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Q&A Richard Schrock

A sustainable chemist

Jonathan Moerdyk asks one of the recipients of the 2005 chemistry prize whether olefin metathesis, the field he helped to pioneer, has peaked.

What impresses you most about olefin metathesis?

That it is still developing. It was discovered more than 55 years ago but it took 30 years to make the first well-defined catalyst. The field is growing exponentially. I like its simplicity and 'cleanliness': the only products of olefin metathesis are olefins, and you can reuse or store the olefins generated. You start and end with olefins, so it is a closed loop. Olefins are the backbone of the chemical industry and are common in nature.

Because I am not an organic chemist, I didn't realize for many years how impressive a reaction metathesis is. Now I know how important it is to turn olefins into other olefins — it avoids all the intermediate entities and therefore reduces chemical waste.

What are the remaining challenges for olefin metathesis?

Applying olefin metathesis and taking it to its extremes: high temperature, tandem catalysis, fancy molecules, polymer chemistry. Also, selective preparation of molecules — it is always good to know the precise structure of the molecules you're dealing with. For example, it is important to be able to make polymers with one uniform structure; olefin metathesis has achieved this, but only with well-defined catalysts. Distributions are fine, but think of DNA: that's a very well defined species and it does fantastic stuff that it couldn't do if its structure were random.

Why are computer models and theoretical calculations not sufficient for optimizing catalytic processes?

You have to remember that you can get complete selectivity for one product over another based on about a 2-kilocalorie (kcal) difference in energy between two reaction pathways. If you look at all the interactions going on — solvent interactions, interactions within the catalyst and substrates, all of them modulated by temperature and other factors — then 2 kcal is nothing. Even today, no theoretician could confidently predict a reaction to within this limit. And they will have to do a lot better than that — to the sub-kcal level — if they are to really understand everything that goes on in a catalytic reaction: for example, to predict whether a catalyst with one methyl group more or less, or with a slightly different bond angle, will be better than another. I wish the theoreticians luck and hope they can do it, but it's going to be tough.

Are the supplies of catalytic metals for olefin metathesis sufficient?

Abundance and sustainability are crucial for the future of olefin metathesis, as they are for other areas of chemistry. The four metals that we know catalyse metathesis are molybdenum, tungsten, rhenium and ruthenium. Molybdenum and tungsten are plentiful enough not to worry.

Molybdenum production was 250,000 tonnes in 2011 and tungsten was 72,000 tonnes; both are used heavily by industry to make tougher steel. They are not as abundant as iron, but iron catalysts are probably not on the cards in the near future. Rhenium and ruthenium are scarcer — in 2011 production was 49 tonnes and around 20 tonnes, respectively.

What are the concerns associated with using low-abundance metals?

If a new application is developed that involves a rare metal, the price of the metal soars. This happened with rhenium and ruthenium in 2006, when new aerospace and electronics applications for these metals were introduced: the price went up by almost a factor of ten. Now the prices have come back down, but no one wants to be subject to that kind of variation. Pharmaceutical companies in particular are very wary because they are tied to a catalyst. If they can't continue to make a drug with that catalyst, they have to start over; that's impractical when they've already spent ten years and $800 million to develop a compound. There's also the matter of scale. If you want to produce anything on a truly large scale, you need tonnes of catalyst. If a lot of companies want tonnes of a catalyst, there just isn't going to be enough to go around. ■

Richard Schrock is a professor of chemistry at the Massachusetts Institute of Technology in Cambridge. With Robert Grubbs (see page S56) and Yves Chauvin, he was awarded the 2005 Nobel Prize in Chemistry for the development of olefin metathesis — the process of changing carbon–carbon double bonds in olefins. This process has found many applications from the preparation of insect pheromones to the manufacture of high-performance plastics.

Jonathan Moerdyk is beginning his fifth year of graduate school at the University of Texas at Austin, where he is studying the development of carbon-based mimics and alternatives to transition metals for small-molecule activation, synthesis and catalysis.

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