Chapter - V
5. Influence of $\text{Tl}^+$ activator ions on the luminescence characteristics of $\text{KBr:Eu}^{2+}$ powder phosphors

5.1 Introduction

Alkali halides doped with Eu$^{2+}$, Pb$^{2+}$, Tl$^+$, Ga$^+$ are being studied to find their suitability as X-ray storage phosphors [1-4]. Recently luminescence studies by Nanto et. al. suggested KBr:Eu$^{2+}$ phosphors as potential candidate of X-ray storage materials for medical imaging [5]. PL emission spectra of phosphors doped with Eu$^{2+}$ ions correspond to a broad emission band around 420 nm in KBr:Eu$^{2+}$ phosphors and its corresponding excitation bands fall in the range between 200 - 400 nm [6, 7].

Luminescence studies of alkali halides containing Tl$^+$ ions have been investigated thoroughly [8, 9]. Thallium doped KBr crystals produce two emission bands ($A_T$ and $A_X$ emissions) at RT when excited at any one of its three main characteristic absorption bands designated as A, B and C bands. Their electronic transitions leading to these absorption and emission bands have been studied extensively in the past [8]. In the X-ray storage phosphor BaFBr:Eu$^{2+}$, some co-
activators (0.1 - 1 mol %) such as Al, Tb, Ce, Ga, Li, alkali halides, etc. were also doped additionally and the role of some of these co-activators have been reported [10-14]. Recently, KCl:Eu$^{2+}$ powder phosphors co-activated with Ti$^+$ showed some interesting results (Chapter 4). The enhancement of PL emission due to Eu$^{2+}$ ions was attributed to an energy transfer from Ti$^+$ → Eu$^{2+}$ ions in the KCl:Eu$^{2+}$, Ti$^+$ phosphors. In the present work as a continuation of the above work on KCl:Eu$^{2+}$, Ti$^+$ powder phosphors, photo and photostimulated luminescence in KBr:Eu$^{2+}$, Ti$^+$ powder phosphors synthesized using graphite crucible under controlled flow of air (Chapter 2) is reported.

5.2 Results and Discussion

5.2.1 Photoluminescence (PL) studies

PL emission spectra of KBr: Eu$^{2+}$ (0.1 mol %), Ti$^+$ (x mol %, x = 0. 0, 0. 03, 0. 05, 0. 075 , 0.1) for $\lambda_{ex} = 364$ nm show single emission band around 420 nm (Fig. 5.1). The 420 nm PL emission band is the well-known characteristic Eu$^{2+}$ emission due to transition from 4$f^65d$ to 4$f^7$ level [1, 5]. The intensity of this band slightly increases with Ti$^+$ concentration up to 0.075 mol % and then it decreases for further increase in ‘x’.
Fig. 5.1 PL emission spectra of KBr:Eu\(^{2+}\) (0.1 mol %) Tl\(^+\) (x mol %) powder phosphors for \(\lambda_{ex} = 364\) nm: (a) \(x = 0.0\), (b) \(x = 0.03\), (c) \(x = 0.05\), (d) \(x = 0.075\) and (e) \(x = 0.1\)

The excitation spectrum for the 420 nm emission in KBr:Eu\(^{2+}\) phosphors (Fig. 5.2) shows the characteristic staircase structure between 300 – 400 nm and a weak band around 264 nm with a shoulder around 250 nm (Fig. 5.2, curve ‘a’). From earlier reports it is known that isolated Eu\(^{2+}\) ions in single crystals of KBr give rise to an absorption / PL excitation band at 251 nm (in addition to the staircase structure between 300-400 nm) [4]. The excitation band around 264 nm may be due to some europium aggregates formed in KBr:Eu\(^{2+}\) phosphors [15].

In KBr:Eu\(^{2+}\) phosphors co-doped with thallium, a new excitation band appears around 270 nm and it shifts slightly towards long wavelength side with increasing amount of TlBr added to it (Fig. 5.2, curves ‘b-e’). The new band
appearing around 270 nm is attributable to the involvement of Ti\(^+\) ions in the emission process.

