Researchers find the accelerator for molecular machines

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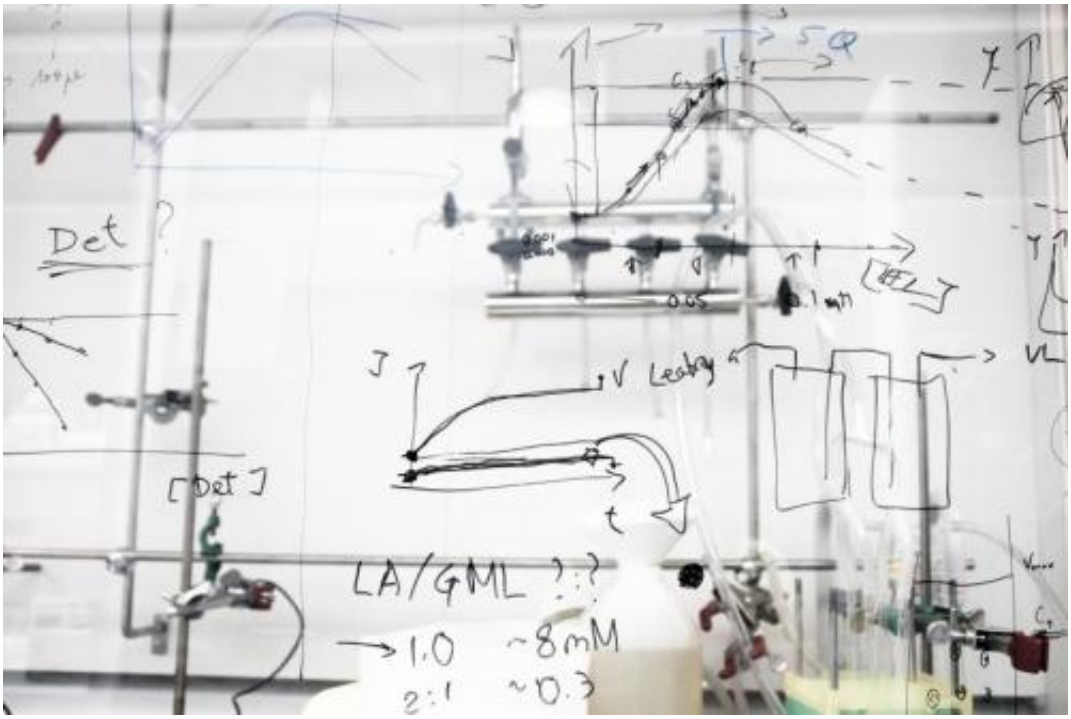

How hard can it be to make a wheel rotate in a machine? Very hard actually, when the wheel sits in one of those nano-small molecular machines that are predicted to be running our future machines. But before the molecular machines become part of our daily lives, researchers must be able to control them. A Danish/American research team have now solved part of this problem.

There are large machines and there are small machines - and then there are molecular machines. They are nano-tiny collections of molecular building blocks that together make up a machine and operate various processes at the cellular level. Biology is full of these natural molecular machines, and now science wants to create artificial ones that operate in the same way. If science succeeds, we can expect significantly smaller machines in our future everyday lives.

From biology we know the molecular machine, ATP synthase. It rotates, and in the process it converts the molecule ADP into ATP, which acts as an energy source for our cells.

"This is a classical biological molecular machine that you can use for inspiration when working with artificial molecular machines", says Sissel Stenbæk Andersen, a postdoc at the Department of Physics and Chemistry, University of Southern Denmark.

"We ultimately want to create an artificial machine that can rotate and run a process. It sounds very low-tech and simple, but it is not. It is indeed a huge challenge to keep track of how the machine rotates and how quickly it does so - and if we want to benefit from molecular machines in the future, we must be able to control the rotation and the speed", says Sissel Stenbæk Andersen.

Together with her colleagues she has now managed to find one of the accelerator pedals that control the speed of a molecular machine.

Together with Dr. Andrew I. Share from Department of Chemistry, Indiana University, USA, she is the lead author of an article on the subject in the *Journal of the American Chemical Society*. The project's research leaders are professor Jan O. Jeppesen, Department of Physics, Chemistry and Pharmacy at the University of Southern Denmark and professor Amar H. Flood from the Department of Chemistry, Indiana

University.

The principle behind molecular machines is that you must apply some kind of stimulus in order to make it move. This research field is still young, and researchers still struggle to study and understand how the movement takes place and what obstacles it may encounter.

"We try to study what happens between a starting point and a stopping point in a molecular machine and look for what may influence the speed. If we can find one or more accelerator pedals that control the increase or decrease in speed, we have information that we can use to insert or remove accelerator pedals in other parts of the machine – and this will give us control over the speed", says Sissel Stenbæk Andersen.

"We found that it actually goes faster when the distance between the starting and stopping point is longer than if it is shorter - and this was a surprise; you would of course expect that it would take a long time to travel a long distance and a short time to travel a short distance. When the road between start and stop is long in our molecule, it is also soft and with fewer obstacles, and then it goes faster than when the road is short and more rough and bumpy. Due to its length the long road is more flexible – this makes it easier for the road to stretch out and become more smooth and with fewer obstacles. The length of the road thus becomes a means to control the speed", says Sissel Stenbæk Andersen.

The experiments also showed that the speed increases significantly when the distance between the starting and stopping points increases.

"When we doubled the distance, the speed was three times faster. And when we doubled the distance again, the speed increased to a point that we could not measure", says Sissel Stenbæk Andersen.

The researchers' work has focused on the processes that occur when a

molecule is set in motion between a starting point and a stopping point. They now hope to transfer this newly harvested insight into creating a machine that can use this kinetic energy to rotate in a controllable way.

How to run a molecular machine

Like all other machines, molecular machines need an input of energy to run. Some researchers use chemicals as an energy source. They pour a single chemical molecule into the machine, and then it starts. This has one problem though: The chemical molecule can only move the starting molecule from its starting point to its stopping point. When the molecule must return to the starting point, the researchers need to add a new chemical molecule, and this repeats itself endlessly. After a while the machine gets contaminated and must be cleaned.

Heat and light can also be used as energy, and then there is the method used by researchers at the University of Southern Denmark. They stimulate the molecule with voltage: One electron is enough to get the molecule going and make it rush toward its stopping point. When the voltage is changed, the molecule will naturally seek back to its starting point and be ready for a new electron-push.

More information: Mechanistic Evaluation of Motion in Redox - Driven rotaxanes Reveals Longer Linkers Hasten Forward Escapes and Hinder Backward Translations. Andersen SS, Share AI, Poulsen BL, Kørner M, Duedal T, Bensor CR, Hansen SW, Jeppesen JO, Flood AH. *J Am Chem Soc.* 2014 April 18.

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