Chemical reactions can be self-stirring (w/ Video)

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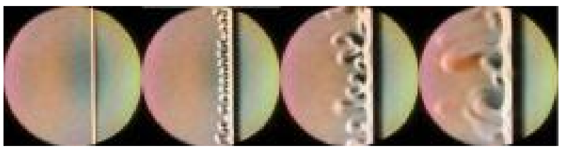

Salt plumes. The formation of salt from the reaction of hydrochloric acid and sodium hydroxide induces convection plumes to sprout up from the boundary between the two reactants. Image: C. Almarcha, Université Libre de Bruxelles

(PhysOrg.com) -- Every chemistry student knows that if you stir a mixture of chemicals you speed up the reactions between them, but less well-known is that chemical reactions can themselves stir up the mixture. This was demonstrated in experiments reported in *Physical Review Letters* on January 29, which showed that common chemical reactions can create fluid motion.

The researchers, from Université Libre de Bruxelles (ULB) in Belgium, developed a hydrodynamic model for a simple acid-base reaction, ran several computer simulations of the fluid motions produced, and then verified the findings with a simple acid-base experiment.

In the computer simulations, researchers Anne de Wit and Christophe Almarcha used a dense solution containing one reactant and placed a lower density solution containing the other on top. Since the densest solution was at the bottom there should be no convection (which occurs if a denser solution is placed on top of a less dense solution and sinks to the bottom). The configuration would normally be stable, but the reaction between the two solutions created a product at the boundary, and the reaction resulted in mixing.

The simulations revealed that the chemical reaction led to the formation of convective plumes or fingers that went only upwards. Diffusion of the dissolved molecules from high concentration to low concentration was expected, and this can create density gradients and result in convection, but without the chemical reaction it would be symmetric, with plumes going up and down.

The team verified their findings by observing the simple reaction of hydrochloric acid and sodium hydroxide to produce salt and water ($HCl + NaOH \rightarrow NaCl + H_2O$). They used an experimental cell consisting of a thin chamber between two vertical glass slides and injected the denser NaOH solution into the cell from the bottom and then slowly added the less dense HCl solution from the top. They measured the variations in fluid density using a laser.

Their experiments verified the predictions of the simulations, producing convective plumes only in the top section of the cell as the salt and water began to form. The “fingers” of salty solution crept upward and began to mix the solution. No convection was seen in the lower half. De Wit said the convection is a result of HCl diffusing downwards faster than NaCl can diffuse upwards, and there is no convection in the lower half of the cell because the diffusion rates of NaOH and NaCl are similar.

The simulations showed the convection made the reactions proceed faster than expected, and this suggests reaction and mixing rates may have been underestimated in natural phenomena such as fluid motions in the Earth’s mantle and inside stars. They may also have been underestimated in proposals for carbon sequestration, since as the researchers pointed out, carbon sequestration models have not considered the effects of convection caused by the interactions between CO_2 and ground water. She said these reactions cannot be neglected.

More information: Chemically Driven Hydrodynamic Instabilities, C. Almarcha, et al., Phys. Rev. Lett. 104, 044501, 29 January 2010, DOI:10.1103/PhysRevLett.104.044501