Fig. 5.2 PL excitation spectra of KBr:Eu\(^{2+}\) (0.1 mol \%) Ti\(^+\) (x mol \%) powder phosphors for \(\lambda_{em} = 420\) nm: (a) \(x = 0.0\), (b) \(x = 0.03\), (c) \(x = 0.05\), (d) \(x = 0.075\) and (e) \(x = 0.1\)

The increase in the 420 nm emission for excitation at the peak of the staircase structure may be attributed to the role of Ti\(^+\) acting as some kind of flux in the mixture during the sintering process thereby increasing the concentration of Eu\(^{2+}\) ions incorporated into the phosphor for lower concentrations of Ti\(^+\). Although this result is similar to that observed in KCl:Eu\(^{2+}\),Ti\(^+\) powder phosphors (Chapter 4), the increase in the 420 nm emission with thallium content in KBr:Eu\(^{2+}\),Ti\(^+\) is not high when compared to that in KCl:Eu\(^{2+}\),Ti\(^+\) for similar concentrations.
Alkali halides doped with small amounts of thallous ions are known to exhibit four absorption bands designated as A, B, C and D bands due to Tl\(^+\) ions which have replaced the host cations substitutionally. The transition from 6s\(^2\) ground state of a Tl\(^+\) ion to its 6s6p first excited state is responsible for these absorption bands [16]. The A, B and C bands of Tl\(^+\) ions in KBr appear at 258, 221 and 209 nm respectively [16]. Luminescence due to A-band excitation has been studied extensively in alkali halides. It is well known that two overlapping emission bands around 310 nm and 365 nm appear in KBr:Tl\(^+\) crystals when excited at the A-band at RT [8, 17]. In heavily doped KBr:Tl\(^+\) crystals, additional, weak absorption bands that appear on the long wavelength side of the A, B, C bands have been reported [8, 16]. The additional A-bands whose intensity increases as the square of the concentration of Tl\(^+\) ions were attributed to the Tl\(^+\) dimers.

Two possible geometrical structures for Tl\(^+\) dimers in alkali halides have been proposed; one with two Tl\(^+\) ions located along (110) crystal axis and the other with two Tl\(^+\) ions along (100) axis separated by an anion. The former is called D\(_{2h}\) dimer while the later as D\(_{4h}\) dimer. At low temperatures, D\(_{2h}\) dimers of Tl\(^+\) ions in KBr single crystals showed absorption bands at 266.7, 265.8 and 257 nm lying close to the monomer band at 258 nm while the D\(_{4h}\) dimers were
absorbed at 262 nm [16]. At RT, the presence of these weak absorption bands were seen only as a broadening of the A-band absorption towards the long wavelength side because of their overlap with the much stronger A-band absorption at 258 nm. Excitation at these additional side bands was reported to result in a new emission band at 443 nm at low temperatures. However, it was found to reduce drastically when the temperature was increased beyond 100 K [18]. Thus the additional excitation bands observed around 260-270 nm (present study) could be attributed to centres involving TI$^+$ ions and their aggregates.

In order to understand the effect of these thallium centres on Eu$^{2+}$ emission at 420 nm more clearly, PL emission spectra of these phosphors are recorded at 262 and 270 nm (Figs. 5.3 and 5.4 respectively). KBr:Eu$^{2+}$ phosphor shows only the 420 nm emission (curve ‘a’ in Figs. 5.2 and 5.3). In KBr:Eu$^{2+}$,TI$^+$ (x mol %, with x > 0) phosphors, in addition to the 420 nm emission, additional emission bands appear in the region between 280-400 nm (curves ‘b-e’ in Figs. 5.3 and 5.4). From the structure of the emission bands in this region, presence of four overlapping bands around 310, 325, 360 and 375 nm could be identified. Of these, the three long wavelength bands appear only as shoulders.
The new emission bands on the short wavelength side of the emission spectra are clearly due to the inclusion of thallium ions in the KBr:Eu$^{2+}$, Tl$^+$ phosphors as they are absent in KBr:Eu$^{2+}$ phosphors (Figs. 5.3 and 5.4, curve 'a').

The growth of the thallium emission bands with TlBr concentration, x, is slow and non-linear which is an indication that aggregates involving thallium ions are formed in these phosphors. These emission bands show maxima for x = 0.05 and for further increase in ‘x’ they decrease. On the other hand, the intensity of the
420 nm emission increases with ‘x’ shows a maximum for x= 0.075 and then it decreases for further increase of ‘x’.

