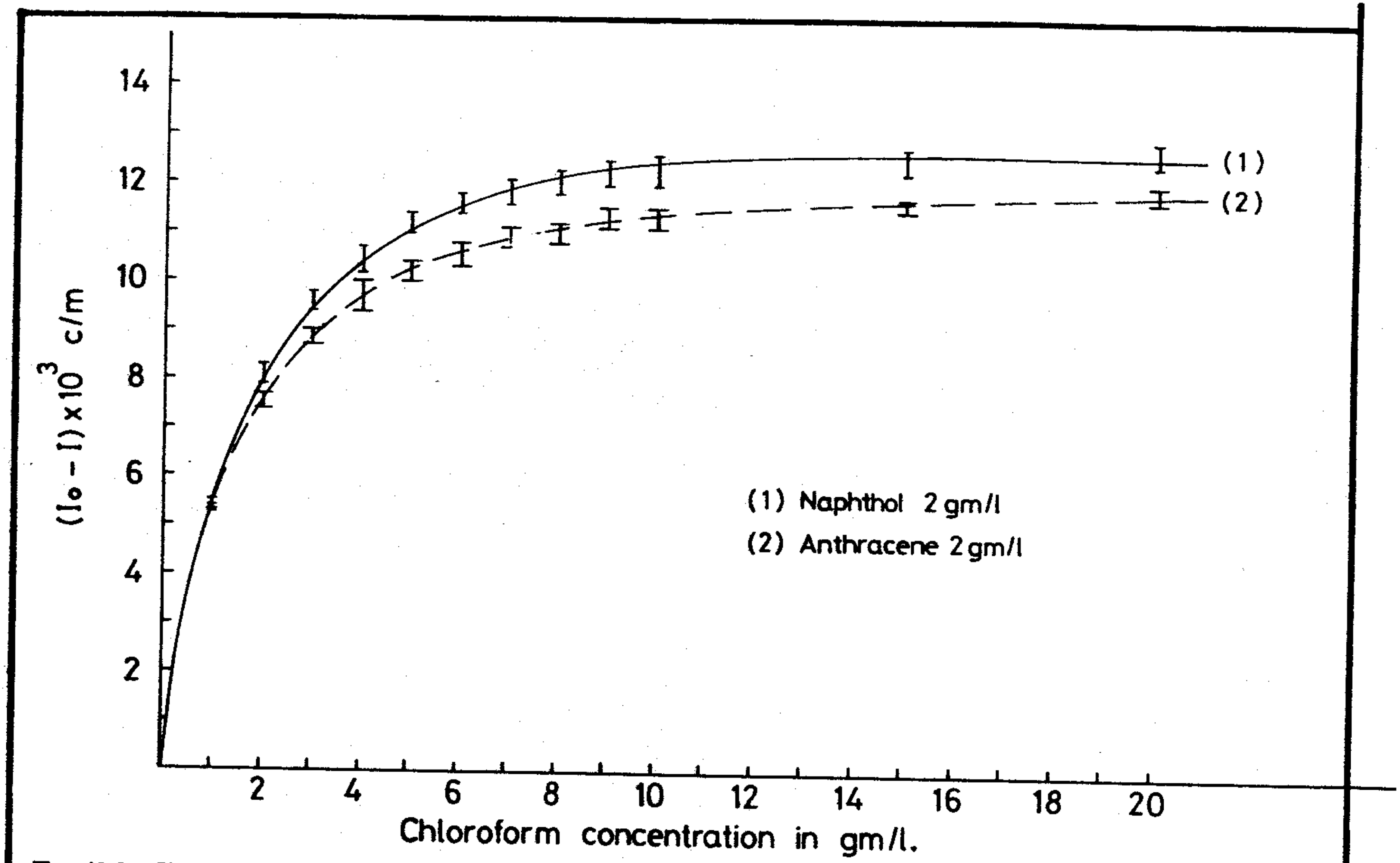

Fig.(30): The quenched energy quantity, $I_o - I$, which is quenched by chloroform at solute concentration 2gm/l.

