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Ping-pong with photons: Light as a tool for a new and, above all, sustainable chemistry

When it comes to advancing knowledge, photocatalysis is at the forefront of chemistry today. Dr. Jola Pospech and her team at the Leibniz Institute for Catalysis in Rostock are developing new approaches to classic reaction pathways in this field. One such approach is hydrofunctionalization, which can produce valuable products such as bioactive amines. These amines occur naturally in neurotransmitters and are important for the development of new drugs. Dr. Pospech uses striking images in her lectures to explain photocatalysis to first-year students.



In this specific case, the right light for photoredox catalysis is provided by a black light panel, such as those used to illuminate discos.

Photocatalysis requires light, and Dr. Jola Pospech's research group often uses a mass-produced product for discos as a light source in the laboratory: black light. This curious name refers to LEDs in the ultraviolet range, UV-A light that is just visible and is used in dentistry as well as in discos.

„In our case, this light has the right wavelength to trigger chemical reactions,” explains Dr. Jola Pospech. “We direct the LED panel at the reaction vessel, where the photons strike the outer electron pairs of the substances involved, in our case the catalyst, which then enters a so-called excited state.” This means that it can now release or absorb an electron, thereby activating the chemical starting materials. Ultimately, new chemical compounds are formed when the substances involved exchange or share electrons.

Photoredox catalysis

Let's take two basic chemical reactions: oxidation and reduction. For oxidation, the catalyst donates an electron and takes it back at the end of the cycle. For reduction, it takes an electron and gives it back at the end. “You can think of the whole thing as a game of ping-pong,” says Dr. Pospech, explaining it using photoredox catalysis, which combines both reactions.

Jola Pospech: “Imagine you are holding two balls in your pocket. When the photon causes a surge of energy, one ball, or electron, moves up to the next level.” Jola Pospech's hand moves with the imaginary ball from her pocket over her head. “The pocket now has access and space for new players. This is how chemical reactions get started. Once the starting materials have been converted, the ball can be released from the hand and the cycle begins again.” The imaginary ball lands back in the pocket.

Example: Hydrofunctionalization

For centuries, chemistry worked as follows: chemists heated their reaction vessels to activate the substances inside them. “With light, I can overcome the activation barrier much faster and with much greater amounts of energy,” says Jola Pospech. Modern LED technology allows the wavelength of the light source to be precisely tuned to the absorption spectrum of the catalyst.

As an example, the chemist cites hydrofunctionalization, a popular reaction pathway that is very “atom-economical”: the substances involved are converted down to the last atom, without by-products. This produces valuable products such as bioactive amines, which occur naturally in neurotransmitters and are important for the development of new drugs.

Many of these reactions currently involve catalysts made from rare and expensive metals, with numerous intermediate steps, co-catalysts, and so-called sacrificial reagents. Jola Pospech: “These only serve to donate an additional electron so that another electron can change partners energetically at the appropriate point.”

Organic catalysts as an alternative

Her research group developed alternative organic photoredox catalysts consisting of nitrogen, hydrogen, oxygen, and carbon. “The compounds we use are inexpensive to manufacture, can be activated precisely and quickly using black light, and are mechanistically multifunctional.” Co-catalysts and sacrificial reagents thus become obsolete.

The Rostock chemists are currently working on giving this catalyst a selective function by incorporating amino acids. This should help to produce right- and left-handed molecules using light. To do this, the catalyst needs a “spatial sense,” or stereo information. According to Jola Pospesch's idea, amino acids could convey such stereo information because they have defined three-dimensional structures.

According to Dr. Pospesch, there is considerable motivation in practice to apply such results from basic research to industrial applications, at least in the long term. “Every major chemical company now has research departments dedicated to photocatalysis and electrochemistry.” LIKAT is, so to speak, on the pulse of the times.

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Dr. Jola Pospesch (photo: privat)