

EFFECT OF ELECTROLYTES ON BUBBLE COALESCENCE IN COLUMNS OBSERVED THROUGH VISUALIZATION TECHNIQUES

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Bubble coalescence has attracted considerable attention in the last decades in reactor design and operation, aerated beds in bubble column and stirred tank reactors, mainly because gas-liquid contact area is one of the key parameters in mass transfer. When bubbles coalesce the contact area diminishes and mass transfer decreases. Bubble size distribution is a result of bubble formation, bubble coalescence and breakup. For these reasons it is important to predict bubble coalescence in order to prevent low yields in reactors and, not least important, to increase enhanced crude oil recovery.

INTRODUCTION

Some studies have been made in the last years in an attempt to explain the bubbles behavior in electrolyte solutions. Prince and Blanch¹ proposed a phenomenological model for the rates of bubble coalescence and bubble breakup in turbulent gas-liquid dispersions. They developed a measurement technique to test the validity of the model. Craig *et al.*² performed experiments using N₂, He, Ar, SF₆ as gas phase, and NaNO₃, KBr, CaCl₂, MgSO₄, NaCl as electrolyte solutions. They found that temperature, viscosity and surface tension have no influence on bubble coalescence. Craig *et al.*² concluded that some electrolytes and some mineral acids have no effect at all on bubble coalescence. Accordingly, they assigned a property (α or β) to each anion or cation; the combination $\alpha\alpha$ or $\beta\beta$ inhibits coalescence (*e.g.* NaCl is $\alpha\alpha$), and the combination $\beta\alpha$ or $\alpha\beta$ has no effect (*e.g.* HCl is $\beta\alpha$). No exceptions have yet appeared. Craig *et al.*² pointed out that these observations could be explained only by the local influence of the ions on the water structure, possibly in a way related to a hydrophobic interaction. The data obtained by Craig *et al.*² shows that electrolytes affect the hydrophobic interaction (*e.g.* KBr).

Liendo³ designed a coalescence cell based on the work of Zahradník *et al.*⁴. The set up consisted of a cell of *plexiglas* with two glass capillaries in opposite positions. Liendo³ used air as the gas phase and NaCl, NaNO₃, HCl, HNO₃, CH₃COOH, CuSO₄, MgSO₄, NH₄OH in electrolyte solutions. Liendo³ obtained results in agreement with Craig *et al.*².

A new set up was designed here based on the work of Liendo³. The gas circuit was improved and a digital high-speed camera was used to visualize the bubble coalescence experiments.

EXPERIMENTAL SETUP

The bubble coalescence visualizations were carried out in three vertical glass columns with two glass capillaries (I.D.: 2mm) in opposite positions⁵. The distance between the capillaries was 5mm. The coalescence was observed in a stagnant liquid. Distilled water and electrolyte solutions of different concentrations were used. The electrolyte solutions were prepared with distilled water and NaCl of analytical grade in concentrations of 0,05 M to 0,125 M. The gas phase was air at a constant feed rate. All experiments were carried out at room temperature and atmospheric pressure. Pairs of bubbles were formed simultaneously in the capillaries. The

frequency of bubble formation was 28 pairs per minute. Bubble interactions were monitored with the following visualization set up: A digital high-speed video camera (4500 frames per second), a VCR, a monitor, a fiber optic lamp and a computer. The selection of the electrolyte solutions was made according to the earlier reported studies^{2,3}.

RESULTS AND DISCUSSION

Bubble coalescence was 0% in 0,125 M solution, and 50% in 0,08 M solution. In distilled water the bubble coalescence was 100%. Figure 1 shows the bubble coalescence in distilled water and Figure 2 shows the bubble interactions in a 0,125 M solution of NaCl.

In Figure 1(a) the bubbles are formed simultaneously. It is observed that there exist sufficiently strong attractive forces between the bubbles in water to coalesce. In these experiments, the attractive van der Waals forces overcome the repulsive forces and the total free energy diminishes, thus reducing the contact gas-liquid area (Figs. 1b and 1c). Finally, in Figure 1(d) a new elliptical bubble arises, the volume of this bubble is the sum of the two original bubble volumes³.