![Fig. 5.4 PL emission spectra of KBr:Eu²⁺ (0.1 mol %), Tl⁺ (x mol %) powder phosphors for λ_ex = 270 nm: (a) x = 0. 0, (b) x = 0. 03, (c) x = 0. 05, (d) x = 0. 075, (e) x = 0. 1]

Comparing with the earlier reports, the observed PL emission bands around 310 and 360 could be attributed to Tl⁺ monomer ions [17]. The additional emission bands around 325 and 375 nm are tentatively attributed to some complex Tl⁺ centres involving aggregates of Tl⁺ ions and perhaps, other impurity ions such as Eu²⁺, Cl⁻ present in EuCl₃, etc. The nature of the centres responsible for these emission bands is not known at present. In KCl:Eu²⁺, Tl⁺ phosphors, the emission band at 380 nm (observed in addition to the well-known A-band emission of Tl⁺
ions in KCl around 300 nm and the 420 nm emission and of Eu$^{2+}$ ions) was suggested to be due to such complex centres (Chapter 4).

Fig. 5.5 Photoluminescence (PL) spectra of KBr:Eu$^{2+}$ (0.1 mol %), Tl$^+$ (x mol%) powder phosphors: a) $x = 0.0$, (b) $x = 0.03$, (c) $x = 0.05$, (d) $x = 0.075$, (e) $x = 0.1$ and (f) PL excitation spectrum of KBr:Eu$^{2+}$ (0.1 mol %), Tl$^+$ (0.075 mol %) for 420 nm emission

PL excitation spectra for the 312 nm emission in KBr:Eu$^{2+}$, Tl$^+$ powder phosphors are shown in Fig. 5.5 (A). For the sake of comparison, PL emission spectra of these phosphors for $\lambda_{\text{ex}} = 262$ nm (shown in Fig 5.3) are reproduced in
Fig. 5.5 as Fig 5.5 (B). Fig. 5.6 shows the PL excitation spectra of these phosphors for $\lambda_{em} = 360 \text{ nm}$. The PL excitation spectra corresponding to the PL emission bands around 312 and 360 nm (Figs. 5.5 (A) and 5.6) show an excitation band at 266 nm with a shoulder around 258 nm and a weak band around 228 nm for small values of $x$. For higher values of Tl$^+$ content, the 266nm band slightly broadens towards long wavelength side and its peak position shifts (to 269 nm) towards long wavelength side. Although weak, the 228 nm band also shows a similar shift towards long wavelength side with ‘x’.

As discussed earlier, the short wavelength shoulder at 258 nm in the excitation spectrum is attributed to Tl$^+$ ions (monomers). From Fig. 5.5 (A) and

![Photoluminescence excitation spectra of KBr:Eu$^{2+}$ (0.1 mol %) Tl$^+$ (x mol %) powder phosphors for $\lambda_{em} = 360 \text{ nm}$](image)

Fig. 5.6 Photoluminescence excitation spectra of KBr:Eu$^{2+}$ (0.1 mol %) Tl$^+$ (x mol %) powder phosphors for $\lambda_{em} = 360 \text{ nm}$ (B), it is observed that the excitation bands for $\lambda_{em} = 312$ and 360 nm are slightly...
more intense (for \( x > 0 \)) than their corresponding 312 nm and 360 emission bands (Fig. 5.5 (A), (B) and Fig. 5.6). This result indicates that the 312 as well as 360 nm emission of Ti\(^+\) centres is partially absorbed by some other luminescence centres.

Comparing with the reports on Ti\(^+\) dimers in KBr:Ti\(^+\) crystals, the 266 and 228 nm bands are attributed to the A and B bands of the Ti\(^+\) dimers respectively [16]. However, it must be pointed out that the 443 nm dimer emission reported in KBr:Ti\(^+\) crystals containing Ti\(^+\) dimers observed at low temperature is not present in the spectra of present room temperature study or its intensity is below the level of detection, if present. This is understandable on account of the drastic reduction of this dimer emission band with temperature [18]. The shifting of peak position and broadening of the band towards long wavelength side may be attributed to the formation of some higher aggregates involving Ti\(^+\) ions [19]. Perhaps, other impurity ions such as Eu\(^{2+}\) ions may also be involved in such centres [20].

Fig. 5.7 shows the plot of ratio of intensity of the 420 nm emission in KBr:Eu\(^{2+}\),Ti\(^+\) (x mol %, \( x = 0.0, 0.03, 0.05, 0.075, 0.1 \)) to that in KBr:Eu\(^{2+}\) as a function of the concentration of Ti\(^+\) for different excitations. This ratio (i.e. the relative intensity) is found to increase with Ti\(^+\) concentration. After reaching a maximum for \( x = 0.075 \), it decreases for further increase in \( x \). The A-band
Fig. 5.7 Variation in the relative intensity of 420 nm PL emission in KBr:Eu²⁺ (0.1 mol %) Tl⁺ (x mol %) powder phosphors with TlBr concentration.

