American Chemical Society AMA: Hi! I'm Peter Mahaffy, Chem Professor and co-director of the King's Centre for Visualization in Science. I'm here to discuss the crucial role for chemistry in addressing

AmerChemSocietyAMA [1] and r/Science AMAs[1]

[1]Affiliation not available

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ABSTRACT

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AmerChemSocietyAMA , r/Science , American Chemical Society AMA: Hi! I'm Peter Mahaffy, Chem Professor and co-director of the King's Centre for Visualization in Science. I'm here to discuss the crucial role for chemistry in addressing , *The Winnower* 2:e144232.20006 , 2015 , DOI: 10.15200/winn.144232.20006

1. **I've heard that the permafrost in the northern tundra contains a vast amount of methane which the current warming trend is likely to cause to be released into the atmosphere and would probably lead to a rapid acceleration of the climate warming process. How much do you agree/disagree with this assessment? Are there other climate change "time bombs" people might not be aware of?**

2. **What are your thoughts on the current state of technologies being developed that could sequester carbon and/or other greenhouse chemicals back out of the atmosphere?**

silly_rabbi

A: Important question! Rather than use the word "time bomb", I would describe this as an extremely important example of a positive feedback loop that we must seriously consider due to the short time horizon in which it may operate. We know that there are many positive and negative feedback loops that regulate earth's climate. The idea here is that as we get regional warming, and we expect to get and see much more warming in the polar regions, the permafrost starts to melt and release methane from methane clathrate hydrates that have been stored for long periods of time. Since methane has a global warming potential 28 times that of carbon dioxide (over a 100-year lifetime), this will release large amounts of methane into the atmosphere, causing a positive feedback loop. Remember also that there is a time lag for emissions of greenhouse gases like carbon dioxide that are causing atmospheric warming, so we will see continued warming even after mitigation measures. You can learn more about this in Lesson 7 of our explainingclimatechange.com interactive resource Peter

Hi there,

How can we encourage scientific literacy in people who are past the typical schooling age?

I have the most trouble talking with fellow adults who may have forgotten all of what they learned in high school chemistry or think climate change will simply not affect them in their life time.

Young_Zaphod

A: A crucial question! A Nature Climate Change paper (http://dx.doi.org/10.1038/nclimate2728) published in July gives data on awareness of climate change and risk perception in 119 countries around the world. The picture it paints about public understanding is troubling. Public awareness and concern vary greatly around the world. The paper concludes that understanding the anthropogenic causes of climate change is the strongest predictor of climate change risk perceptions, especially in Latin America and Europe. To attain that understanding we need targeted strategies to communicate the current state of our climate and the anthropogenic causes. The Paris COP21 meetings in December will bring this to the political agenda across the world. The profession of chemistry has an important role to play in addressing sustainability issues, including climate change, in formal education curriculum at all levels, and also in reaching out to various publics that are within our circle of influence. The explainingclimatechange.com resource is an initiative from the International Year of Chemistry - 2011 to reach an audience with a Grade 12 or 1st year university background, highlighting the many connections that some fundamental understanding of chemistry can play. The ACS climate science tool kit is at a higher level and helps professional chemists know how to communicate with their peers and neighbours. Peter Mahaffy

What do you believe are the most important chemistry projects currently underway, or proposed?

SciPup3000

A: There is a long list. Some of the most visible ones have to do with weaning our way off of fossil fuels and instead of starting with carbon sources that have taken geological time to create, making use of biomass. We need to apply appropriate metrics to these new technologies to ensure that they are real solutions, and this is an evolving field. One great example is the Presidential Green Chemistry Award given a few months ago to a company that is using algae to produce four of the leading transportation fuels. Application of green chemistry and engineering principles to many other processes in industry is crucial – often energy use is one of the lower hanging fruits for improving the carbon footprint of an industry. Catalysis is one strategy that can often be helpful in addressing energy balance for processes. A challenge that we need to solve relates to the Haber-Bosch process for the fixation of nitrogen. This Nobel Prize winning technology has made a huge difference in the availability of food for a hungry planet and the survival of a significant portion of earth's population. But the process consumes 1- 2% of the world's total energy and runs at high temperature and pressure. Chemists are trying to learn from nature, where nitrogenase enzymes in bacteria are able to fix nitrogen at ambient temperature and pressure. We'd like to find and develop catalysts made from earth abundant materials that could impact significantly on the energy requirements for producing fertilizers. Peter Mahaffy