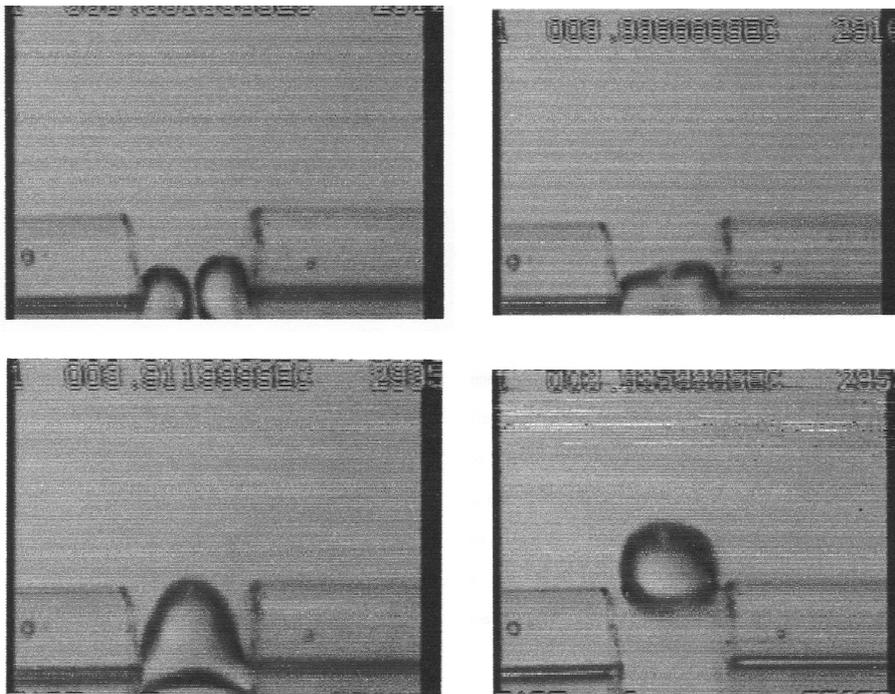


Figure 1. Bubble interactions in distilled water. (a) Formation of bubbles, (b) Coalescence of bubbles, (c) Formation of a new bubble, (d) A new elliptical bubble arises.

In Fig 2a bubbles are formed. NaCl acts to prevent coalescence, because the bubbles approach and seem to coalesce (Fig. 2b). However, a substantial hydrodynamic repulsion force acts and the bubbles are unable to coalesce. Therefore, the bubbles separate completely (Fig. 2c) and two spherical bubbles arise (Fig. 2d). In these experiments coalescence was not observed, however, some bubbles coalesced at concentrations of NaCl under 0,08 M, but the percentage of coalescence decreased as NaCl concentration increased. This behavior was also observed by Craig *et al.*, who defined NaCl as an $\alpha\alpha$ combination².

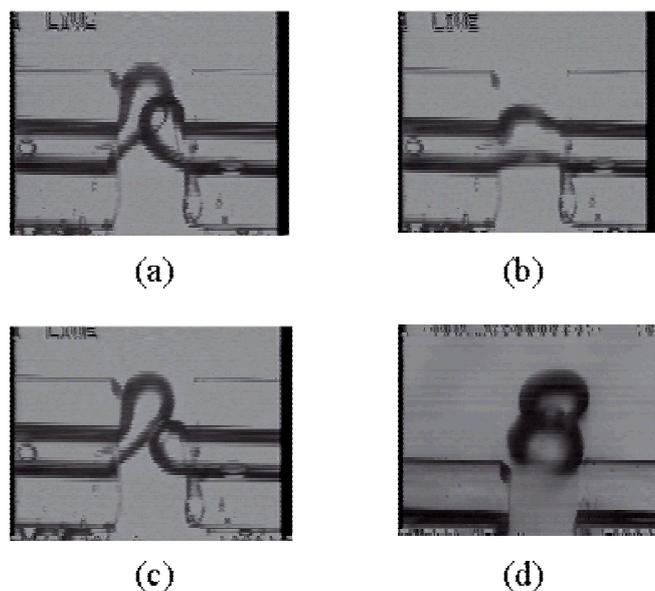


Figure 2. Bubble interactions in a 0,125 M solution. (a) Formation of bubbles, (b) Superposition of bubbles, (c) Separation of bubbles, (d) Two spherical bubbles arise.

CONCLUSIONS

Previous studies have shown that concentrations of NaCl over 0,12 M inhibit the bubble coalescence. The contribution of this work is in the visualization of the coalescence phenomenon, since attraction and union of bubbles could be clearly observed. Therefore, the bubbles volumes and contact gas-liquid area can be measured in future studies.

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