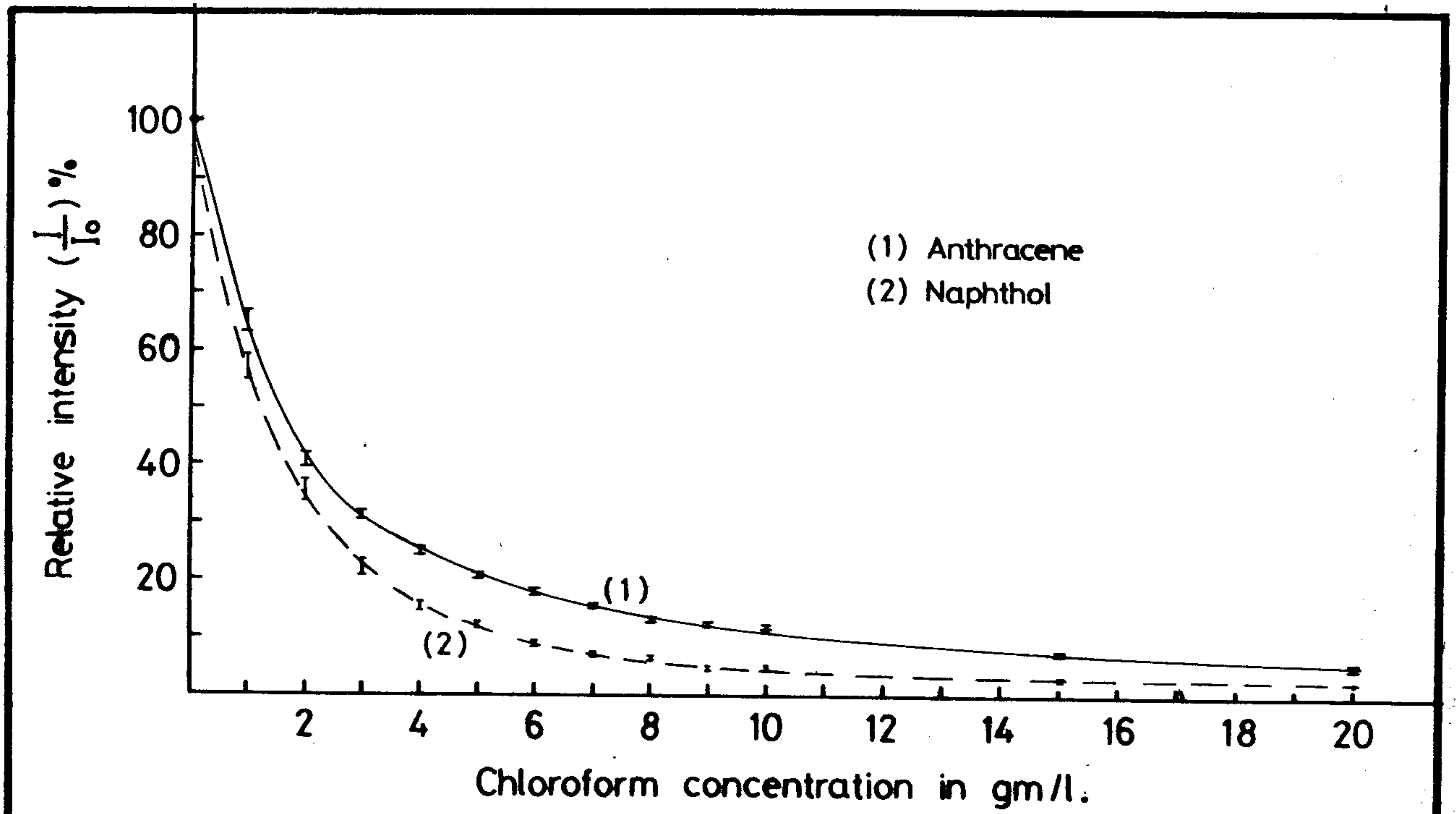

Fig.(31): The relation between the relative intensity percent (I/I_o)% and chloroform concentration at solute concentration of 1.5 gm/l.

I_0, is 100%. It is clear that for all values of chloroform concentration the relative intensity $(I/I_0)\%$ in case of anthracene is larger than that in case of naphthol. At chloroform concentration of 10 gm/L., the relative intensity percent for toluene-anthracene-chloroform system is 11 %, while for toluene-naphthol-chloroform system is 5 % as shown in table (19).

Table (19)

The relation between the relative intensity, $(I/I_0)\%$, for the two systems (A and B) at solute concentration 1.5 gm/L.

Chloroform conc. in gm/L.	$(I/I_0)\%$ Anthracene + Toluene + Chloroform	$(I/I_0)\%$ Naphthol + Toluene + Chloroform
0	100	100
1	65.2 ± 1.8	57.35 ± 2.25
2	40.7 ± 1.2	35.7 ± 1.8
3	31.3 ± 0.9	22.45 ± 1.25
4	24.95 ± 0.65	15.55 ± 0.65
5	20.65 ± 0.45	12.1 ± 0.60
6	17.85 ± 0.65	8.95 ± 0.65
7	15.45 ± 0.35	7.05 ± 0.45
8	13.30 ± 0.50	6.55 ± 0.35
9	12.20 ± 0.30	5.6 ± 0.40
10	11.80 ± 0.40	4.85 ± 0.25
15	7.45 ± 0.35	3.45 ± 0.25
20	5.65 ± 0.35	2.45 ± 0.15

(IX) Comparison between the quenching effect of chloroform in Anthracene + Toluene system and Anthracene + Xylene system :

The mathematical calculation of the transfer and quencher parameters (K_3/K_1 , K_7/K_1) for the two systems, anthracene + toluene + chloroform, and anthracene + xylene + chloroform, indicates that the ratio of these parameters in the first system is equal 11-times, while this ratio for the second is 3 only. This result proove that the amount of fluorescence which quenched from the excited solvent toluene molecules is larger than that quenched from the excited xylene molecules. A result which indicates that the xylene is more active solvent than toluene. The values of these two parameters for both systems are summerised in table (20)

Table (20)

Comparison of the probabilities constants for anthracene + toluene + chloroform system, (A), and anthracene + xylene + chloroform system, (C).