Do you think it's feasible to tackle Carbon Dioxide after it's been emitted, for example by reacting it and turning it into carbonates? Or is our only option to cut back on emissions at the source?

jaredjeya

A: An important question! Given the scale of the challenge, we know we must cut back on emissions at the source. The challenge with tackling it after it's been emitted is entropy – efficiently pulling CO_2 out from the air at the hundreds of ppm level, after it is emitted by mobile sources like transportation, is very difficult, although people are trying! There are more effective approaches to go straight to the emissions source and couple power generation with CO_2 capture and storage. It's But even better would be if we can use that carbon dioxide instead of burying it. Chemists are also working with others to develop strategies to use carbon dioxide as a feedstock for fuels, polymers, and other chemicals. Promising work and lots of challenges! There is also innovative work to use that CO_2 as a carbon source for algae. Peter

In what way is green chemistry affecting the work towards reversing climate change?

How do make the public care about these issues without resorting to the media's fear mongering tactics?

puppiesgoesrawr
A: You've got two great questions. (1) Green chemistry and engineering give us the tools we need to think about the design of reactions and processes to make them more sustainable. One of the design features that we can more carefully pay attention to using green chemistry and engineering concepts and metrics is the climate impact of reactions and processes. This is best done with a system view, and carrying out a life-cycle analysis that includes the energy consumption of a process, the emission of greenhouse gases, and other considerations. (2) We are all responsible for the sustainability of this planet for our children and great grandchildren. So we need strategies to communicate that are based on an understanding of barriers to change and that move us toward the understanding of both earth systems and people required to make a change. Our group's work is focused on two things - bringing sustainability literacy, including climate change, into the mainstream of formal chemistry education, and also on the public understanding of basic scientific ideas that are needed to make informed decisions. Peter

What do you think is the most important chemical change taking place during Climate Change, and what do you wish people understood more about it?

SciPup3000
Perhaps the most important chemical change is ocean acidification, since it is directly a result of the chemistry of carbon dioxide dissolving in water. What is important for people to understand is that the effects of the pH decrease in the oceans is first being felt by the tiniest organisms, the primary producers, that are the base of the oceanic food chain. Crudely put, without plankton, the krill are in trouble, and, without krill, the whales are in trouble. Effects of acidification are also showing up in shellfish farming. JABell

Budding chemical education-er just about to finish their PhD. What are some feasible routes to end up doing what you do? Post-doc? Teaching Post-doc? Adjuncting?

Looking to teach at the university level, but not run a lab at an R1. Any thoughts?

julianfri
A: Teaching has to be one of the most rewarding professions – especially if you can work to help learners see that the fundamental content knowledge in a discipline like chemistry is not just isolated facts, but can equip the next generation to use that knowledge to tackle important global and local problems. Lots of doors will open up if you have a background both in chemistry and chemistry education research in graduate school, and this is possible in some of the graduate schools that have chemistry education research programs. A teaching post-doc is a good route, or a conventional post-doc, and gain any experience you can through adjuncting or taking on some teaching assignments. In my case it has really been rewarding to team up with an astrophysicist and science educator extraordinaire (Brian Martin) and to build a team of undergraduate researchers across disciplines to address visualization challenges at kcvs. So interdisciplinary connections should be built, if you can, while in grad school as well. We have learned a great deal from cognitive and learning scientists. Peter

Hello, i find climate change so very depressing - its like there is nothing we can do to stop it. Or rather there is nothing that the decision makers will do to stop it. is there any good news in this area that you can share with us? or are we doomed?

junglistjim

Really important question! I find it impossible to be depressed when I work with students like the group of organic chemistry students gathered in the room here to help identify challenges and work toward solutions. The carbon stabilization wedges resource identified in the thread were also created by a gifted team of undergraduate students at our King's Centre for Visualization in science [kcvs] (www.kcvs.ca) who realized that understanding of the magnitude of the challenge is only the important first step, and they became hopeful when realizing that breaking that big challenge into smaller ones leads to achievable outcomes.

