Problem 3-08 Quantum yield of a photochemical reaction

Quantum yield of the ethylene formation from dipropyl ketone due to the light of wavelength of 313.5 nm was found to be $\phi = 0.21$. What is number of molecules and what is number of moles of ethylene per second will arise during irradiation by a lamp which has a power of 50 W in the spectral region of interest? Assume that the sample absorbs all incident light.

[$N_{ethylene} = 1.656 \cdot 10^{19}$ molecules s^{-1} , $n_{ethylene} = 2.75 \cdot 10^{-5}$ mol s^{-1}]

Solution:

$\phi = 0.21$ $\qquad$ $C_3H_7COC_3H_7 \xrightarrow{h\nu} CH_2{=}CH_2 + CH_3COC_3H_7$

$\lambda = 313.5$ nm $= 3.135 \cdot 10^{-7}$ m

$P = 50$ W $= 50$ J s^{-1}
$\tau = 1$ s
$\Big\}$ $E = 50$ J

$c = 3 \cdot 10^8$ m s^{-1}

$\varepsilon = \boldsymbol{h} \cdot \nu = \boldsymbol{h} \cdot \dfrac{c}{\lambda}$

Number of light quantums: $N_\varepsilon = \dfrac{E}{\varepsilon} = \dfrac{50}{6.625 \cdot 10^{-34} \cdot \dfrac{3 \cdot 10^8}{3.13 \cdot 10^{-7}}} = 7.8868 \cdot 10^{19}$

$\phi = \dfrac{N_{ethylene}}{N_\varepsilon}$

Number of formed ethylene molecules = number of decomposed dipropylketone molecules

$N_{ethylene} = N_\varepsilon \cdot \phi = 7.8868 \cdot 10^{19} \cdot 0.21 = 1.65623$ ethylene molecules

$n_{ethylene} = \dfrac{1.65623}{6.022 \cdot 10^{23}} = 2.75 \cdot 10^{-5}$ ethylene moles