Anthracene + toluene + chloroform	Anthracene + xylene + chloroform
$K_7/K_1 = 98.039 \times 10^{-2}$ L /gm. (174.74 L/mole).	$K_7/K_1 = 333.3 \times 10^{-2}$ L/gm. (594.05 L/mole).
$K_3/K_1 = 9.28 \times 10^{-2}$ L/gm. (16.54 L/mole).	$K_3/K_1 = 111.1 \times 10^{-2}$ L/gm. (198.02 L/mole).

Fig. (32) shows the relation between the quantity of energy which quenched expressed as (I_o - I) and chloroform concentration at anthracene of 1.5 gm/L. for both systems. From this figure see that the anthracene + toluene curve for all chloroform concentrations is higher than that for anthracene + xylene one; which gives the same conclusions. These results are tabulated in Table (21).

Table (21)

Comparison between anthracene + toluene + chloroform system, (A), and anthracene + xylene + chloroform system, (C), at solute concentration 1.5 gm/L.

Chloroform conc. in gm/L.	Quenched quantity (I_o - I)	
	Anthracene + toluene + chloroform	Anthracene + xylene + chloroform
1	4675 ± 31.5	1666 ± 297
2	7965 ± 13	4107 ± 325.5
3	9231 ± 43	5457 ± 300.5
4	10081 ± 69.5	6866 ± 306
5	10657 ± 87	7520 ± 336
6	11032 ± 55	8058 ± 313.5
7	11354 ± 95	8352 ± 347.5
8	11642 ± 71.5	8790 ± 350.5
9	11794 ± 100	8889 ± 282.5
10	11844 ± 84.5	9079 ± 362
15	12426 ± 82	9557 ± 353
20	12670 ± 87	9836 ± 212.5

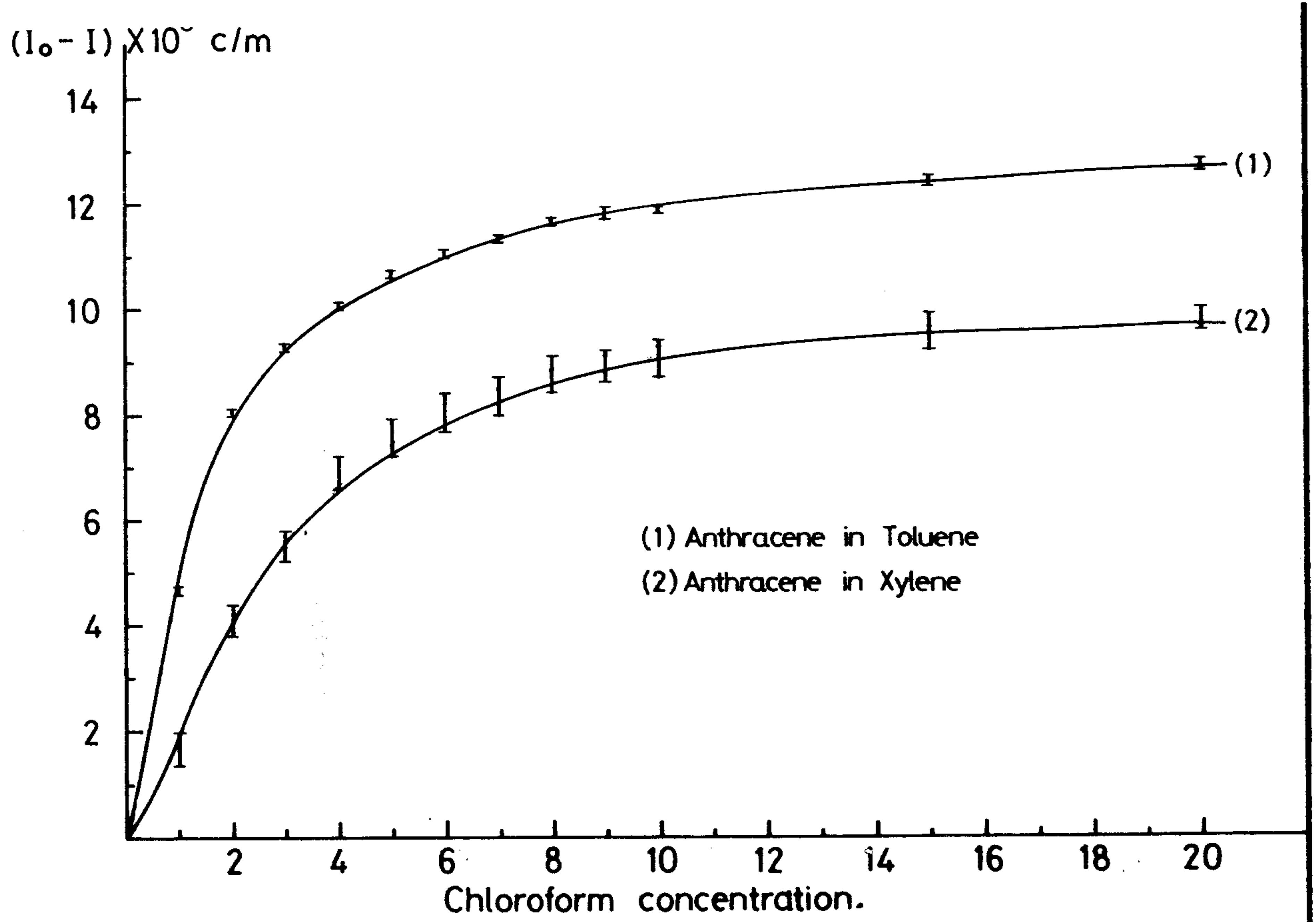

Fig.(32): The relation between the quenching quantity measured as $(I_o - I)$ and chloroform concentration at anthracene concentration 1.5 gm/l.

