



I O C D

International Organization
for Chemical Sciences
in Development

*A group promoting
the chemical sciences
for sustainable development*



Chemists
for
Sustainability

Sustainable development is one of the overarching global challenges of the 21st century. In 2015, governments agreed at the United Nations on a set of 17 Sustainable Development Goals (SDGs) to be achieved by 2030

Chemists for Sustainability (C4S) was formed in 2014 by an international group of chemists who believe that **chemistry and related sciences have indispensable roles to play in helping the world to achieve the SDGs and move to a path of planetary sustainability.**

C4S has built upon earlier work and writings by IOCD members and has served advocacy and think-tank roles through written articles, lectures at various fora and web materials. It has held brainstorming meetings about twice a year alternately in India and Europe, interacting in between by teleconference and email, to maintain a high momentum and deliver topical products via diverse international platforms. There are currently four core members in the group (from Africa, Asia and Europe), while collaborations are established with others (e.g. from Belgium, Canada, China, Ethiopia, Germany and USA) to bring additional expertise and perspectives to IOCD's work. **C4S has recognised that chemistry itself must undergo deep-seated reforms in its vision, scope and conduct in order to achieve its goals.** The following is an overview of IOCD/C4S products.

Chemistry for sustainable development

The **C4S** group discusses how chemistry's contributions are vital to helping achieve the UN Sustainable Development Goals and, more broadly, to moving towards a pathway of sustainability for the planet. As the science that focuses on the analysis, synthesis and transformations of matter, chemistry is concerned with the material basis of the world, including its environment, society and economy. It has a critical role to play in providing the molecular basis of sustainability.

The **C4S** group has called for the concept of waste to be replaced by one in which all material is regarded as 'post-trash' – matter that is managed to be available for potential further use – to prevent the pollution of the environment on land and in the air and oceans and the depletion of the planet's useable stocks of resources.

- S.A. Matlin, G. Mehta, H. Hopf, A. Krief. [The role of chemistry in inventing a sustainable future](#). **Nature Chem** 2015, **7**, 941-943.
- H. Hopf, A. Krief, S.A. Matlin, G. Mehta. [Die globale Verantwortung der Chemie](#). **Nachrichten aus der Chemie**, 2016, **64**, 547-548.
- S.A. Matlin. [The Chemical Sciences and a sustainable future](#). [Text](#); [Slides](#). Based on TGH Jones Memorial Lecture presented at the University of Queensland, 16 July 2018. International Organization for Chemical Sciences in Development, Namur, 2018.
- S.A. Matlin. [Earth Day and the role of chemistry in sustainable development](#). Perspective, **International Organization for Chemical Sciences in Development, Namur**, published online April 2019, 2p.
- H. Hopf, A. Krief, G. Mehta, S.A. Matlin. [Waste does not exist: there is only post-trash](#). **SciDev.Net**, published online 22 April 2019.
- A. Krief, H. Hopf, G. Mehta, S. A. Matlin. [World Environment Day and the role of chemistry for sustainability](#). **International Organization for Chemical Sciences in Development, Namur**, posted online June 2019.
- S.A. Matlin. [The planetary climate and environment crisis: It's time for emergency action](#). **International Organization for Chemical Sciences in Development, Namur**, posted online August 2019, 2p.
- S.A. Matlin, H. Hopf, A. Krief, G. Mehta. [Ending the time of waste: Clean up, catch up, smarten up](#). **Angle Journal**, published online 1 November 2019.
- S.A. Matlin. [Sustainability and chemistry](#). Perspective. **International Organization for Chemical Sciences in Development, Namur**, published online May 2020, 13p.

- S.A. Matlin. [Chemistry and the end of waste: Towards sustainability in a post-trash age](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, published online 7 March 2020, 2p.
- S. A. Matlin. [The 2020s: A critical decade for sustainability](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, published online 7 March 2020, 4p.
- H. Hopf, S. A. Matlin. [Earth Day 2020: Listen to the science](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, posted online April 2020.
- S.A. Matlin, G. Mehta, H. Hopf, A. Krief, Lisa Keßler, K. Kümmerer. [Material circularity and the role of the chemical sciences as a key enabler of a sustainable post-trash age](#). **Sustainable Chemistry and Pharmacy** 2020, 17, 100312, doi: 10.1016/j.scp.2020.100312.

Repositioning chemistry for the 21st century

The **C4S** group argues that chemistry as a discipline needs redesign and reform, in order to ensure that it is attractive and productive as a science and relevant to solving 21st century challenges.

