Chapter 7

ABSORLUE TL EMISSION SPECTRUM AND EVALUATION OP
INTRINSIC EFFICIENCY

7.1 New method to construct the absolute TL spectrum;

a) Experimental:

Basically the method consists of recording the monochromatic TL glow curves fully at regular wavelength intervals of 2.5 nm each in the entire wavelength region of interest (300 - 800 nm), correcting the integrated TL outputs at each wavelength for the absolute spectral response of the instrument and plotting the absolute intensity of emission thus obtained against the respective wavelength.

The spectral analyser used is the same as described in sec. 2.2.2 with an ASCOP photomultiplier. The automatic motor drive of the grating was however not employed and hand-setting of the wavelength in steps of 2.5 nm starting from 300 nm was done for each reading in these experiments. 250 μ slits were used in the monochromator which corresponded to a band spread of ± 0.8 nm at the exit slit for any wavelength setting of the monochromator.

Sufficient quantity of CaSO₄(Dy) powder in packets of 15 mgms (± 2%) each were irradiated to 8.3 x 10⁴ Rads under
water (to make sure about electronic equilibrium conditions during irradiation so that absorbed energy by the phosphor could be accurately calculated and also to maintain the sample at RT during irradiation) and stored in the refrigerator (at about 5°C) so that there was no decay of peaks V and VI during the course of the experiment which lasted for about six hours.

Fast-heating type was employed to record the glow curves with the heater and the recorder being operated simultaneously by a master switch. With 15 mgms of the irradiated powder spread on the central depression of the heater pan, a current of 20 amps was first passed for 30 secs and stopped during which time the glow curve is recorded upto about 300°C with peaks appearing around 110°C and 220°C and without bleaching any of the higher temperature peaks. After the heater has cooled to RT, the d.c. amplifier range is set one decade lower than the previous setting and a current of 50 amps was passed for 30 secs and the reading terminated. In this second run, glow curve was recorded upto about 500°C with peaks appearing around 350°C and 480°C. Thus the entire 12 peak glow curve pattern above RT normally obtained with a linear heating rate of 25°C/min (cf. fig. 23) was compressed into a four peak glow curve pattern in this fast heating system. The temperature as well as the glow curve pattern were completely reproducible for any number of flashes attempted with the same
current settings. Typical glow curves obtained by a set of such two consecutive runs with the monochromator setting at 450 nm are shown in fig. 35 along with the temperature traces for the two runs.

The area under the glow curves obtained at each wavelength setting was measured and normalisation of the values were done at 400 nm (when change of grating was effected) and 600 nm (when C4 filter was introduced). A standard of spectral irradiance (cf. Ch. 2) was used to calibrate the spectral analyser (coupled response of the monochromator and the photomultiplier) with the settings of the monochromator and photomultiplier remaining the same as were during the monochromatic glow curve recordings. The absolute spectral response factors in terms of watts/cm$^2$-nm-amp. at each wavelength setting thus obtained, was applied to the normalised integral TL glow curve areas obtained earlier for each wavelength setting, to arrive ultimately at the absolute intensity emitted in terms of watts-cm$^2$-nm which are plotted against the respective wavelengths to obtain the absolute TL emission spectrum.

b) Results:

Fig. 36 presents the TL spectra obtained separately for the two temperature regions of RT-300°C and 300°C-500°C. It is clearly seen that the same emission lines are observed both at
FIG. 35. TYPICAL MONOCHROMATIC GLOW CURVE RUNS USING FAST HEATING
PHOSPHOR: CaSO₄ (Dy)
WAVELENGTH SETTING: 450 nm.
temperatures below and above 300°C although there are
differences in the relative intensity distribution among the
various emission lines observed. This is thought of, purely
as a temperature effect rather than due to creation of any new
type of emission centre.

7.2 Intrinsic efficiency calculation:

(a) Formulation:

The TL spectral analyser is calibrated with a standard
of spectral irradiance with certified irradiance values i.e.
a calibration factor is known at each \( \lambda \) setting of the analyser,
given by \( C_\lambda \) watts/cm\(^2 \)-nm-amp.