DISCUSSION

As it is well known, the organic liquid scintillators are made up of a solvent, primary solute, and perhaps a secondary solute, e.g. quencher substance. The purpose of their ingradients is as follows: the solvent acts as the principle stopping medium; energy deposited in the solvent is transferred both to the primary and secondary solute which may quenche or enhance the part of energy transferred to it. At small solute concentration, the transport of the excitation energy to the fluorescent material is most effective and little self quenching between their molecules occurs, Figs. (7, 15, 23). In the middle part of the curves self quenching competes with increasing transport of energy. In the decreasing part of the curves, both quenching and saturations in the transport of energy to their molecules are effective.

In case of adding quencher molecules as a second solute to a system containing already solvent and first solute, energy is transferred to it, and this transfer becomes more probable with increasing quencher concentration. In the quencher molecules, the energy is either quenched or transferred to the solute.

Our results are interpreted as the occurence of both quenching by and energy transfer from chloroform. Toluene, or xylene (stopping medium) transfer energy to both chloroform and the solute (anthracene, naphthol). The energy is quenched more rapidly in chloroform than in solvent, but still has a finite life time in chloroform (reciprocal of the rate constant ratios). Thus a small fraction of chloroform molecules transfer their energy to the solute before it is quenched.

As the chloroform concentration is increased, more and more of the energy of the excited solvent molecule is transferred to chloroform until the amount transferred to the solute (anthracene, naphthol) via chloroform becomes significant compared to that transferred directly from solvent, Figs. (10, 17, 25, 30).

As a result, we can say that chloroform quenching action depends on energy transfer to it from the solvent. On the other hand, the addition of the quencher molecules; leads to an increase of the self quenching of the system, so the optimum intensity must be shift to larger solute concentration, as the quencher concentration increase, Figs. (7, 15, 23).

The mathematical calculations of the probabilities of energy transfer (rate constant ratios), from solvent to solute (K_3/K_1), and from solvent to quencher (K_7/K_1)

indicates that K_7/K_1 is larger than K_3/K_1 in the three systems. This means that the amount of energy transferred from the original solvent, (toluene, or xylene), to solute is smaller than that transferred to the quencher at the same conditions.

By comparing the transfer parameter, K_3/K_1, for the first two systems (Sec. VIII) we find that this parameter is higher for toluene-naphthol system than for toluene-anthracene system, which means that the amount of energy transferred from the toluene molecules to naphthol is higher than that transferred to anthracene ones at the same chloroform concentration. Also by comparing the transfer and quenching parameters K_3/K_1 and K_7/K_1 respectively, for toluene + anthracene + chloroform and xylene + anthracene + chloroform systems, where the solvent is differ in the two systems, we observe that the two parameters for the latter system are higher than those for the first system which is interpretted as the more activity of xylene than for toluene.

ENHANCEMENT OF LIGHT EMISSION BY THE ADDITION OF SECOND SOLVENTS.

Introduction:

It has been found that the addition of some substances (as a second solvent) to fluorescent materials which produce only a small light emission of their own, result in increasing or decreasing the fluorescence yield(46). This depends on the emission and absorption of the solute.

In this part we added high fluorescence substance (POPOP)* to the system (naphthol, anthracene) in the presence of a quencher.

(I) Effect of adding POPOP to solutions of toluene and naphthol adding to n-butylphosphate:

Fig. (33) shows the relation between the gamma ray induced fluorescence of solutions in n-butylphosphate containing different concentrations of POPOP as a function of additional toluene and naphthol. It is seen for all the solute concentration, the naphthol curve is above the toluene curve by a factor of (1.29). This is explained as being due to a faster energy transfer from the n-butylphosphate to naphtol than to toluene when equal masses of

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* POPOP is p-Bis [2-(5-Phenyloxazolyl)] - Benzene.

