Science AMA Series: I'm Will Dichtel, an organic chemist at Cornell University working to find new practical uses for nanostructured materials. I was also named a MacArthur Fellow in 2015. AMA!

Will$_Dichtel^1 and r/ScienceAMAs^1$

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Abstract

Hi reddit! I'm Will Dichtel, I'm an organic chemist at Cornell University and am currently on sabbatical leave as a Visiting Miller Professor at UC-Berkeley. My research group addresses challenges in energy storage, sensing, and other applications. We often study polymers with permanent voids and high surface areas. The material described in our recent Nature article is derived from corn starch, rapidly removes trace pollutants such as pesticides and pharmaceuticals from water, and may be easily regenerated and reused. In 2015, the MacArthur Foundation named me a MacArthur Fellow, recognizing me for "pioneering" the development of porous polymers known as covalent organic frameworks (COFs). To learn more about my research, feel free to follow me on Twitter (@dichtel) or check out my website at http://dichtel.chem.cornell.edu/. I'll be back at 1 pm EST to answer your questions, ask me anything! EDIT (1p ET): Hi Everyone, I'm here and starting now. EDIT2 (2p ET): Thanks for your questions - I need to run now but will check back later and try to answer a few more this afternoon. EDIT3 (11p ET): I came back to answer a few more questions but am done for good now. THANKS SO MUCH FOR YOUR QUESTIONS!

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WILL_DICHTEL R/SCIENCE

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Hello! I have a question with regards to process design. Your sorbent exhibits incredibly fast kinetics and high capacity for trace contaminants, but in its current form it exists as a fine powder.

Typical treatment processes normally use a packed bed, and packed bed of powder would suffer incredible head losses and would not be able to be used in this fashion.

My question is: how do you imagine a typical treatment process using this sorbent would work? Similar to powdered activated carbon where there is some sort of recovery step afterwards? Are there any plans of making a similar sorbent but with a larger cross section so they could be used in packed columns?

rseasmith

Hi rseasmith,

I think your questions are good and have already provoked some discussion from folks more knowledgeable about water treatment process design. Our cyclodextrin polymer shows excellent performance and can be regenerated easily. We envision incorporating it into flow-through column architectures to take advantage of those characteristics but I'm not able to comment on the exact implementation in a water treatment process. Outside my expertise.

What do you think about concerns that the release of nanoparticles into the environment could have harmful effects that we haven't recognized yet? Somewhat like the recent beads that will be discontinued from soaps, etc.

I'm thinking about 'asbestos-like' effects on lungs, for example.

3literz3

The microbead technology never made any sense to me - basically dosing the environment with a bunch of hard-to-remove plastic particles.

More generally, identifying the toxicity of nanoparticles is a huge issue and difficult. The same material will behave differently depending on its size, shape, and especially its surface chemistry. There are many articles on the toxicity of carbon nanotubes that draw different conclusions because these factors are different.

Can you explain how a new technology gets out of the University and into the market? If you invented some material that could work as a microscopic sponge for toxins or that quadrupled the efficiency of a battery, how would that make it out of your lab and into my life?

LazloHo

We file patents on discoveries that might have commercial applications - more specifically the university files them and owns the intellectual property. After that, any company can negotiate with the university to license the technology. In my area, a major chemical company like Dow or BASF might be interested in our patents and seek to license them. Another mechanism is for the inventors to start a company to commercialize the technology themselves. In that case the start-up company would license the technology from the university but the inventors would typically be heavily involved in the new company.

I study agriculture. What applications can you forsee for nanotech in the act of growing food, bioremediation, environmental data collection, disease management, moisture management, and other areas I'm not even thinking of?

tetral

I don't know a lot about agriculture (despite Cornell having a great ag school). I think cost and a high burden of proof about the safety of the materials to be used will dominate this space.

Graphene received enormous press coverage back in late 2010 when two people won the Nobel Prize in Physics for their work on the material. It was lauded as a revolutionary technology that would drastically change the face of many fields. Since then there have been many one-off stories about graphene being used by scientists in research but nothing tangible for the general public. What makes graphene such an exciting material to work with and what do you envision it allowing scientists/engineers to accomplish? When will consumers start seeing products that use graphene technology?

shiruken

I think it takes a long time for a fundamental discovery to make a commercial impact to the extent that you are describing. Perhaps the nobel prize for graphene came relatively quickly, so that has enhanced expectations for products that contain it. Graphene has a range of properties not seen in other materials in terms of its size, mechanical toughness, electrical conductivity, etc. Its discovery has also inspired a huge effort to develop other 2D materials. I am quite certain these types of materials will have major impacts on human lives. But it will take many years, if not decades, to see that sort of impact IMO.