- S.A. Matlin, G. Mehta, H. Hopf. [Chemistry embraced by all](#). **Science**, 2015, **347**, 1179.
- S.A. Matlin, G. Mehta, H. Hopf, A. Krief. [Repositioning chemistry for the 21st century](#). **Atlas of Science**, 27 Jan 2016.
- G. Mehta, H. Hopf, A. Krief, S.A. Matlin, [Chemistry in a post-Covid-19 world](#). **AsiaChem** 2020, 1(1), 60-67, doi: 10.51167/acm00013.

'One-world' chemistry and systems thinking

The concept of '**one-world chemistry**' (OWC) is presented by the **C4S** group as a new orientation for the discipline. OWC **emphasises the need for chemistry to be a science for the benefit of society**, embracing the understanding that human health, animal health and the environment are all interconnected. Acting on the consequences **requires ethical behaviour at all times, the employment of systems thinking in relation to all aspects of the practice of chemistry, and strengthening the capacity of chemistry for cross-disciplinary working**.

- S. A. Matlin, G. Mehta, H. Hopf, A. Krief. ['One-world' chemistry and systems thinking](#). **Nature Chem** 2016, **8**, 393-6.
- **IOCD Web pages: 'One-world' chemistry**.
- H. Hopf, S.A. Matlin, A. Krief, G. Mehta. [Chemie für die eine Welt](#). **Nachrichten aus der Chemie** 2016, **64**, 1190-1191.
- H. Hopf, S.A. Matlin, A. Krief, G. Mehta. [Die Rolle der chemischen Wissenschaften im 21. Jahrhundert - one-world chemistry](#). In: T.K. Lindhorst, H.-J. Quadbeck-Seeger, Gesellschaft Deutscher Chemiker, **Unendliche Weiten: Kreuz und quer durchs Chemie-Universum**. Weinheim: Wiley-VCH 2017, 183-188.
- H. Hopf, G. Mehta, A. Krief, S.A. Matlin. [One-world chemistry and the quest for global sustainability](#). **Chem. Soc. Japan: Chemistry and Chemical Industry**, 2017, **10**, 873-875 ([English](#)); 876-878 ([Japanese](#)).
- S.A. Matlin. [Systems thinking in chemistry: A key competence for a sustainable future](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, published online 7 March 2020, 2p.

Systems thinking in chemistry education

The reforms in chemistry, including the OWC approach, advocated by the **C4S** group call for the **adoption of systems thinking by chemistry**. In collaboration with **Peter Mahaffy** (The Kings University, Edmonton, Canada), the group sets out the case for chemistry education to adopt systems thinking and points to pathways through which this can be achieved.

- S.A. Matlin, P.G. Mahaffy. [One-World Chemistry: Implications for Education](#). **International Organization for Chemical Sciences in Development**, September 2017, 6pp.
- P.G. Mahaffy, A. Krief, H. Hopf, G. Mehta, S.A. Matlin. [Reorienting chemistry education through systems thinking](#). 2017, **Nature Chemistry Reviews**, 2018, 2, 1-3; doi:10.1038/s41570.018.0126.
- P.G. Mahaffy, S.A. Matlin. [Learning Objectives and Strategies for Infusing Systems Thinking into \(Post\)-Secondary General Chemistry Education](#). **IUPAC** Project No. 2017-010-1-050, 2017-2019.

IOCD supported and participated in a project on **Systems Thinking in Chemistry Education (STICE)** of the International Union of Pure and Applied Chemistry. Members of the STICE project group, including **Peter Mahaffy** and **Stephen Matlin** (who served as co-chairs), published a paper in *Nature Sustainability* which discusses the potential roles and approaches that chemistry education can follow and introduces a new visualization tool, the systems-oriented concept map extension (SOCME) to illustrate systems thinking in chemistry. Further publications in the *Journal of Chemical Education* address the value and implementation of systems thinking in chemistry education.