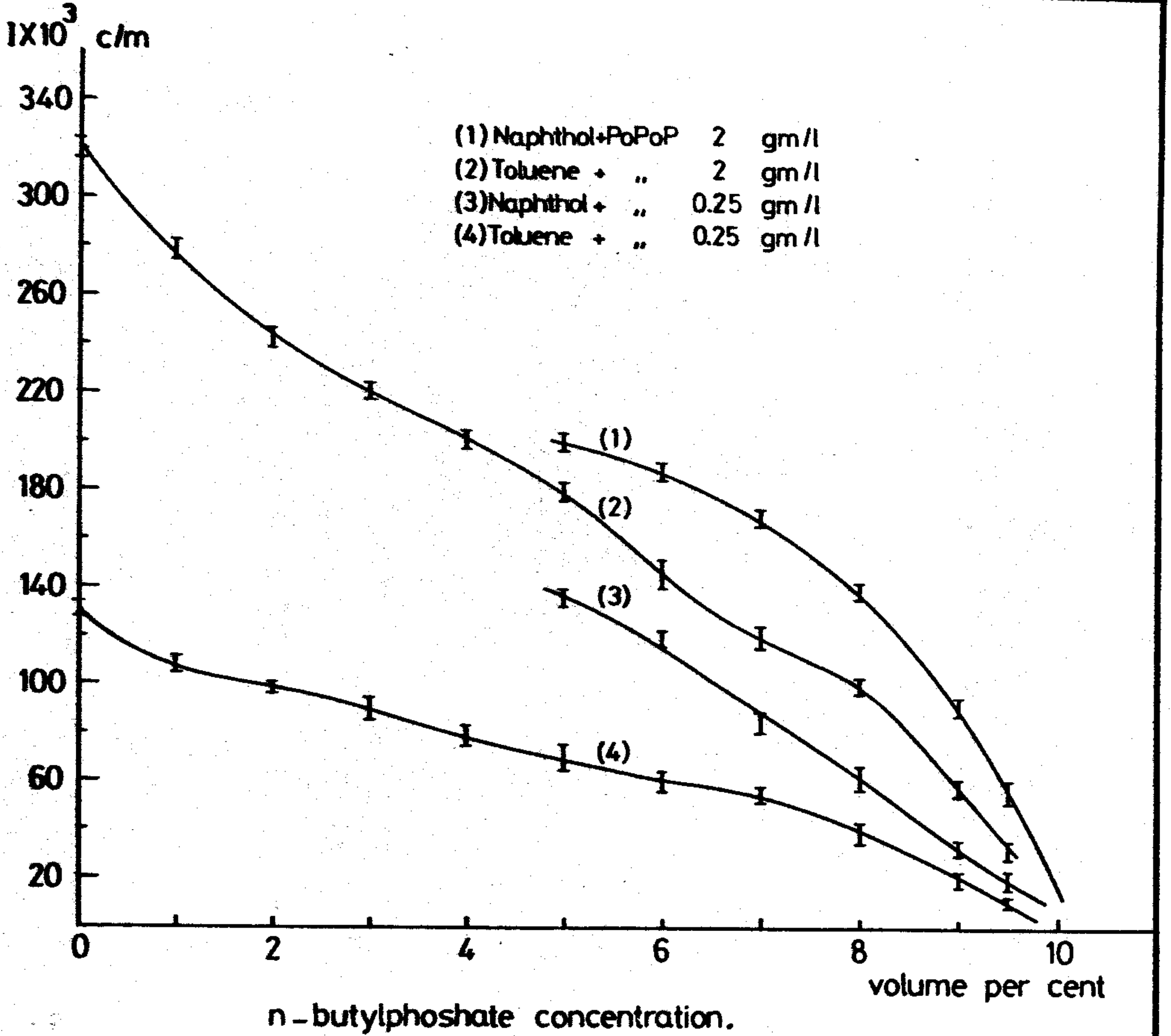

Fig.(33): Relation between light emission and n-butylphosphate concentration.

naphthol and toluene are added, since there is no difference in energy transfer from naphthol or toluene respectively to the solute as shown from the figure. As a result of high fluorescence yield in case of n-butylphosphate-naphthol-POPOP system relative to n-butylphosphate-toluene-POPOP system, it can be concluded that the life time of the excited naphthol molecule is larger than the life time of the excited toluene molecule. In n-butylphosphate, however, with the same amount of naphthol only a small fluorescence change occurs because of the poorer transfer of energy to the naphthol due to the shorter life time of the excited butylphosphate molecule. Only when larger amounts of naphthol are present can this effect of shorter life time be overcome. As a general, the energy transfer process from n-butylphosphate to naphthol does not involve much loss of energy.

This behaviour may, however, be understood by considering the action of naphthol and toluene as intermediate solvents in n-butylphosphate. In unquenched systems, the energy is transferred to naphthol and transport by naphthol-naphthol migration which occurs efficiently at 1.5 gm/L. naphthol. This result in more rapid energy transfer to the solute (POPOP) because of the longer life time of naphthol, the greater efficiency of transfer from naphthol to solute and the more efficient energy migration in naphthol. In quenched systems the process is the same, except that larger naphthol concentrations are required to extract the energy. The absence of an energy state in the quencher which can readily accept the solvent excitation energy results in a smaller cross section for quenching than for energy transfer(47).

Fig. (34) represents the fluorescence light output as a function of POPOP concentration for various amounts of naphthol and toluene in n-butylphosphate. For the maximum naphthol concentration (350 gm/L.) the intensity is allready 72% of that of 100% toluene solution, while for toluene in n-butylphosphate, this percent is 60%. Since 28% of the primary energy is directly absorbed in the naphthol.

From Fig. (34), it is clear that the addition of naphthol or toluene does not change the behaviour of light output and thus the internal quenching of such a solute, and since the curves of fluorescence vs. concentration for naphthol and toluene respectively in n-butylphosphate have the same forms. These cuves display shifts of the optimum concentration towards higher concentrations when compared to the curve of POPOP in toluene only. This means that the life time for excited naphthol and toluene molecules becomes shorter, due to a stronger quenching, when surrounding by n-butylphosphate than without this substance being present.