Saw an article recently that you're moving from Cornell to Northwestern. First of all, congrats! Second, what prompted the move, and what were the pros and cons you weighed going into the decision? Always a tricky process in academia, even more so for us who don't have MacArthur Fellowships!

mpate17

Thanks!

These decisions have to be made carefully, and moving has both personal and professional aspects.

I have greatly enjoyed my time at Cornell. It has been a wonderfully supportive environment for my career and I've loved living in Ithaca. I will always think fondly of my time at Cornell and would strongly encourage others to go there.

At the same time, I am incredibly excited for new opportunities at Northwestern. They have made impressive investments in chemistry and materials science over the last decade. In evaluating it closely as part of my decision, I became convinced that it was the best place for the future of my research and teaching efforts.

Hi there! Thanks for doing this AMA! Your work is outside my field, so forgive the naivete of the questions- what does it actually mean to "remove" organic micro pollutants? Are they being converted into something inactive, or sequestered in some way?

Has this technology been used in practical applications to control pollutants, and if not what is your vision for how you would like to see it in use?

Finally, how has winning the prestigious MacArthur award affected your work?

Many congratulations to you and your lab for the impressive achievements!

p1percub

Thanks!

"Remove" in this context means to sequester - the pollutants stick inside the "cups" of the cyclodextrin such that they are no longer present in the water. The water can pass by or through the material and the pollutants will be stripped away.

This material is at the basic discovery phase (i.e., we discovered it in the last year and just published the first paper on it). It will take some time to bring this to market but we are looking into this now.

Winning the MacArthur fellowship has been an incredible validation of the work that my students are doing. We have received increased atttention for our own work and the areas of covalent organic frameworks and porous polymers in general. I am extremely appreciative!

Greetings professor.

Why do I always hear about the fantastic use of nanoparticles in pretty much everything (batteries, nanobots, construction) but I never see anything that can take them to mass market? Is there a large gap between the lab and production?

rob132

As above - it takes a long time. Academic research pushes the performance limits of materials but often doesn't take cost into consideration. Or we study a fundamental question that points the way forward for solving important problems, yet lots of development work remains. There is a gap between lab and production. An alarming trend is to see a lot of corporate R&D labs disappear (such as Bell Labs or now DuPont Central Research) because these groups made amazing discoveries in their own right and helped to bridge this gap.

Congratulations on making the cover page of Nature! A very clever solution.

I'm researching polymer membranes for the removal of oil contaminants in wastewater at Imperial. Less than 1% of the Earth's water is drinkable and alot of that is used for processing food, materials and oil recovery - more research is required to preserve the water we can drink and cheaply recycle that which is used industrially.

Have you studied how these polymers affect the flux and fouling in microfiltration systems?

How much did your custom solvent purification system cost? And have you tested the humidity in your solvents?

sBoon_

Thanks.

We haven't tested flux per se, but our porous polymer does not swell a lot in water because of its high degree of crosslinking. We don't see a lot of backpressure in pushing water through it but need to test this more thoroughly.

Custom solvent purification systems run $50-100K last time I checked. They are based on alumina columns and several vendors now offer them.

Incredible research, I applaud you on your works and all that you and your team have accomplished! How far in the future would you say that this corn starch based material will be seen in a practical sense? I'm not impatient, just excited! That fact that this pollutant-cleaning material made out of a relatively easy-to-get compound is no small achievement!

Yet again, thank you for your scientific contributions.

Chalupa112

Thanks!

In other questions I have discussed the gap b/t basic academic research and commercialization. That being said, our material is set up well to explore commercialization because it is a simple, one step reaction between two commercially available chemicals. We are exploring this now and hope to see it through to having an impact on human lives.

Professor Dichtel,

I am a UCL Master's in Chemistry graduate focusing on nanoparticle applications, currently looking for a possible PhD topic following a period of employment. Nanomaterials, with their unique properties an dhigh tunability via supporting structures and frameworks, seem to me to be the way forward in environmental chemistry.

What do you think abou the capabilities of COF nanostructured materials in remediating/removing airborne pollutants? The field seems relatively unexplored, with a high volume of work being done in China. I'd also like to inquire if you're aware of any work being done by groups Stateside?