The emission spectrum of Tl⁺ ions in KBr:Tl⁺ overlap partially with the excitation spectrum for the Eu²⁺ emission in KBr:Eu²⁺ crystals. The overlap between the thallium emission bands in KBr:Eu²⁺, Tl⁺ powder phosphors and the excitation spectrum for Eu²⁺ emission is shown in Fig. 5.5 (A). Due to overlap between the excitation band of europium ions at 264 nm and the thallium excitation bands around 258 and 270 nm, excitation by radiation of any wavelength between 260 - 270 nm would excite both types of impurity ions in the KBr:Eu²⁺, Tl⁺ phosphor resulting in the 420 nm Eu²⁺ emission as well as the thallium emission bands between 280 - 400 nm. If a part of the above thallium emission energy is
transferred to some of the unexcited Eu$^{2+}$ ions (since the main excitation band of Eu$^{2+}$ ion also lie between 300- 400 nm), it will produce some additional Eu$^{2+}$ emission at 420 nm.

Thus an energy transfer between Tl$^+$ $\rightarrow$ Eu$^{2+}$ in KBr: Eu$^{2+}$,Tl$^+$ is expected to produce an enhancement in the 420 nm emission when excited with radiation of wavelength around 260 - 270 nm. The larger increase in the relative intensity of 420 nm emission for $\lambda_{ex}$ =262 and 270 nm with TlBr concentration is higher than that for $\lambda_{ex}$ = 364 nm. This indicates that such an energy transfer is taking place between Tl$^+$ $\rightarrow$ Eu$^{2+}$ ions. The decrease of relative intensity with ‘x’ after reaching a maximum (for $x = 0.075$) may be due to some luminescence quenching mechanism such as concentration quenching occurring at higher concentrations of activators.

Similar results were observed in the KCl:Eu$^{2+}$, Tl$^+$ powder phosphors (Chapter 4). But the enhancement in intensity of 420 nm emission of Eu$^{2+}$ ions in Tl$^+$ co-doped KBr:Eu$^{2+}$ phosphors is not as high as expected (the maximum relative intensity is about three times in KBr:Eu$^{2+}$, Tl$^+$ phosphors against about 16 times in KCl:Eu$^{2+}$, Tl$^+$ phosphor). The chances of energy transfer between Tl$^+$ $\rightarrow$ Eu$^{2+}$ ions were expected to be higher in KBr:Eu$^{2+}$,Tl$^+$ phosphors than that in KCl:Eu$^{2+}$, Tl$^+$ phosphors since the thallium emission bands in KBr based
phosphors (280-400 nm) cover almost the entire range of excitation band of Eu$^{2+}$ ions (300-400 nm) while the thallium emission in KCl based phosphors (300 nm and 380 nm) covered only portions on the short wavelength and long wavelength tails of the above excitation band.

Contrary to the expectations, the Ti$^+$ $\rightarrow$ Eu$^{2+}$ energy transfer in KBr:Eu$^{2+}$, Ti$^+$ phosphors is not very high. It suggests that, perhaps, Ti$^+$ and Eu$^{2+}$ ions are not spatially well correlated in KBr:Eu$^{2+}$, Ti$^+$ phosphors for the energy transfer to take place efficiently between these impurity ions in KBr based powder phosphors. The formation of Eu$^{2+}$ aggregates in large numbers in KBr:Eu$^{2+}$, Ti$^+$ phosphors rather than the isolated Eu$^{2+}$ ions (as indicated by the presence of the short wavelength excitation band at 264 nm in these phosphors) could be one of the reasons for the poor energy transfer.

5.2.2 Photostimulated luminescence (PSL) studies

PSL emission spectra of $\gamma$-irradiated ($\gamma$ dose = 14 Gy) KBr:Eu$^{2+}$ (0.1 mol %), Ti$^+$ (x mol %, x = 0. 0, 0.03, 0.05, 0.075, 0.1) phosphors under F-band stimulation show a single emission band around 420 nm (Fig 5.8). The stimulation spectrum for the 420 nm PSL emission shows a broad stimulation band around 620 nm (Fig. 5.9). The stimulation band clearly resembles the F-band absorption in KBr crystals and hence F-centres are suggested to be the electron-
Fig. 5.8 Photo stimulated luminescence emission spectra of KBr:Eu$^{2+}$ (0.1 mol %), Tl$^+$ (x mol %) powder phosphors under F-band stimulation: (a) $x = 0.0$, (b) $x = 0.03$, (c) $x = 0.05$, (d) $x = 0.075$ and (e) $x = 0.1$