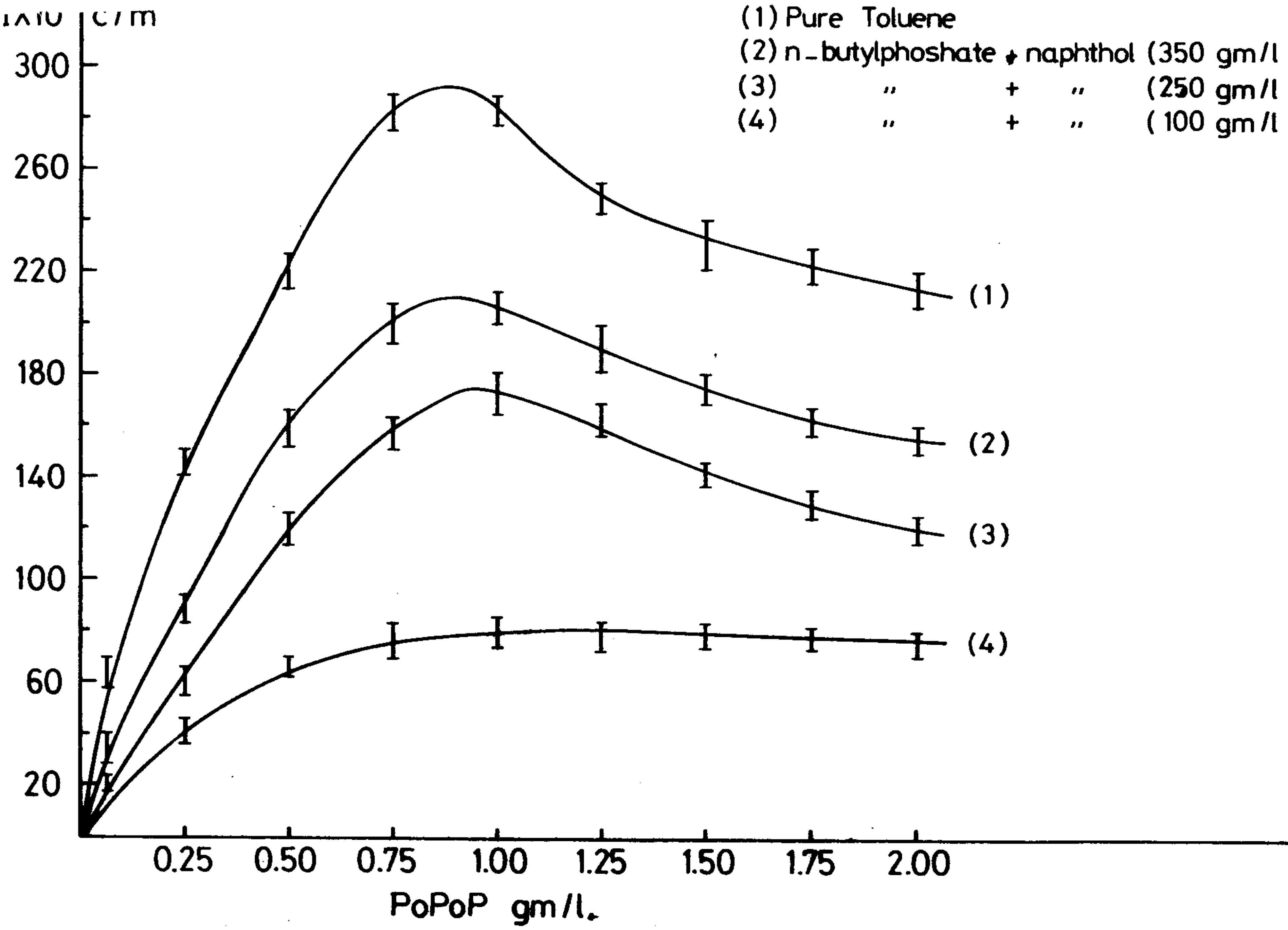

Fig.(34): Relation between light emission and PoPoP concentration in gm/l.

Such an increase of quenching reduces the true life times of the excited molecules thereby decreasing the energy transfer probability to the solute. The result of shortening of life time is a shift in the maximum of fluorescence vs. concentration curve.

Such stronger quenching by the addition of n-butylphosphate to toluene can be also seen from the toluene curve of Fig. (33).: There;the drop in fluorescence yield occuring when small amounts of the n-butylphosphate are added to toluene is probably.

(II) Effect of adding chloroform as a quencher to toluene + anthracene + POPOP system:

Fig. (35) represents the light output emission as a function of chloroform concentration in an solution of 1.5 gm/L. anthracene in toluene for different concentrations POPOP. The behaviour of the relation is the same for all curves : increasing chloroform concentration results in an decrease of the light output emission rather sharply followed by an decrease of slow rate. This behaviour can be interpreted on the hypothesis that : as the chloroform molecules increase, more and more of energy of the excited toluene molecules is transferred to the chloroform(quencher) molecules, results in an increase of the amount of energy that is quenched, until the amount of excited energy that reaching the fluorescence solute (POPOP) molecules via chloroform becomes significant compared to that transferred via toluene molecules directly to the solute. Thus the curves reach a minimum of enhancement which corresponds to the fraction of the energy quenched by chloroform molecules compared to that transferred to the solute molecules.