Naturally, my sincerest congratulations on the fellowship.

Thank you in advance.

dxjustice

Thank you!

I have not seen much work for COFs or other porous polymers to trap airborne pollutants, though a huge amount of effort in the MOF field has focused on capturing CO2 or now even reducing CO2.

Most of the early COFs were too water sensitive to seriously consider such applications, but more recent developments in the field might make this application feasible. Cost would be a major driver in a final solution, but I think there would still be a lot of fundamental questions to answer first.

Quick question about energy storage. Do you foresee this nanotechnology being used to improve power storage? Maybe used to increase the capacity of in home power storage or for electric cars? I feel like one of the largest hiccups for the change into complete renewable energy is power storage. Thank you!

jbane1

Definitely! There are major efforts in research in batteries and supercapacitors, and controlling the structure and behavior of matter down at the nanometer scale and below will be important to improve their capacity, power density, and ability to be recharged as many times as possible without performance fade.

So a couple of questions regarding your cyclodextrin work. First, how is this different from other crosslinked cyclodextrin polymers using epichlorohydrin, etc. these have been explored for years. Ex: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwikltaT2L3KAhWFnIMKHXi6C00QFggmMAE&url=http%3A%2F%2Fitn-cyclon.eu%2Ffiles%2FAnnouncements%2FCyclodextrin%2520News_December_2011.pdf&usg=AFQjCNHwrWQwpggalFK0L_klkqCZWLjH

Secondly, what distinguishes this chemistry as nano? Typical nano applications are microemulsion with particle size in the nano scale, yet most of these polymers are well below that as individual molecules. I've seen a lot of rebranding of polymer solutions as nano when the term does not really apply.

Zetavu

Our CD material is permanently porous, which provides better performance. We directly compare our material to the epichlorohydrin crosslinked cyclodextrin polmyer in the Nature article.

On "nano" versus "chemistry" - I would say that all chemistry is "nano" (or smaller if you are talking individual molecules). Nanotechnology has many different definitions. One of the unfortunate things about "nano" catching so much public attention and hype is that it has taken away from a public appreciation of chemistry.

Congrats on being named a MacArthur Fellow. Do you have any advice for how one should approach the study of organic chemistry to maximize their chance of truly understanding the material?

IsReadingIt

I love teaching undergraduate organic chemistry. It's part science, part foreign language, and part rational problem solving. My advice is to not fall behind in the course and to identify patterns instead of memorizing in a brute force way.

Hey professor, not very well versed in the day to day of a professor but how difficult is it to move from research to the development of a product that is created in your lab? Say you were to decide to mass produce and sell the polymer that you've created either by a startup created by yourself or if you were to license it our to a preexisting company? Is there any reason that someone would not move away from strictly research to development?

It seems like on the day to day there are so many advancements in science and tech but very few inventions ever move towards developing the actual product.

Thanks professor

edit: someone asked a similar question and I didn't even realize, woops

Prot00ls

It is difficult, and I will need a lot of help to commercialize a technology. I'm good at being a professor. I need to work with others more experienced in business to have any hope of success in the commercialization efforts.

Details of how this works are answered above.

How did you get into Chemistry? Also, congratulations on being a MacArthur fellow!!!! :)

Lollipoprotein

Thanks!

I had two experiences that influenced me going into chemistry. I went to a small high school in southwest Virginia that let me take science courses at an accelerated pace. I ran out of courses my senior year, and my HS chemistry teacher, who had a PhD in organic chemistry, gave up his free period to teach me organic one-on-one. I am forever grateful to him for doing that.

My other experience that heavily influenced me was getting an undergraduate research position in the lab of Tim Swager at MIT, which was my first exposure to "big" science. Tim is an incredible chemist and mentor and also inspired me to continue on that path.

When dealing with nanostructures, who seems to have the most prominent role: materials scientists, physicists , chemists, or engineers?

firmkillernate

All of the above. The best work in the area is collaborative among teams that can understand the structure and function of matter at many different length scales. As long as the team has that expertise, calling it chemistry, materials science, or physics can be somewhat arbitrary.

Hi Professor Dichtel! I was curious what you think the best way to learn organic chemistry is for an undergraduate. For a lot of students, organic chemistry is a real struggle and its a requirement for their major. Personally, I know that I struggled a lot with it and still do, and I'd love to have your opinion on how to better learn and study it. Thank you very much for this AMA!

