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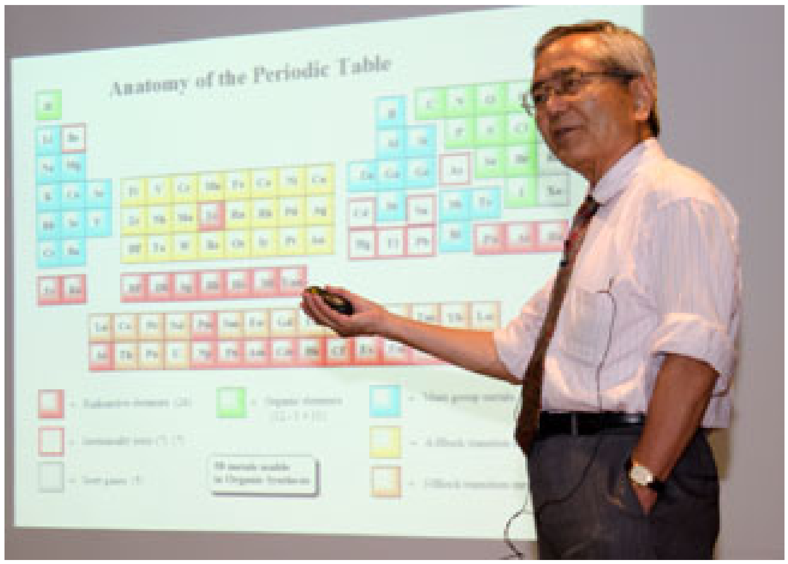
Ei-ichi Negishi, Nobel Laureate in Chemistry



“We must find an economic way to reduce CO2 emissions by using catalysts”

Ei-ichi Negishi, winner of the 2010 Nobel Prize in Chemistry, recently visited the UAB on an invitation by the Department of Chemistry as a speaker of its PhD programme. Over 40 years ago, he discovered the cross coupling reaction catalysed by palladium, a method which revolutionised the world of organic chemistry and allowed for fundamental advances in the fields of medicine and health, agriculture and electronics. In the following interview, Ei-ichi Negishi is convinced that more advances can be made in the use of metal elements as catalysts, especially in the d-block, such as gold and silver and which he calls "magical". He considers it key to apply them massively in the reduction and recycling of CO2.

Ei-ichi Negishi was born in 1935 in the city of Changchun, China, which at the time was under Japanese rule. He studied Organic Chemistry and graduated from the University of Tokyo in 1958. Two years later he moved to the US on a Fulbright scholarship and obtained his PhD from University of Pennsylvania in 1963. Three years later he began his professional career at Purdue University and became assistant professor, working with Nobel Laureate Herbert C. Brown. In 1972, he went on to become associate professor at Syracuse University. In 1979, however he went back to Purdue University, where he currently carries out his research.
He has received several awards throughout his career, including those conferred onto him from the chemists' societies of Japan, the United States and Great Britain. He is author of over 400 publications and several books, one of his most important being the *Handbook of Organopalladium Chemistry for Organic Synthesis*. He has been cited over 20,000 times.

- What are cross coupling reactions catalysed by palladium?

- They are reactions which allow linking two groups of carbon. And if we can do that voluntarily, we can assume that we can create the majority of organic compounds. And talking about organic compounds means talking about food, construction materials, sources of energy, fuel, drugs, etc. We'd like to be able to synthesise these objects at will. I believe that we developed a very good method with the palladium-catalysed cross coupling reactions. It's as if it were an assembly game, like LEGO. You have a carbon group with a hole and another with an extruding part which fits perfectly and forms a link. This, repeated several time, makes it possible to create a large variety of organic compounds. But, without the use of palladium or other transition metals as catalysts, this process wasn't possible.

One century ago, the French chemist Victor Grignard was able to create organic compounds with magnesium but without using catalysts, which made their applications very limited.

Now we can offer a wide variety of applications. Take drugs, for example. They contain very complex structured compounds whose synthesis is very difficult to change, specifically in pure form. With reactions such as the one I discovered, this part of the organic synthesis was greatly improved and now many drugs are made using this method.

- What are the main advances that have been made with these reactions?