Fig. 5.9 Photostimulated stimulation spectra of KBr:Eu$^{2+}$ (0.1 mol %), Tl$^+$ (x mol%) powder phosphors for $\lambda_{em} = 420$ nm: (a) $x = 0.0$, (b) $x = 0.03$, (c) $x = 0.05$, (d) $x = 0.075$ and (e) $x = 0.1$
trapped centres involved in the PSL emission process [5]. The PSL emission at 420 nm and the PL emission at 420 nm due to the Eu$^{2+}$ ions are similar suggesting the involvement of Eu$^{2+}$ ions in the PSL process. Unlike the case of PL studies, PSL emission of $\gamma$-irradiated KBr:Eu$^{2+}$, Tl$^+$ phosphors do not show any emission band (between 280 - 400 nm) attributed to the centres involving thallium ions. Further, with the increase of thallium concentration in the KBr:Eu$^{2+}$, Tl$^+$ powder phosphors, the above PSL stimulation and emission bands decrease in intensity. The absence of PSL emission due to centres involving Tl$^+$ ions and the decrease of 420nm PSL emission in KBr:Eu$^{2+}$, Tl$^+$ phosphors with Tl$^+$ concentration could be explained as follows. It is well known that, upon exposure to ionizing radiations, Eu$^{2+}$ ions in alkali halide crystals trap holes becoming Eu$^{3+}$ ions [5]. On the other hand, Tl$^+$ ions in alkali halide crystals may trap holes or electrons. If the Tl$^+$ ions trap holes during irradiation they become Tl$^{2+}$ ions and when they trap electrons they become Tl$^0$ centres. Several authors have studied the nature of new thallium centres created upon irradiation in KBr:Tl$^+$ single crystals [21, 22].

In the present study, if both the doped impurities (Eu$^{2+}$ and Tl$^+$ ions) trap holes during irradiation, they will become Eu$^{3+}$ and Tl$^{2+}$ ions respectively. The free electrons released into the conduction band from these ions wander through the crystal and when some of them are trapped at anion vacancies they form F-centres. In the KBr:Eu$^{2+}$, Tl$^+$ phosphors, if both the impurity ions trap holes during
irradiation, then the F-centre concentration is likely to be higher than the case when the phosphor is doped with only any one of the above two impurity ions for the same dose of irradiation. This is due to the availability of a larger number of free electrons in the conduction band which will increase the rate of trapping of free electrons by anion vacancies during irradiation.

In this case, upon irradiation, $\text{Eu}^{3+}$, $\text{Tl}^{2+}$ and F-centres will be produced. On the other hand, if the $\text{Tl}^+$ ions act as electron trapping centres also, then the same kind of increase in the concentration of F-centres created on irradiation is not possible as they will be competing with anion vacancies to trap electrons [23]. In the case when $\text{Tl}^+$ ions trap only electrons during irradiation, the concentration of F-centres in the double doped KBr with $\text{Eu}^{2+}$ and $\text{Tl}^+$ ions will be less than that produced in KBr that is doped only with the same amount of $\text{Eu}^{2+}$ ions and exposed to the same dose of irradiation.

If, on the other hand, the $\text{Tl}^+$ ions act as both electron and hole trapping centres then the concentration of F-centres generated may be higher or lower depending on the relative efficiency of $\text{Tl}^+$ ions for trapping holes and electrons during irradiation. In either case, on irradiation, $\text{Eu}^{3+}$, $\text{Tl}^{3+}$, $\text{Tl}^0$ and some F-centres will be produced but with different relative concentrations depending on the efficiency of $\text{Tl}^+$ ions in the double doped phosphors to trap electrons or holes.
Photostimulation at F-band wavelength subsequent to γ-irradiation of the KBr:Eu$^{2+}$,TI$^+$ powder phosphors releases electrons from F-centres into the conduction band. When a part of the free electrons recombine with Eu$^{3+}$ and Ti$^{2+}$ ions, they are converted to Eu$^{2+}$ and Ti$^+$ ions in their respective excited states. When the impurity ions relax to their ground states they would give rise to Eu$^{2+}$ and TI$^+$ emission respectively.