JohnnyMcG

The first 1-2 organic chemistry courses involve learning a lot of reactions, and I think students struggle by trying to memorize each step of every one independently. If you really understand Lewis Acids/Lewis Bases and related concepts of electrophiles and nucleophiles, it will be easier to develop an intuition as to what is likely to happen in a reaction. You still will need to learn some details about each one, but it becomes a lot easier because it will all seem more logical.

What are the chances your technology could be adopted to clean blood of toxic materials?

(THis is just an example and may not even be a valid scenario for anything you're working on, but my conscience cries out for those people in Flint, and though the blood and soft tissues technically clear out after 40 days, but their bones will be leaching lead into their systems for 40 years. which will be present in the blood and then the soft tissue as it leaches out.)

It would be a great thing to be able to deal with substances in the blood sooner then waiting for them to be removed, and I particularly like the Idea of nano machines and nano manufactured particles to freeze these things into cages to remove them, so that it's not so much a drug as a medical device.

Now I understand that isn't a simple question simple answer kind of thing, often times the chemical bonds with the blood cells or platelets, which would seem to be a much harder process to handle.

However many chemicals are simply held by the plasma, and the plasma is mostly water and is most of the volume of blood, so there is definitely room for nano structures and/or particles to be designed to clean blood (eg structures that act like an artificial liver or kidney, or particles/tools that act as an assistive "enzyme" that trap substances in a way that allows them to be flushed out by a person's kidneys or handled by their liver.)

These seem like the sorts of areas of technology I'd always hoped would be here by the early 2000s

(And to go to a whole exponentially more far-flung high-flying level with a (possibly 'fluff') sub question:

- I'm always wondering if the "Fallout" series concept of "Rad-X" or even "Rad away" can be achieved -- one day, down the road two hundred years from now perhaps -- using nano technology that trap the radioactive particles in a way which causes the body to eliminate them immediately before the can be "used" or absorbed into tissues.

  I specifically wonder a nano molecule/machine might be able to be designed to differentiate between a radio-active and non-radio-active version of an element or compound and add "capture it" or add some other molecules to it, to it to render it to be seen as useless to the body so it just ends up being eliminated instead of used.)

QSquared

I think your body does an amazing job cleaning your blood already but developing a new material for kidney dialysis certainly might be an interesting thing to do. It might be possible to clean blood but it is a hugely complicated mixture and you'd have to worry about both clotting and immune responses. Not easy!

Hi Prof Dichtel, I'm a PhD candidate in gas separation at University of St Andrews, working on toxic gas removal in respirator cartridges.

Are you doing any research into removal of toxic hydrides or other small-molecule contaminants with COFs? And if I wanted to expand my knowledge of sensing using COFs, where would I start?

mattzm

Great! We are interested in the ability of our cyclodextrin polymer to remove toxic gasses. Joe Hupp and Omar Farha also have some nice papers out on using MOFs to trap and deactivate toxic gasses.

Chemical sensing with COFs has been limited. We also have some papers out on explosives detection using conjugated polymer networks that you might want to check out.

There has been some debate over whether biofuels made from corn are viable long term both because they cost a significant amount to make and due to their environmental & human impact. Large scale cultivation of corn for biofuel has been accused of taking resources from food production, water scarcity, loss of biodiversity, and issues resulting from fertilizers and pesticides.

Have there been any similar debates about using corn starch in your projects? If so, how can we mitigate these concerns with the obvious benefit of a renewable resource that is very useful in projects like yours? Is there a balance?

firedrops

Yes - but I did a back of the envelope calculation of existing cornstarch production. The production of our material, even on a truly huge scale, is not likely to compete with food sources significantly. Plus I think cyclodextrin could be made from other sources if there was a sufficient economic incentive to do so.

What about investment opportunities? Is it smart to look to graphene? Or is there something else?

beangay

Yes, but as with all things, there are smart investments and less smart investments...

Prof. Dichtel,

Thank you for this AMA and your fascinating research! as a chemical engineering student I now wonder about how this research gets implemented into industrial application.

It is clearly demonstrated how your mesoporous material works better than activated carbon, but the latter is mentioned to be more inexpensive. What are, then, the current limitations for β-cyclodextrin? is it because of the likely high pressure drops for downstream separation of the nanomaterial? or low yields in the polymerization of β-cyclodextrin? (as I understand, corn starch is mainly formed by amylose and amylopectine chains). What about the use of methanol for the regeneration of the active sites.. would'nt it be troublesome to include MeOH for a water purification process?