- Synthesising is much easier now and a wider range of products and objects can be synthesised, such as those I mentioned before. Among construction materials, for example, we can find carbon fibres which make planes more efficient and sustainable. Carbon fibre is 100% carbon, but it must be manufactured by organic synthesis. The benefits are numerous and I am convinced that the 21st century will be important for these reactions, because they will contribute to higher prosperity and sustainability, making fuel and other products cheaper. They will have a great effect on our society.

- How and in which areas?

- In all areas which involve organic chemistry. Both organic and organometallic elements. The more we work with organic elements, the more we need transition metals as catalysts and the more benefits we can achieve for humanity. We can start to see some of these benefits, as in the case of graphene. This almost miraculous material can be obtained simply by peeling off a layer of graphite. But there are many nanomaterials, apart from graphene, that can be synthesised in a more artificial manner. Of course, we need a large variety of methods for the synthesis of these compounds, but I am fully convinced that in many cases we will need transition metals as catalysts. And in those cases it will be necessary to use cross coupling or other new catalyst reactions for transition metals.

- Why do you say that transition metals such as palladium are "magical"?

- Because without the d-block transition metal catalysts, the Lego pieces wouldn't work. But with a bit of palladium or another catalyst, they do work. And one tiny piece of palladium can produce, hundreds, thousands or millions of the compounds we want. And I say that's magical chemistry!

- What is the main obstacle in applying this method to other metals?

- I think we need to explore at the basic level what can be done with the 24 existing d-block transition metals. The more we explore, the more we learn about how we can use them, especially as catalysts, because they are too expensive to be used on other applications.

- Which metals are you researching into now?

- Several, the one we use by far is palladium, but also nickel and copper. Others aren't used, maybe because we think they are too expensive, such as platinum, and therefore we cannot use them in chemical transformations. But we shouldn't think like that. Every day, each one of us uses platinum, whether we are rich or poor, and I'm not talking about jewellery.

- What do you mean?

- Let me give you an example: we use cars that have a device which reduces the toxic gases we release into the air. Carbon monoxide - toxic - enters and carbon dioxide exits, which is not toxic but does contribute to global warming. There is also nitrogen monoxide (NO) and it turns into nitrogen dioxide (NO2), which is also toxic, but not as much. This system uses the tiniest particles of the most expensive metals, such as platinum or iridium or palladium, as catalysts. Each car must have this device to clean the exhaust gases. Can you imagine that? These devices are very dirty, very cheap, but they contain three or four of the most expensive metals existing. And they can work for 150,000 kilometres. That's magic!

This is one of the best stories on how expensive transition metals can and should be used in an economic manner and it should be explained in chemistry classes even in secondary school.

Half of the world's production of platinum and iridium is used for these purposes. It is surprising that so few people know this. And as far as I know, these metals are not recycled when the useful life of a car ends. We are losing a large amount of these metals which are needed also for other things, so maybe it is time to start thinking about the possibility of recycling them.

Therefore, we cannot say that platinum is expensive. Even cars owned by poor people have platinum in them.

- What is your main object of interest now?

- I think in general chemists working with organometallic transitions are mainly interested in reducing CO2 emissions, catalytically of course. We need to do it and obviously for that we need transition metals. No one has used them in pollution-reduction devices. We've worked on it, but haven't been successful.

If we could make it work it would reduce the excess of CO2. Carbon dioxide is the most oxidised form of carbon: plus 4. When you reduce it to a plus 3 you get carboxylic acid: fat, which is a source of energy. This would be fantastic if we could achieve this economically. Plus 2 gives you CO, carbon monoxide. This is toxic but it is also a very useful gas with which you can make a variety of organic compounds. Plus 1, zero... Zero is carbon, in other words, diamonds and other useful things. Minus 1 gives you methanol, a fuel but which can also be converted into products of high added value for the chemistry industry. And we could go on: minus 2, minus 3, minus 4... that gives you methane. And methane is a good gas!

If someone comes up with a cheap way to reduce CO2, I think they'll be given a Nobel Prize, or two!!

- Are you convinced that this can be achieved?

- Well, many of the best chemists in the world are trying to do it. But at the moment no one has been able to, in part due to the difficulty of finding a process that is economic enough and that can take advantage of the catalysts as much as possible. A million of uses at least!

A few days ago I was in Washington, D.C. and there were approximately 20 of the top chemists talking about how to reduce CO2 emissions. I'd say no one is close to finding the way to do it.

Universitat Autònoma de Barcelona
premsa.ciencia@uab.cat