- P.G. Mahaffy, S.A. Matlin, T.A. Holme, J. MacKellar. [Systems thinking for educating about the molecular basis of sustainability](#). *Nature Sustainability* 2019, **2**, 362-365.
- S.A. Matlin, P.G. Mahaffy. [Systems thinking: A vital contribution to strengthening the role of chemistry in achieving the UN Sustainable Development Goals](#). Paper presented at the CHED Symposium, 1 April 2019, UN Sustainable Development Goals: Unique Opportunities for the Chemical Enterprise, during the American Chemical Society National Meeting, 31 March - 4 April 2019, Orlando, FL. **International Organization for Chemical Sciences in Development, Namur, May 2019.**
- S.A. Matlin, P.G. Mahaffy. [Systems thinking, green chemistry and the molecular basis of sustainability](#). [Text](#); [slides](#). Paper presented at the 4th Green and Sustainable Chemistry Conference, Dresden 6 May 2019. **International Organization for Chemical Sciences in Development, Namur, May 2019.**
- P.G. Mahaffy, S.A. Matlin, T.A. Holme, J. MacKellar. [Systems thinking for education about the molecular basis of sustainability featured in Nature Sustainability](#). Joint Media Release, **International Organization for Chemical Sciences in Development, Namur**, published online May 2019.
- P. G. Mahaffy, S.A. Matlin, [Systems thinking in chemistry education: An IUPAC project](#). Presented to the IUPAC Committee on Chemistry Education Meeting at the **47th IUPAC World Chemistry Congress, Paris, 7-8 July 2019.**
- P.G. Mahaffy, S.A. Matlin, [Systems thinking to educate about the molecular basis of sustainability](#). Paper presented at **47th IUPAC World Chemistry Congress, Paris, 7-12 July 2019.**
- P.G. Mahaffy, S.A. Matlin. [Systems thinking in chemistry education](#). Poster presented at **47th IUPAC World Chemistry Congress, Paris, 7-12 July 2019.**
- S.A. Matlin. [Earth emergency: Systems thinking, chemistry education and sustainability](#). Perspective, **International Organization for Chemical Sciences in Development, Namur**, published online 15 May 2019.
- D.J.C. Constable, C. Jiménez-González, S.A. Matlin. [Navigating complexity using systems thinking in chemistry education](#). *J. Chem Educ.* 2019, **96**, 2689-2699.
- P.G. Mahaffy, S.A. Matlin, J.M. Whalen., T.A. Holme, [Integrating the molecular basis of sustainability into general chemistry through systems thinking](#). *J. Chem Educ.* 2019, **96**, 2730-2741. ****Editor's Choice**
- K.B. Aubrecht, Y.J. Dori, T.A. Holme, R. Lavi, S.A. Matlin, M. Orgill, H. Skaza-Acosta. [Graphical tools for conceptualizing systems thinking in chemistry education](#). *J. Chem Educ.* 2019, **96**, 2888-2900.
- A. Flynn, M. Orgill, F. Ho, S. York, S.A. Matlin, D.J. C. Constable, P.G. Mahaffy. [Future directions for systems thinking in chemistry education: Putting the pieces together](#). *J Chem Educ* 2019, **96**, 3000-3005, doi: 10.1021/acs.jchemed.9b00637.
- P.G. Mahaffy, S.A. Matlin. [Next hundred years: Systems thinking to educate about the molecular basis of sustainability](#). *L'Actualité Chimique*, December 2019, 446,47-49.

A number of technical resources to support teaching, learning and practice in systems thinking in chemistry have been prepared by C4S members and are made [freely available](#) for download and use:

- S.A. Matlin. [Introducing the SOCME tool for systems thinking in chemistry](#). Technical Resource. **International Organization for Chemical Sciences in Development, Namur**, published online May 2020.
- S.A. Matlin. [Systems-Oriented Concept Map Extension \(SOCME\) for biogeochemical flows of CO₂](#). Technical Resource. **International Organization for Chemical Sciences in Development, Namur**, published online May 2020.
- S.A. Matlin. [Systems-Oriented Concept Map Extension \(SOCME\) for biogeochemical flows of reactive nitrogen from NH₃](#). Technical Resource. **International Organization for Chemical Sciences in Development, Namur**, published online May 2020.

Reforming the role of chemistry organizations

Chemistry organizations should play **a leading, pro-active role in the repositioning of chemistry** that is required in the 21st century. The **C4S** group argues that this **necessitates reforms in both national (e.g. chemistry societies) and international (e.g. IUPAC) bodies that represent the interests of the discipline and the profession.**

- G. Mehta, A. Krief, H. Hopf, S. A. Matlin. [Chemical societies must adapt – here's how to do it](#). *Chemistry World* published online 11 October 2016.
- S.A. Matlin, A. Krief, H. Hopf, G. Mehta. [Chemistry organizations in a changing world](#). *Chemistry International* 2017, **39**, 15-19.

Championing chemistry; advancing science

The **C4S** group discusses the **need for new champions of chemistry to step forward** to help drive the reforms that are required in the discipline.

- S.A. Matlin, G. Mehta, H. Hopf, A. Krief. [Championing chemistry](#). *Chem & Eng News* 2017, **95(6)**, 20-21.