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junglistjim

We are only doomed if we give up. Yes, things can seem fairly bleak on the political front in the US and Canada (although there are bright spots as well—largely at local, state, or province level). A way to help avoid depression is to take personal action that will make a tiny dent in the problem, since that is what is going to be required on a larger scale in the long run. The Union of Concerned Scientists has a book available, "co2oler smarter: practical steps for low-carbon living" (electronically and in paper--getting it electronically is a first step in low-carbon living) that can help you with ideas for personal action. This surely includes voting for local, state, and national representatives that have a commitment to lowering carbon emissions. JABell

If you had unlimited resources and could only pursue one plan to drastically reverse or slow the effects of global climate change what would it be?

I know there's no magic bullet, but let's say you're in a room with all the bullets of applied chemistry but could only fire one. Which one?

AlaskanSkunkBear

A: Unlimited resources to address the climate change threat to our planetary boundaries – now there is a dream come true! I think it would have to be a bullet that would bring in some resources to address our extreme reliance on fossil fuel combustion for energy, and there is promising work being done on this in coupling the use of solar energy to split water with fuel cell technologies to put hydrogen and oxygen back together again and provide power at a smaller scale than our large electricity infrastructure. I think this has potential to improve the quality of life in places that are currently short of energy for everyday needs. We've been fortunate at the King's university to be a part of the Engaging Chemistry lecture series that has brought both Dan Nocera and Harry Gray to our campus in the past few years. I'd give them, the solar army of students that Harry has mustered, and the people working in this area a generous chunk of those unlimited resources to help move this along. Peter

I've read about proposals to put sulfur dioxide or other chemicals into the upper atmosphere to slow or reverse global warming.

Is this a pipedream or is it really possible? And if it is possible, what would be substantive objections? Why wouldn't or shouldn't we do it?

TommBomBadil

See "A Case for Climate Engineering," David Keith (ISBN 978-0-262-31779-5, e-book). The author outlines a geoengineering "solution" and provides an excellent pro/con discussion. In essence, stopping sunlight coming in does not have the same effects as allowing long-wave radiation to leave and the effects may exacerbate the climate change problem, not alleviate it. Also, Google "NRC

Geoengineering Climate" to access two reports, one on CO2 capture and sequestration and the other on albedo alteration. No albedo altering "solution" speaks to the problem of ocean acidification. JABell

Hi, I'm a programmer who's quite interested in getting more involved with Chemistry, specifically in creating web-based tools for learning. What do you think are good areas for computer scientists and chemists to collaborate together? Are there any software tools you feel are lacking currently, or wish existed?

TLHM
Great question, that I've turned over to Mckenzie, who is a chemistry undergraduate who is doing just this kind of work. She writes: One of the fantastic ways that interdisciplinary work between Computer Science and Chemistry is, as you mentioned, creating resources for learning. Climate Science is a really interesting place for this work to happen because it is such a publicized issue, though it is certainly not the end of this kind of collaboration! I happen to be a chemistry student who works at a place that does this kind of work: The King's Center for Visualization in Science. The task of creating programs that accurately depict chemistry phenomenon in a way that can be understood by students—even by people with no science background!—is a difficult one. Interdisciplinary work to create visualizations is a really great way for programmers to get involved with chemistry.

As for which tools are important to develop, there are a lot of concepts that could benefit from really concise learning tools, I mentioned climate change earlier because it is not only a subject that many people have been exposed to, but is also an area which is so widespread on media, that there is a lot of misinformation. Subjects like that are hugely important to address in a web-based (highly accessible) context because they can have a great positive effect. Two of the resources KCVS has developed in this area are highlighted in the intro to this AMA above.