Finally, I have a question about fundamental research and scaling-up, as in this case. I took a quick glimpse at the paper and the flow rates for the kinetic experiments are low (~ 10, 20 mL/min) in comparison to those that would be encountered in a large scale process. Would the Langmuir model still hold under higher flow rates?

Thanks again for your hard work!

TristeLeRoy

Thanks Triste!

All excellent questions. Beta cyclodextrin is already inexpensive and mass produced. The methanol regeneration might be an issue but can be replaced with other solvents that are probably even more benign.

Our flow rates are relatively fast in the sense that the contact time with the thin layer of adsorbent are very short (<1 sec). Going to higher flow rates will involve actually packing a column with the material, which we are doing now.

Hi Will. I heard you on This Week in Science and so I know that the molecule that sequesters the pollutants in this polymer is the same molecule that is used in Febreze. You mentioned that the polymer was reusable after a cleansing with methanol or such. What happens to the pollutants during the rinsing? Do they go right back down the drain and back into the water supply?

rockhoward

One would take the material out of contact with the water source, flush it with the methanol (or other solvent), and then put it back in line with the water. The methanol/pollutant mixture could be disposed of in a number of ways but would not be reintroduced to the water.

Hi professor,
How soon will nanotechnology have an impact on pharmaceuticals/healthcare?
Is it safe to expect small companies to make a profit in producing nano-products for mass consumption, be it pharmaceuticals or disposable medical equipment, or is nanotech reserved only for the big companies with high-end laboratories and workforce?

HighBouncingL

I think nanotechnology is already impacting health-related areas.

I also think that small companies have a role in this space. One interesting opportunity is to locate companies near research universities with high-end facilities. These facilities welcome many external users from both big and small companies, dramatically reducing the capital investment that any one company would need to work in the area.

Hi!

So I'm currently a chemical engineering and chemistry undergrad working in a polymer synthesis lab. I am really hoping to turn to polymer electronics and using them as energy storage. Do you have any literature recommendations to introduce me to the field? Thanks!

Wheresthewind

Too many to recommend one in particular, but there are a huge number of contemporary reviews on organic electronics and emerging electrical energy storage technologies to use as a jumping off point.

What is your take on the idea of a new type of industrial revolution in the coming years the basis being nanotechnology or 4D materials?

jakelovesguitar

I'm not sure what qualifies as a "new industrial revolution" but I do think most human activities will be affected by newly developed materials and the improved control of structure at small length scales.

Typically organic frameworks are great at providing a large surface area but are too fragile for many applications, such as pressurized gas storage. What can you do chemically (or physically) to overcome such limitations?

Cmdr_R3dshirt

We don't work on gas storage - you'd have to ask someone else, but I think a strong link between understanding the mechanical properties of these materials and the theoretical prediction of tougher networks (strong chemical linkages and the most advantageous topologies) might overcome this problem.

Thanks for doing the AMA

How has your experience been, thus far, with running a research group and taking a sabbatical? I know that taking a sabbatical, especially one where you are away from your home city, can be difficult for students/post docs in your lab. Have you found that progress in your research has significantly slowed during this time?

GP4LEU

I've only been on sabbatical for two weeks, so I'm just learning myself. I'm trying to balance supporting my students (lots of video conferencing) with taking enough time for myself out here to learn new things.

I'm not anti-science, so forgive me if this concern sounds akin to those raised by people who are anti-vaccine or anti-GMO (I love not getting polio and having cheap plentiful food). But, I'm really afraid of nano materials specifically because it seems like creating materials that our bodies have no evolutionary history of coping/interacting/dealing with is a bad idea... like asbestos-bad. What sorts of checks are there in place to make sure that these sorts of products aren't the next asbestos? Would those checks have caught asbestos before it became so widely distributed/produced? By asking this I don't mean to say that nanomaterials shouldn't be developed - it is clearly the future and the potential applications are mind boggling. I'm just afraid that EVERYONE is going to have cancer 30 years from now.

KitsuneKarl

I addressed this a little bit above. Developing a strong (and ideally, predictive) model for understanding nanomaterial toxicity is incredibly important. But it's not as if we are introducing tons of these materials into the environment without thinking about potential effects.

