Fast chemical reactions in gels

A gel is like a solid network in which a liquid, like water, can be hosted. Within this liquid it is possible to dissolve other substances, and they can undergo chemical reactions. These reactions can be affected by how fast the chemicals move, diffuse. We know quite well how this movement modulates reactions in simple liquids, like pure water, but not so much in media like gels. And gels are important! For example, the extracellular matrix, the medium that connects different cells in tissues like muscles, is a gel. Therefore, the information exchange of the cell is done through a gel, and this is a process that involves diffusion of chemicals. Moreover, delivering drugs must take into account this structure. A better understanding of how chemical reactions proceed in this media is very important to improve the efficiency of pharmacological treatments. Technology may also benefit from the knowledge we want to acquire in this project: as usual many new technologies try to mimic nature. Gels have been used to detect chemicals, study proteins that lose their structure in solution, store energy, produce energy from the sun and many other applications. Many of these applications involve chemical reactions and diffusion of the substances.

A good way to study these reactions is using light to start them. This is like setting a stop-clock and observing how fast it takes for a chemical product to appear or disappear. By measuring the fluorescence or the light absorption of these chemicals we can obtain very precise information of what is called kinetics of the reactions. Diffusion is affecting the kinetics, and the environment determines the diffusion. A major factor is the viscosity of the liquid, but also how much space is available for the molecular movement. Gels modify both in the liquid they host. The viscosity in confined space of water is known to be different, higher, than the viscosity of pure water. Moreover, the space available for the molecules in the gel is restricted. We roughly know what happens at long times: chemical reactions are usually slowed in gels with respect to pure liquids. However, at smaller time scales things may be quite different. In our laboratories of the Institute of Physical Chemistry of the Polish Academy of Sciences we have techniques that allow us to trigger the stop-clock of the reactions with a very high precision. We can study the reactions in time scales from less than hundred femto-seconds. A femto-second is 1 divided by 1.000.000.000.000.000 seconds, and it is the time scale at which the most fundamental chemical movement can take place. In other words, there are no chemical reactions faster than this time scale. Having such technology enables us to uncover the most refined details of the reactions. In gels it is possible to imagine that the lack of space available to move makes the reactants come closer to each other. This means that at short time scales the reactions could be even faster than in dilute solutions. Though this will not be reflected in the kinetics at longer times, it is decisive to the total yield of the reaction. Another important effect is that following reactions between the products of the first one will also be very much affected by the mentioned space constrictions: they may not be able to separate and could lead to new chemicals after further re-combining reactions.

If we are successful with this project we will be able to provide with a physico-chemical description of reactions in gels that will help to design better drug delivery methods, analytical methods and even solar cells. Smart new materials could also be imagined based on gels within which a photo-chemical reaction is properly controlled. There have been some researchers exploring the possibility to store information in these kind of matrixes, and writing and reading information from a chemical reaction is a nice possibility.