VISUALIZATION OF A PURE DIFFUSIVE PHENOMENON AT A PLANAR GAS/LIQUID INTERFACE BY PLANAR LASER INDUCED FLUORESCENCE

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ABSTRACT: When studying mass transfer in gas/liquid system, diffusion is a phenomenon as crucial as awkward to characterize accurately. Existing correlations have limited applications and diffusion-based experiments are constrained by the slowness and the high sensitivity of a pure diffusive phenomenon. The purpose of this paper is to consider two laser techniques, Particle Image Velocimetry (PIV) and Planar Laser Induced Fluorescence (PLIF) to face these difficulties and to visualize and quantify the gas behavior when diffusing in liquids.

The study considers the diffusion of oxygen through a flat air/water interface. A transparent Hele-Shaw cell ($5\times5\times0.2$ cm^3) is filled with the liquid and has two openings to let run an air flow above the liquid (Fig.1 (a)). PIV is first considered to determine the liquid behavior when constrained by the air flow. PIV experiments are realized by filling the liquid phase with reflecting particles (silver-coated hollow glass spheres with a 20 µm diameter, Dantec Dynamics) that will reflect the light generated by a laser (Dantec Dynamics, Nd: Yag laser, λ = 532 nm, 15 Hz, 30 × 2 mJ). The reflection is then captured by a Charge Coupled Device camera (Imager Intense, LaVision, 12 bits) and analyzed by the software Flow Manager that determines the velocity field in the liquid phase. It has been shown that only airflows smaller than 0.01L/s do not disrupt the diffusive process at the interface (Fig.1 (b) left).

To visualize the diffusion of oxygen in the liquid at the interface, PLIF is then used. A specific dye, the ruthenium complex $C_{72}H_{48}N_8O_6Ru$ (Nanomeps), is added to the liquid with 20% w/w of ethanol to dissolve it in water. This dye is fluorescent when excited by the laser (Nd: Yag laser, Quantel, λ = 532 nm, 10 Hz, 200 × 2 mJ). In presence of oxygen, this fluorescence is inhibited, oxygen can thus be "tracked" when diffusing at the air-liquid interface. The fluorescence level is recorded, at the gas/liquid interface, by the CCD camera surmounted by a 105 mm objective (Micro-Nikkor 105 mm f/8, Nikon) and a 570 nm high-pass filter to block the laser light. The recorded images have a window of about 9×12 mm². The solution is first fully deoxygenated by nitrogen and once the airflow is running in the cell, five images are recorded at 8 Hz every minute during about 30 minutes to visualize the diffusive process (Fig.1.b right). If the airflow is not well controlled, Rayleigh Taylor instabilities appeared (Fig.1(c)).

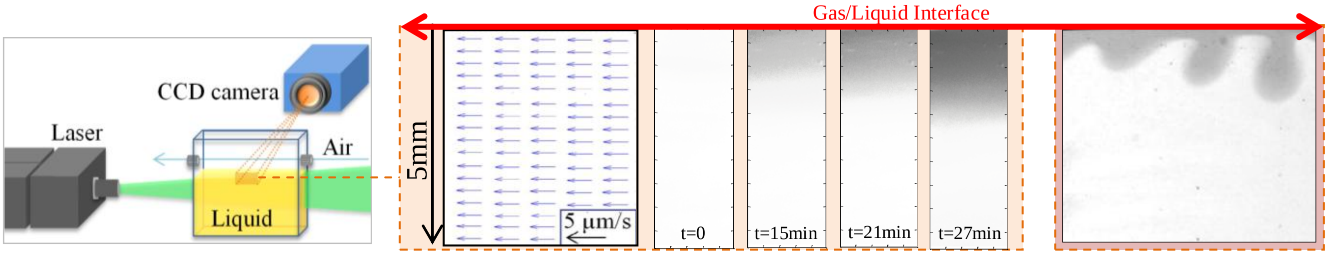

Fig.1 (a) Experimental set-up

Fig.1 (b) Velocity (left) and concentration fields (right) near the interface when O_2 diffuses (the darker the area, the more O_2)

Fig.1 (c) Instabilities

Based on these images, a simplified mathematical analysis has been developed to determine the diffusion coefficient of oxygen. This technique was tested in different liquids and measurements were in agreement with literature and presented high accuracy (error < 5%), which is especially challenging for diffusion measurement.