The TL glow curve areas obtained at each \( \lambda \) setting \((A_\lambda)\)
are converted into absolute units as \( e_\lambda = A_\lambda \cdot C_\lambda \text{ watt sec/cm}^2 \text{-nm}.\)

Hence the total energy incident on the entrance slit of the
spectral analyser is given by the area of the absolute TL
spectral curve drawn as

\[
e_\lambda \text{ vs. } \lambda
\]

\[
i.e. \quad e = \int_{300 \text{ nm}}^{800 \text{ nm}} e_\lambda \cdot d\lambda \quad \text{watt sec/cm}^2 \quad (25)
\]

If 'd' is the sample-slit distance measured in cms,
assuming the sample to be a point source emitting light
isotropically, the total energy emitted as TL can be calculated
If the weight of the sample taken for each flashing is the same \( m \) gms, then the energy emitted is \( E/m \) ergs/gm.

From the irradiation dose (R rads) given under electronic equilibrium conditions and assuming the mass absorption coefficient \( \mu/\rho = 0.869 \) for CaSO\(_4\), the absorbed energy can be calculated as
\[
A = 0.869 \times R \times 100 \text{ ergs/gm}.
\]

The intrinsic TL conversion efficiency can now be calculated as:
\[
\gamma = \frac{E}{mA} \times 100\%
\]

(b) Limitations:

1) self absorption in the sample has been neglected;

2) the sample is assumed to be a point isotropic source whereas the actual size of the phosphor-spread is about one sq.cm.;

3) reflection from the heater plate has been neglected.

Lucke\(^{101}\) has arrived at a factor of 1.5 for the non-isotropicity of a phosphor with a thickness of about 15 mgm/cm\(^2\) for the increase in detected intensity compared to an isotropic source of the same total mass; he has also estimated that kanthal
heater plate reflectivity could be about 25%. Taking these two factors as applicable to the present work, the intrinsic efficiency will be \( \frac{1}{1.875} \times \frac{E}{A} \times 100\% \).

(c) Results:

In the present experiment using \( \text{CaSO}_4(Dy) \), the following were the various values involved in the evaluation of the intrinsic efficiency:

\[
\begin{align*}
e &= 19 \text{ u watt-sec/cm}^2 \\
d &= 5.5 \text{ cms} \\
m &= 15 \text{ mgms} \\
R &= 8.3 \times 10^4 \text{Rads}
\end{align*}
\]

The intrinsic efficiency works out to be 35%.

The intrinsic efficiency for TL of natural \( \text{CaF}_2 \) phosphor evaluated by the same method gave a value of about 1.3% which compares very well with the already reported \(^{(20)}\) values which are in the range of 1.3% - 3.0% for \( \text{CaF}_2 \) phosphors. From a comparison of TL glow curve areas obtained from both \( \text{CaSO}_4(Dy) \) and nat. \( \text{CaF}_2 \) for the same gamma dose, a factor of about 8 is expected between the TL efficiencies of these two phosphors. Hence the value of 35% obtained for the TL efficiency of \( \text{CaSO}_4(Dy) \) falls in the expectation range of values.

Conclusions:

It has been shown that, by recording monochromatic TL glow curves at various wavelengths, the absolute intensities
emitted as TL from a phosphor could be evaluated which in turn could lead to an estimate of the intrinsic TL efficiency of the phosphor. CaSO_4(Dy), which exhibits maximum TL sensitivity among all the RE-doped CaSO_4 phosphors excepting CaSO_4(Tm), as well as other commonly known phosphors like LiF and CaF_2, seems to possess as high as 35% efficiency for TL conversion after gamma irradiation (compare with Table-1 in sec. 1.3.3 b). Although the absolute value may not be very accurate owing to many uncertainties involved, nevertheless it does give the order of magnitude to be expected for the value of the efficiency.