Example question: Interphase mass transfer

1. Derive the overall mass transfer coefficient with gas phase as a reference, K_G, for air-water interface as a function of k_L, k_G, and H_{cc}. Recall that the overall mass transfer coefficient with liquid phase as a reference is given as

$$K_L = \frac{k_L k_G H_{cc}}{k_L + k_G H_{cc}}$$ (lecture note slide 20)

Derive the relationship between K_L and K_G.
(30 points)

2. You set up an experiment to determine the overall mass transfer coefficient, K_{tot}, for gas-liquid transfer of oxygen and ethanol in a well-mixed reactor. You also need to estimate the K_{tot} for nitrogen, which was not determined by the experiment. The results of the experiment, the unitless Henry's law constants, and the diffusion coefficients in water are as follows:

Compounds	K_{tot} (m/s)	H_{cc}	D_w (m^2/s)
Nitrogen, N_2	-	65	1.9×10^{-9}
Oxygen, O_2	2.0×10^{-5}	30	2.1×10^{-9}
Ethanol, C_2H_5OH	4.1×10^{-7}	2.7×10^{-4}	1.2×10^{-9}

i) Determine whether gas or liquid phase will control the mass transfer for each compound assuming a k_G/k_L of 100. Show your reasoning.
(20 points)

ii) Assuming that film theory is applicable, predict the K_{tot} for nitrogen from the K_{tot} data for oxygen. (20 points)

3. You sampled 200 cm^3 of water with a dissolved oxygen (DO) concentration of 5.0 mg/L in a beaker with a diameter of 5 cm. How long will it take for the DO to reach 6.5 mg/L? Use the overall mass transfer coefficient, K_L, of 0.01 m/h for still water in indoor environment suggested in the literature. Use the saturation DO concentration of 9.2 mg/L at 20℃. (30 points)