Problem: chapter 2-3

As stated in the book **[1]** oscillator strength or decay rates for real atomic transitions in real environments are very complex and hard to evaluate. In practice, these rates are measured or simply estimated. Unfortunately numbers given in literature are not in agreement.

Using fluorescence spectra Pokhrel *et al.* estimated radiative decay times for different transitions **[2]**. Their results are provided in the Appendix. Compare their results to Singh *et al.* **[3]** results provided in the book. We will refer to their results as "laser crystal".

1. Experimentally Pokhrel *et al.* **[2]** obtained fluorescence decay time to be 70 µs for nanocrystals for $^4F_{3/2} \rightarrow {}^4I_{11/2},$ transmission. Calculate internal quantum efficiency (experimental decay time is the sum of radiative and non-radiative processes). Compare quantum efficiencies between nano-crystal and laser crystal (page 124).
2. Which transition **X** from **fig. 1** corresponds to emission around 1064 nm? Write answer as R_x -> Y_x.
3. Let's assume, that nano-crystals have same branching ratio for **X** transition as for laser crystal measured by Singth **[3]**, which is 0.135. Calculate purely radiative decay rate and lifetime for nano-crystal's **X** transition. (Use correct Boltzman population ratio for nano crystal!).
4. Calculate upward and downward oscillator strengths for nano-crystal and laser crystal using purely radiative decay rates or lifetimes.

   Bonus- check whatever your **X** transition is the same as in the book.

All required equations can be found in the book **[1]** in 84 and 123-124 pages.

[1] A. E. Siegman, "*Lasers*", 1986.

[2] M. *Pokhrel et al.*, "Comparative studies of the spectroscopic properties of Nd^{3+}: YAG nanocrystals, transparent ceramic and single crystal", OPTICAL MATERIALS EXPRESS 235, Vol. 2, No. 3 , (2012)

[3] S. Singth et al., "Stimulated-emission cross section and fluorescent quantum efficiency of Nd^{3+} in yttrium aluminum garnet at room temperature", Phys. Rev. B 10, 2566-2572, 1974.

Appendix:

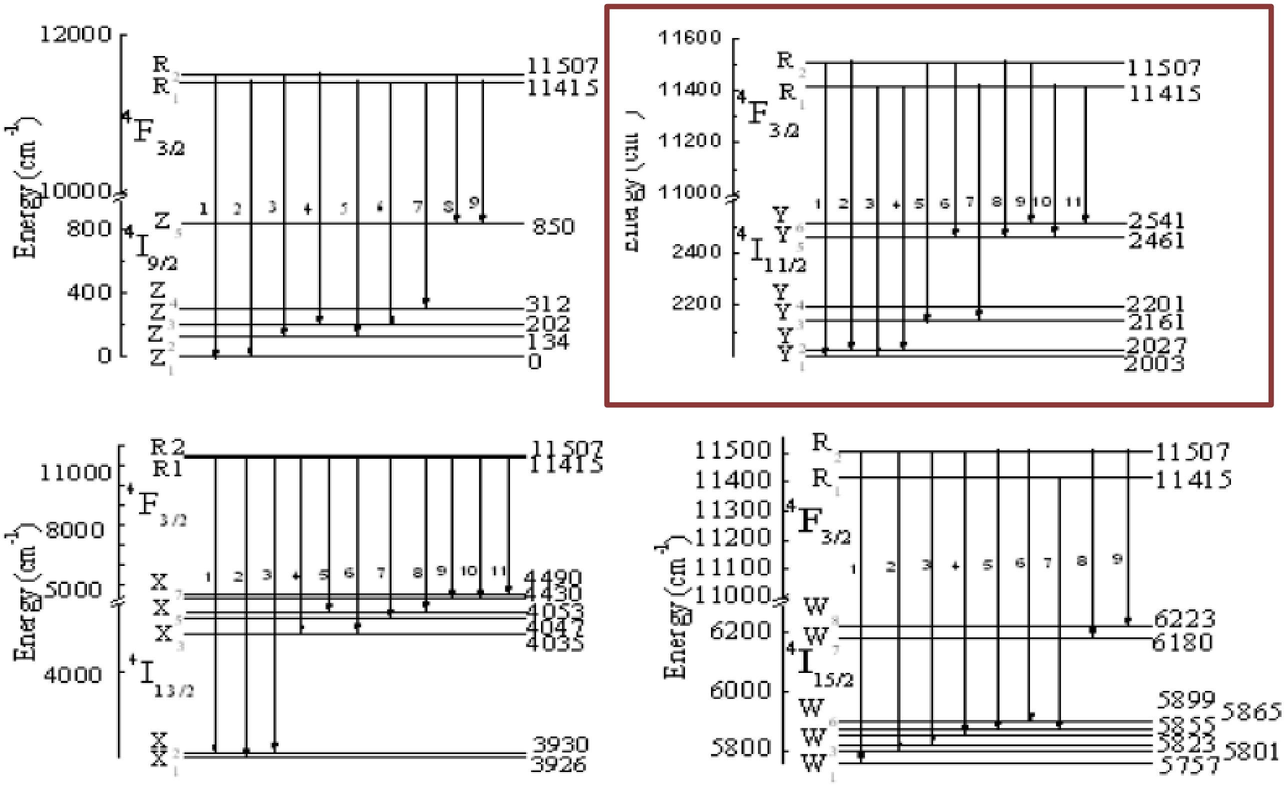

Fig. 1 Energy level diagrams of Nd^{3+}: YAG, $^4F_{3/2} \rightarrow {}^4I_{11/2,}$ transition highlighted in red.

Table 1 Radiative properties of $^4F_{3/2} \rightarrow {}^4I_{11/2,}$

Transition $^4F_{3/2}\rightarrow{}^4I_{11/2}$	l (nm)	1052	1055	1062	1064	1068	1075	1079	1106	1112	1116	1123
Nano Crystal β(0.536) τ_{rad} (0.275 ms)	Δn (cm^{-1})	9.85	16.7	9.2	10.2	20.2	10.3	15.4	24.4	16.5	20.9	16.8
	A_{ij}(S^{-1})	211	24	518	895	277	348	259	193	232	149	149
	σ_e(10^{-20} cm^2)	10.1	0.66	27.3	42.7	6.6	16.7	8.35	4.15	7.46	3.78	4.78
Single Crystal β(0.500) τ_{rad} (0.250 ms)	Δn (cm^{-1})	7.7	20.3	9.1	10.6	16.6	10.6	15.2	20.6	16.6	20.7	16.7
	A_{ij}(S^{-1})	135	18	538	949	256	364	261	195	234	151	151
	σ_e(10^{-20} cm^2)	7.35	0.45	25.2	38.5	6.68	15.1	7.6	4.39	6.63	3.46	4.33
Ceramic β(0.528) τ_{rad} (0.274 ms)	Δn (cm^{-1})	5.88	18.9	11.34	11.9	11.6	4.5	8.7	15.4	13.6	13.88	10.9
	A_{ij}(S^{-1})	246	11	478	993	202	342	242	207	208	157	157
	σ_e(10^{-20} cm^2)	17.5	0.42	18.9	37.6	7.5	33.2	12.2	6.25	7.21	5.36	6.93