How long a timeline realistically between development of these breakthroughs and the common-place adoption by municipalities within the united states?

Does your team include engineers and so forth to help determine methodologies and mechanisms for implementation/retrofitting, to try to seed the community of interested parties (Manufacturers/municipalities/etc.), with the tools (awareness/trainin/etc.) to adopt these new technologies, or is that left up to someone down the road?

If the Former what are some of the types of ways you're assigning with this, any good examples of a "win"?

If the Latter, how is the IP for the research disseminated?

ie. Is it entirely up to the funder of the grant or are some/all sold to a highest bidder, or some/all donated to a Not for Profit Organization such as "TheWaterFund" or donated to the public (national/global community), and those parties are in charge of coming up with patentable™ processesses to then sit on or resell?

I guess what I am most interested in, is how much impact the research might be able to have on our daily lives, and in what timeline, and how much ability you have to affect that process?

(Full disclosure:

I find the march of progress and the uptake of valuable improvements available to us is unendingly slow, and we're finally "about" where I felt like our technology should be by the late 1980s, so I struggle with being repeatedly excited by new breakthroughs that should affect our lives, which disappoint me as they go by the way side for 5, 10, 15 or more years wasting lives and money.

Whether because the adoption costs are too high, or a company sits on a patent because their old method is too lucrative, or they simply don't have the knowledge or means to implement changes, or feel like by the time they make one change they will just have to spend money on another, which can be valid, but often times can be flawed reasoning.

So I just really want to hear a realistic time frame to keep my hopes in check, and to get really exited I want to hear not just that people are working to further the adoption of these breakthroughs, but how they are doing it and in what ways it makes an impact.)

PS: My apologies I come off borish and long winded, its just I'm passionate about improving the lives of others, and cleaning water is a definite solid way to make an impact in improving the lives of others.

QSquared

Some of this is answered above, but I think expectations of technology development speed have been heavily influenced by Moore's Law (which is itself a triumph of chemistry!). Computers are the only technology that I can think of that have improved exponentially over my lifetime. Even then - that has been largely achieved by making the same transistors smaller and smaller. The advance that affects our lives is the complex software that can be built on the increased computing power.

Other technology development is happening, almost certainly faster now than ever before, but it still takes time to take basic science advances and master them sufficiently to use them in a product within a competitive marketplace.

If there is one thing you would say to a freshman undergrad thinking about majoring in chemistry, what would it be?

KantReid

Go for it!

In what ways have your studies influenced the way you see and interact with the world around that might surprise a person like myself, who has a below-average science education?

samfuller

Not sure if this is what you mean, but being a scientist is a humbling experience because one often realizes how difficult it is to make solid and rational conclusions.

I also think that scientists are among the most creative, interesting, and empathetic people I know. In fact, one of the best parts about being in science is getting to know other scientists.

Hi Dr. Dichtel! Amazing work on the poly-cyclodextrin, my imagination ran wild with applications methods of scaling it up.

I work with a number of bioplastics and biopolymers, and as such I am curious as to whether you have considered the synthesis of the P-CD in a more industrial scale with polymers of glycidyl methacrylate, or even as a polyol in a thermoset of polyurethane or epoxy? An open-cell thermoset foam of beta-cyclodextrins would potentially still retain the high surface area, and also produce a product that can be scaled-up quite rapidly.

Thank you!

bucad

Interesting ideas! Thanks.

Since RO is such an expensive process energywise, would any of your materials lend themselves to the removal of dissolved salts for the purpose of creating potable water in a cost effective manner?

btribble

Based on how cyclodextrin works, it is unlikely that our material would be useful for desalination.

Were you at Cornell in 1977?

SouthTampon

Ha! I wasn't even born yet. :)

I've noticed that in addition to being a great chemist, you are an amazing family guy. How do you manage to have such an awesome family, while still trying to save the world?

chickduck

Thanks. My family is very important to me, and I would not be able to do what I do without their support.

How can (high) schools better engage and interest young people in science?

redditreddit4444

I certainly had a lot of false notions about what scientists do when I was in high school. A challenging aspect of science education is that there is both a lot of knowledge and a lot of technical skill to be developed before one gets to the really creative parts. Exposure to open-ended problems instead of canned laboratory exercises as early as possible is important. Also teaching science as a process, and as one of the greatest collective undertakings of humanity, rather than a collection of facts might also help.

What is your favorite cheese?

walshy9587

Humboldt Fog