If an impurity ion (Ti$^+$ or Eu$^{2+}$) located in a complex centre has captured a hole on irradiation, then its relaxation to the ground state subsequent to the recombination of a free electron (released by photostimulation at F-band) with it, will give rise to PSL emission that corresponds to the PL emission of the complex centre. But the PSL emission spectra of γ-irradiated KBr:Eu$^{2+}$, Ti$^+$ phosphors show only the 420 nm emission due to Eu$^{2+}$ ions. The absence of any of the thallium emission bands in the PSL emission spectra suggests that relatively less or no Ti$^{2+}$ ions are formed on irradiation in the KBr:Eu$^{2+}$, Ti$^+$ phosphors.

This is possible if the Ti$^+$ ions of the KBr:Eu$^{2+}$, Ti$^+$ phosphors (present study) trap electrons more efficiently than trapping holes during irradiation. In this case they compete with anion vacancies (F-centre traps) to trap electrons thereby reducing the concentration of F-centres formed on irradiation. Upon photostimulation at the F-band subsequent to irradiation, only the electrons from
F-centres are released into conduction band and no electrons will be released from Tl\textsuperscript{0} centres as their absorption bands lie in the IR region [22]. Thus, upon F-band stimulation only a small part of the total trapped electrons will be made available for recombination with Eu\textsuperscript{3+} ions in the irradiated phosphors and hence Eu\textsuperscript{2+} emission will be less than that observed in KBr:Eu\textsuperscript{2+} phosphors.

The decrease of the intensity of both PSL stimulation and emission bands with increasing Tl\textsuperscript{+} content in the KBr:Eu\textsuperscript{2+}, Tl\textsuperscript{+} phosphors suggests that, when a large number of thallium ions are present in the phosphor they compete more effectively with F-centre traps to trap electrons during irradiation. This implies that, for the same conditions of irradiation, a smaller concentration of F-centres will be produced in the KBr:Eu\textsuperscript{2+}, Tl\textsuperscript{+} phosphors having higher concentrations of Tl\textsuperscript{+} ions. As a consequence, the PSL emission of γ-irradiated KBr:Eu\textsuperscript{2+}, Tl\textsuperscript{+} phosphors with a higher Tl\textsuperscript{+} content will also be less.

As energy transfer from Tl\textsuperscript{+} → Eu\textsuperscript{2+} ions is observed in the PL emission of KBr:Eu\textsuperscript{2+},Tl\textsuperscript{+} phosphors. However the absence of any of the thallium emission bands in the PSL emission spectra suggests that the role of Tl\textsuperscript{+} ions in the PSL process of KBr:Eu\textsuperscript{2+},Tl\textsuperscript{+} phosphors is negligible. Luminescence decay and lifetime of emission of these doubly doped phosphors have not been studied. However, the change in intensity of PSL signal (normalized to unity at its maximum) with time
under continuous stimulation at the peak of the PSL stimulation band (620 nm) of γ-irradiated KBr:Eu$^{2+}$ (0.1 mol %) and KBr:Eu$^{2+}$ (0.1 mol %), Tl$^+$(0.075 mol%) phosphors is shown in Fig. 5.10. The variation in PSL intensity with time in both KBr:Eu$^{2+}$ and Tl$^+$ co-doped KBr:Eu$^{2+}$ powder phosphors was almost similar. In contrast, in γ-irradiated KCl:Eu$^{2+}$, Tl$^+$ (chapter 4) phosphors, the decay of PSL emission was considerably slower than that in γ-irradiated KCl:Eu$^{2+}$ phosphors. This indicates that such an energy transfer from Tl$^+$$\rightarrow$ Eu$^{2+}$ is insignificant / does not occur in the PSL process of KBr:Eu$^{2+}$, Tl$^+$ powder phosphors.

![Diagram](image-url)

Fig. 5.10 Variation in peak intensity of PSL of γ-irradiated phosphors a) KBr:Eu$^{2+}$, b) KBr:Eu$^{2+}$, Tl$^+$ with time on continuous exposure to F-light (620 nm).

Source of F-light: Xenon lamp of the spectrofluorometer, slit width = 1 nm
5.3 Conclusion

Influence of Tl⁺ activators on the luminescence properties of KBr:Eu²⁺ powder phosphors were investigated. An enhancement in PL efficiency is observed in Tl⁺ co-doped KBr:Eu²⁺ phosphors. It shows a maximum for a Tl⁺ concentration of 0.075 mol %. This enhancement is attributed to the energy transfer from Tl⁺ → Eu²⁺ ions. The decrease in PSL intensity of γ-irradiated KBr:Eu²⁺, Tl⁺ powder phosphors with Tl⁺ concentration and the absence of thallium emission bands in PSL were attributed to the efficient electron trapping by Tl⁺ ions during irradiation.
References