There are other places doing this kind of work too, PhET for instance. Feel free to visit us at kcvs.ca to see what kind of work we're doing! Mckenzie

Why is everyone talking about CO2, when methane has a much shorter half-life? What impact would you foresee from the elimination or reduction of intensive, industrial animal husbandry?

BlitzerkidSix
Great question. We need chemists helping with understanding about some of the other key greenhouse gases, and after carbon dioxide, methane is near the top of the list. We've discussed this in another thread. Three factors are important in determining whether a gas like methane will contribute significantly to atmospheric warming: its concentration, atmospheric lifetime, and its infrared spectral properties. You might find it interesting to look at the IR Windows Learning Tool in Lesson 6 of explainingclimatechange.com to understand why relatively small amounts of methane in the atmosphere can have a big effect. We know that the carbon footprint of our carnivore habits is quite large as this is a very energy intensive industry, and so in certain parts of the world, we should eat less meat. But things can be done with animal husbandry, as well. Research is being carried out on ways to alter animal feed, for example, to lessen the amount of methane being produced. Peter

What can we do as average everyday people to help prevent climate change?

tisjustbrandon
Climate change is already upon us, but you can do your part to make a tiny dent in the problem, since that is what is going to be required on a larger scale in the long run. The Union of Concerned Scientists has a book available, "co2oler smarter: practical steps for low-carbon living" (electronically and in paper--getting it electronically is a first step in low-carbon living) that can help you with ideas for personal action. This surely includes voting for local, state, and national representatives that have a

commitment to lowering carbon emissions. JABell

Based on everything you know about our planet's efforts to reduce global warming, do you personally think we'll actually succeed in doing so by a meaningful amount?

abc127
A: This is the question we'd all like to see answered with a yes! I think we have an imperative to try. When we confront the magnitude of the challenge to our planet, it is tempting to think we can't possibly succeed. But there are examples from history where we have encountered substantial challenges and found the will and way to turn things around. One example we put into our explainingclimatechange.com resource Lesson 9 was the successful way in which the world dealt with an earlier oil crisis – reaching "peak oil" in about 1850 when the hunting of whales for sperm oil became unsustainable. Kerosene became the new source of oil….In that same lesson we have also found it helpful and important to break big problems down into smaller ones. We visualized the model developed by a Princeton group in an interactive tool called the carbon stabilization wedges tool. The enormous challenge of avoiding a doubling of anthropogenic atmospheric carbon over the next 50 years (carbon stabilization triangle) is divided into 8 smaller problems (stabilization wedges. When you interact with the tool you see that simple strategies that you and others can do , if carried out on a larger scale, can make a difference. Some of the assumptions in the model could now use updating, as we worked to visualize the published assumptions, but the approach is very informative and hopeful. Link Peter

How do biofuels work better compared to regular gasoline? Isn't it still combusting and creating carbon dioxide?

UV_ray
The idea behind the use of biofuels is that the carbon dioxide from which they are made has come from the atmosphere just recently and is simply being returned to be used once again by another crop, etc., etc. That is, it is a cyclic process that, over a reasonably short period of time, simply cycles the same carbon in and out of the atmosphere. Fossil fuels, like gasoline, are putting into atmosphere carbon that was removed by plants many millions of years ago and is adding a net amount to the atmosphere. A question to be asked about biofuels is whether their energy payback is larger than the amount of energy used to produce them and where that energy comes from. Some would argue that that energy might better be put to another use. JABell

Hello Dr. Mahaffy, former student of yours here.

