absorption and excitation, (ii) transfer and storage of energy and (iii) emission.

1.5 Radioluminescence :

The luminescence excited by high energy radiations such as X-rays or radioactive rays is termed as radioluminescence. These
exciting radiations can cause excitation or ionization of the
luminescence centre followed by luminescence emission. 5

(i) The excitation and emission processes  - X-rays incident
on a phosphor
are absorbed by its lattice and give rise to an avalanche of
electrons. As long as the energy of these are greater than the
band gap they lose their excess energy by exciting new electrons
from the valence band into the conduction band. When their
energy becomes less than the band gap they can lose their energy
as phonons or they may excite a luminescence centre. The energy
lost to lattice vibrations is quite small. Hence an appreciable
part of the incident X-ray energy may be transformed into light.

It can also be assumed generally, that the luminescence
under X-ray excitation is due to bimolecular recombination of
conduction electrons with empty emission centres.

The radiative transition process is usually independent
of the mode of excitation and we obtain for example, in radio-
luminescence, the same emission bands as in photoluminescence.
Detailed studies reveal that the exciting source may modify the
relative intensities of the bands, the luminescence yield of the
phosphor and the after glow of the phosphor. 35

(ii) Luminescence yield and phosphor efficiency  - Each X-ray
photon produces a very large number of visible quanta. Thus for X-ray
excitation, the quantum yield is much greater than unity, while in most favourable cases, quantum yield for photoluminescence is nearly unity.

The efficiency is approximately independent of X-ray wavelength. Kallmann and Dresner \(^{37}\) have shown that the volume of the channel of excitation is nearly proportional to the energy of incident beam. This proportionality remains the same even when the channel changes form, roughly cylindrical for 35 keV X-rays, it becomes a sphere for 3.5 keV X-rays (the channel of excitation is associated with each of the fast secondary electrons created by X-rays).

Klasens \(^{33}\) treated the problem of light output of fluorescent screens excited by X-rays. In practice, the efficiency of an X-ray screen is determined not only by phosphor efficiency but also by the intensity of X-ray absorption.

1.6 Statement of the Problem:

Alkaline earth oxides constitute a class of simple materials both from a structural and purification point of view. The oxides are further known to have a comparatively higher temperature of quenching which is an important factor in any application.

Much interest has been centered round ZnO phosphors in recent years. ZnO is known to exhibit edge emission in the near
UV and also a more common green band whose origin is still a matter of controversy. The use of ZnO phosphors in flying spot scanners, C.R. tubes for television and film scanning has been promoted due to the fast decay of its edge emission.

The absorption and emission spectra of rare-earth activated phosphors consist of lines due to f - f forbidden transition and the intensity of absorption is weak. Sensitization experiments have therefore been carried out in several systems activated by rare-earths. Complications of self absorption are almost negligible because of its weak absorption thus permitting larger concentrations of the activator.

The interest in Eu$^{3+}$ activated oxides has increased recently in view of their application as red phosphor in colour television tubes and fluorescent lamps. Addition of MgO to ZnO shifts the emission in the visible region from green towards blue. Still the rare earth activated ZnO-MgO system has not been investigated in detail.

Therefore it was proposed to study the luminescence of europium and samarium activated ZnO and ZnO-MgO phosphors i.e., the effect of MgO on luminescence properties of Eu and Sm activated ZnO phosphors.

The following studies of these phosphors have been carried out choosing X-rays as the main source of excitation.
(a) **Absorption** — The absorption study of rare-earth activated ZnO:MgO polycrystalline phosphors has been done with "PYE UNICAM SP - 8000 Ultra-violet Recording Spectrophotometer" with a reflectance unit attached to it in the wavelength range from 200 to 700 nm; in order to study the variation of band gap.

(b) **Emission** — The fluorescence emission spectra under X-ray and cathode ray excitations have been studied at room temperature, in order to obtain information about the levels involved in emission. A Bellingham and Stanley Spectrometer in conjunction with a photometer is used for luminescence intensity measurements.

(c) **Phosphorescence decay** — The phosphors were excited by X-rays and then allowed to decay after cessation of excitation and the luminescence intensity was measured during this period using a galvanometer. This study was made in order to obtain information about energy distribution of trap levels in the phosphor matrix.

(d) **Thermoluminescence** — The phosphors were excited by X-rays, allowed to decay after the end of excitation and then heated at a uniform rate. The TL glow curves were plotted. After analysing these glow curves, trap depths were calculated. The trap levels calculated from decay studies have been compared with these. The order of kinetics involved has also been determined.
(e) Temperature dependence of emission - The influence of temperature on the fluorescence intensity under X-rays for all prepared phosphors and that under UV (355 nm) excitation for some ZnO : MgO : Eu phosphors is studied in temperature range between 300° and 500°K.

Finally an attempt has been made to correlate and discuss the results of the above studies.
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