The excitation energy in naphthol is about at the same level as that of chloroform, so that it can be assumed that the energy transfer to chloroform is quite small. This is similar to the earlier finding that naphthol as intermediate solvent does not enhance energy transfer to the quencher.

Thus chloroform is less effective as a quencher in toluene-naphthol-POPOP solutions; since its quenching action depends on energy transfer to it due to this quenching.

It is consider also that some energy transfer still takes place directly from n-butylphosphate (bulk solvent) to the POPOP (solute); this increases with increasing solute concentration. Its contribution, however, is still too small in the case of 350 gm/L. of naphthol or toluene to account for the observed shift in the curve; with only 100 gm/L. of naphthol present this process does become important and partially accounts for the different shape of the corresponding curve. The forms of 350 gm/L. naphthol curve and that of the respective toluene, one, however, are so similar to each other that no difference in life time between the excited toluene and excited naphthol molecules, i.e., in energy transfer from these molecules to the solute (POPOP) is indicated under these conditions where the n-butylphosphate quenching is relatively small from the solvent. If the above interpretation is correct, naphthol should enhance energy transfer to a solute when the bulk solvent has still shorter life time than naphthol form.

From Fig. (35), we observe also that increasing POPOP concentration results in an enhancement of light emission. The fluorescence yield for both systems with and without

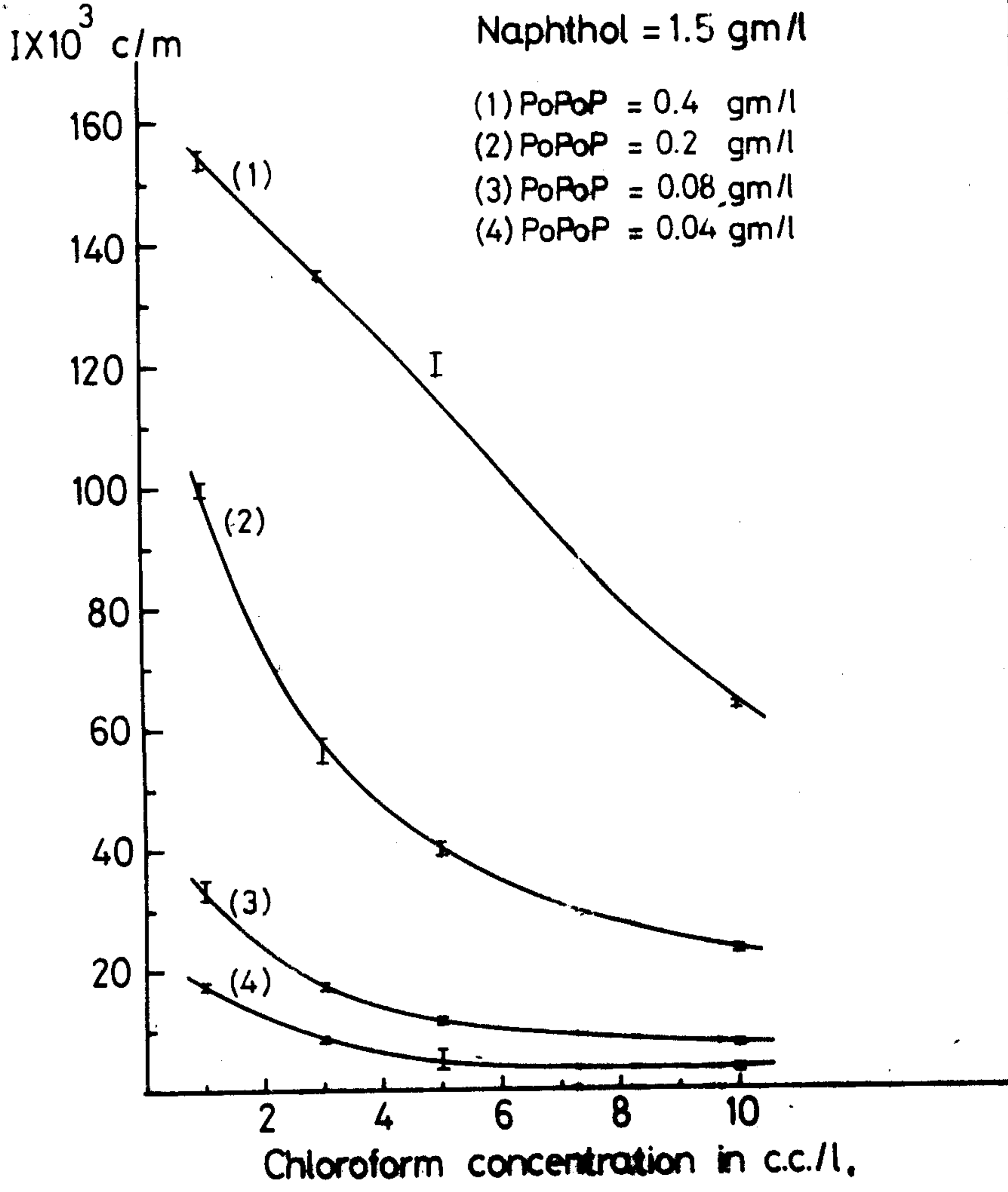

Fig.(35): Relation between light emission and chloroform concentration in c.c./l.