1. **What is the role of the scientifically literate in relation to the scientifically illiterate in society?**
2. **How can we be most productively engaged, in your opinion, in working to mitigate or reverse the effects of climate change? Particularly in places like Alberta, where, as you well know and experience, a substantial portion of the population is loathe to support such action?**

waddayalookinat
A: Great to hear from a former student – and with important questions! Let me start with the first. Chemists and chemistry educators have to take on the responsibility to a much greater extent than we have, I think, to use the powerful tools we have to help others in society obtain the knowledge that empowers them to be responsible decision makers. Roald Hoffman talks about this as the democratizing power of chemistry. How do we do this? In our universities, we can give priority to developing new courses for arts, social science, and business students (like the "chemistry for poets" course I teach). In our science majors courses like general chemistry, we can make sure that the

knowledge our students take away is not just in isolated bits, but is contextualized so that students can see how their scientific knowledge can make a difference. This sort of knowledge can empower students to help others see how scientific knowledge applies to the problems their neighbours or family members care about. This requires resources and pedagogies that take new approaches. We've tried to help with this in a new general chemistry set of learning resources (shameless plug to follow), Chemistry: Human Activity, Chemical Reactivity, published by Nelson/Cengage, where we begin each chapter with a rich context that relates the specific chemistry content to a context of importance to students. We also need to be sure that both oral and written communication skills are emphasized as learning outcomes in our science courses. Peter

Hi Dr. Mahaffy! Super exciting to see my organic chemistry professor on the front page of Reddit!

I wanted to ask your opinion about carbon capture technologies and their role in combating climate change. To be honest, I'm quite pessimistic that any of the technologies I'm aware of could capture a meaningful amount of CO2, or that they could make economic sense even with significant government subsidies.

How much of a risk is there of governments, researchers and/or the general public putting blind faith in a technological solution for climate change?

Thanks very much! Joel Kelly

infiniflux
A: You're asking questions that are just as tough (and good!) as the ones you asked as a student, Joel :). Carbon capture technologies come in many shapes and sizes, and the term is used to apply to very different technologies. To tie this in to your second question, I think it is seductive, but short-sighted to think that as an **alternative** to dealing with the more difficult question of reducing emissions, we can stay on the present trajectory of fossil fuel combustion and solve the atmospheric carbon problem through carbon dioxide capture and sequestration by injection into underground rock formations. Having said that, carbon capture and storage is a strategy that we need to use as one of our short-term approaches to slowing the rate at which carbon dioxide from fossil fuels enters the atmosphere, while we work at transitioning to much more carbon-neutral alternative energy sources. As discussed in some other threads, there is exciting work being done on capturing carbon dioxide in other ways, such as with Algae – a technology that won one of the Presidential Green Chemistry Awards this year. And ultimately, we would like to exploit fundamental chemistry to use carbon dioxide as a feedstock for polymers, chemicals and fuels – a real challenge! Peter

What is your opinion of Nathan Myhrvold's Stratoshield?

liarandathief
See "A Case for Climate Engineering," David Keith (ISBN 978-0-262-31779-5, e-book). The author outlines a similar geoengineering "solution" and provides an excellent pro/con discussion. In essence, stopping sunlight coming in does not have the same effects as allowing long-wave radiation to leave. No albedo altering "solution" speaks to the problem of ocean acidification. JABell

Is there a theoretical point when the damage caused by humanity on the earth would be irreversible? How would one quantify it? And if so, how close are we to reaching that point?

carnivorous_banana
The present load of carbon dioxide in the atmosphere is irreversible (with present technology) on at least a centennial time scale and the earth has not come to equilibrium with it yet. Nor will it have a chance to come to equilibrium until emission of carbon dioxide ceases, or is compensated by

processes that use it up as it is formed. The changes to the climate do not become more irreversible, just greater, as time goes on. JABell

Hello, do you believe global warming is caused by humans? Edit: I do

zxcvbnm9878

I am not sure I would call it a "belief," but the results of numerous studies of past and present climatic conditions on earth all lead to the same conclusion: the atmosphere is warming and the oceans are acidifying because of the build-up of carbon dioxide in the atmosphere. Isotope studies of the carbon dioxide show that its source is fossil fuel burning, which is a human activity. Yes, humans are causing global warming. JABell

Hello, do you believe global warming is caused by humans? Edit: I do

zxcvbnm9878

A compelling case is made in the careful work of the intergovernmental panel on climate change. Their 5th Assessment 2014 Synthesis report walks carefully through what data tells us and the qualitative level of confidence the scientific community has in the summary conclusions. The starting point in the summary for policy makers is the conclusion that: "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems." Peter