POPOP, we found that adding 0.4 gm/L. POPOP to the system and at 5 c.c./L. chloroform, the light output emission increased by a factor of 48-times.

The following table (22) gives the relation between the increasing factor of light output emission and POPOP concentration at 5 c.c./L. chloroform.

Table (22)

The relation between the enhancement factor and POPOP concentration at 5 c.c./L. chloroform.

POPOP conc. in gm/L.	Increasing factor $(I - I_0)$
0	2461 ± 85
0.04	7822 ± 3.4
0.08	8741 ± 427.4
0.20	37873 ± 648.6
0.40	130300 ± 825

From the above result, we can conclude that adding POPOP which is a good scintillator substance overcome the quenching effect of chloroform.

Fig. (36) describes similar experiments, this time with using anthracene instead of naphthol. The enhancement effect of POPOP to light output emission in case of toluene-anthracene-chloroform solution and at 5 c.c./L.

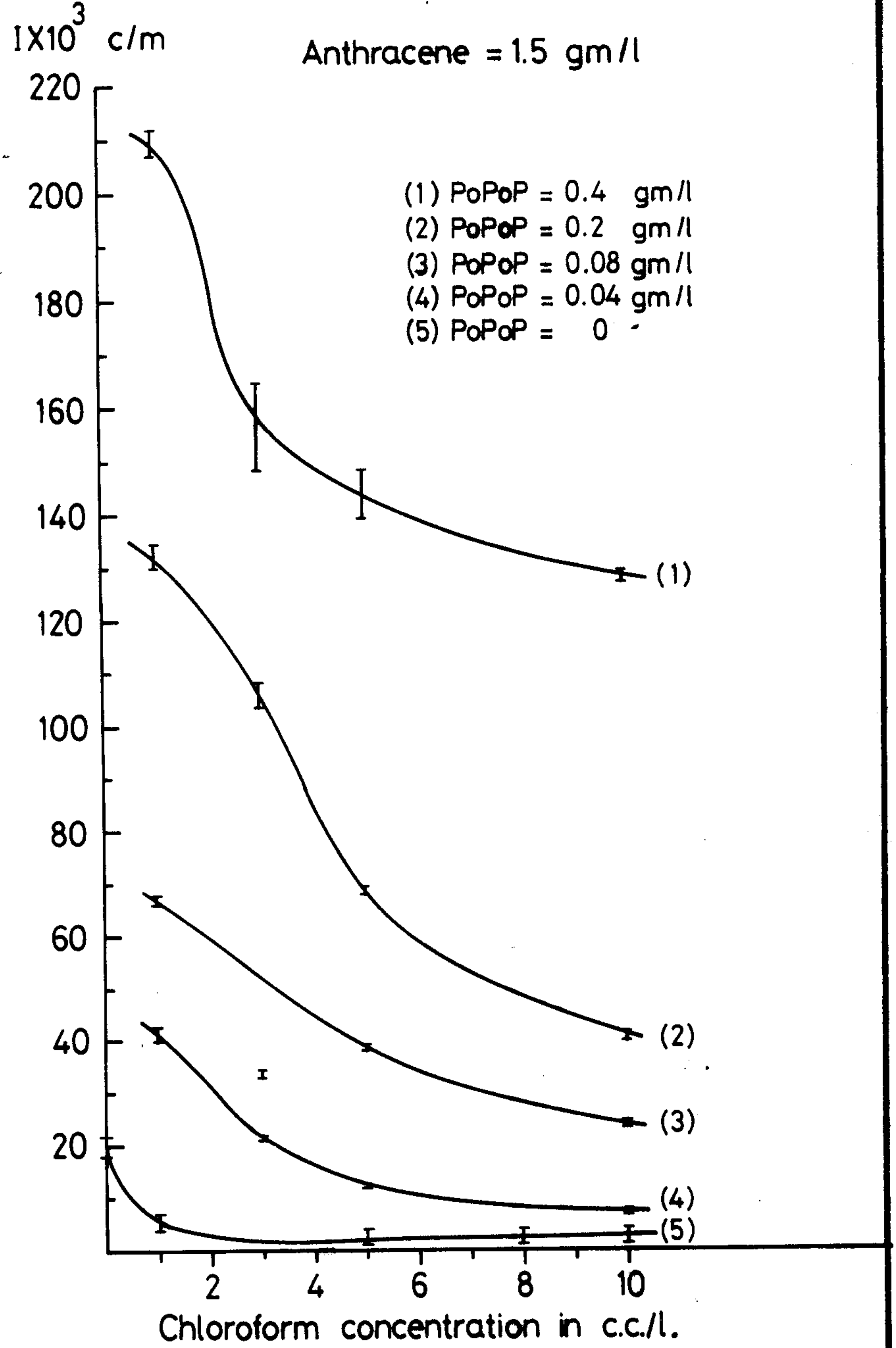

Fig.(36): Relation between light emission and chloroform concentration in c.c./l,