The **C4S** group analyses the **system of scientific publishing**, with emphasis on a perspective from the chemical sciences, and identifies a **deep crisis** that is unfolding, driven by the conjunction of sub-systems that connect the primary purpose of scientific advancement with financial and reputational rewards. It argues that piecemeal solutions are unlikely to be effective or sustainable and **the time is ripe for the stakeholders in science publishing to seek new, systemic approaches that comprehensively address the fundamental flaws**. The outlines of an action plan for the science community to generate such a process are suggested.

- S.A. Matlin, G. Mehta, A. Krief, H. Hopf. [The scientific publishing conundrum: a perspective from chemistry](#). *Beilstein Magazine* 2017, 3, No. 9, doi:10.3762/bmag.9.

In the 'post-truth' era, the **C4S** group emphasises the importance of chemists and other scientists **vigorously promoting 'scientific temper'** (the adoption of the culture of science, in and beyond the field itself, as a way of life that rejects anti-science thinking).

- S.A. Matlin, H. Hopf, A. Krief G. Mehta. [Why Scientists Are Marching](#). Posted online by **Project Syndicate** 17 April 2017: this article was syndicated in newspapers around the world.
- A. Krief, H. Hopf, G. Mehta, S.A. Matlin. [Science in the post-truth era](#). *Current Science* 2017, **112**, 2173-2174.
- H. Hopf, A. Krief, G. Mehta, S.A. Matlin. [Die Welt des Postfaktischen - ein Widerwort aus der Wissenschaft](#). *Nachrichten aus der Chemie*. 2017, **65**, 659-661.

The growing problem of fake science and its interface with fake news more broadly is presenting major challenges for scientists, the public and policy makers. It affects the credibility and standing of science and the capacities of all individuals to make evidence-informed choices. The **C4S** group discuss the problem and a possible pathway towards solutions. The dangers of hype and hypocrisy as first steps down the slippery slope towards falsification and fakery in science are examined.

- H. Hopf, A. Krief, G. Mehta, S.A. Matlin. [Fake science and the knowledge crisis: ignorance can be fatal](#). *Royal Society Open Science*, 2019, 6, 190161, doi: 10.1098/rsos.190161.
- A. Dunn, S.A. Matlin, A. Krief, G. Mehta, H. Hopf. [Ignorance can be fatal: countering the crisis in fake news and fake science](#). *Royal Society Open Science*, published online 2 May 2019.
- H. Hopf, S.A. Matlin, G. Mehta, A. Krief. [Blocking the hype-hypocrisy-falsification-fakery pathway is needed to safeguard science](#). *Angew. Chem. Internat. Edn.* 2020, **59**, 2150-2154.
- S.A. Matlin. [Hype and hypocrisy: The slippery slope to falsification and fakery in science](#). Perspective. **International Organization for Chemical Sciences in Development, Namur**, published online 7 March 2020, 2p.

Chemistry has made central contributions to **improving health, wellbeing and life expectancy** – but even more is needed now. The **C4S** group identifies a number of **disconnections that are preventing the optimal contributions** that can be made and suggests systemic approaches to developing solutions.

- S.A. Matlin, G. Mehta, A. Krief, H. Hopf. [The chemical sciences and health: strengthening synergies at a vital interface](#). *ACS Omega*, 2017, 6819-6821.
- S.A. Matlin. [Chemistry and health: the need for a comprehensive approach](#). Lecture at the School of Chemistry & Molecular Biosciences, University of Queensland: 17 July 2018. **International Organization for Chemical Sciences in Development, Namur**, 2018.
- S.A. Matlin. [The changing landscape of health innovation networks to foster research and development](#). [Text](#); [Slides](#). Paper presented at the **2019 World Conference on Access to Medical Products - Achieving the SDGs 2030**. 19-21 November 2019, New Delhi, India.

Promoting the chemical sciences and IOCD's role

Prior to the formation of **C4S**, a review written for the 2011 International Year of Chemistry by IOCD scientists Stephen Matlin and **Berhanu Abegaz** (Ethiopia) highlighted achievements of the chemical sciences during more than two centuries of advancing knowledge and creating useful processes and products. The **C4S** group presents insights from notable chemists of the past, which have stood the test of time and resonate with contemporary contexts beyond the science discipline itself; and overviews the work of C4S to promote IOCD and its role. The group reflects on the significance of the International Year of the Periodic Table of the Chemical Elements.

- S.A. Matlin, B.M. Abegaz, [Chemistry for development](#). In: J. Garcia-Martinez, E. Serrano-Torregrosa (eds), **The Chemical Element: Chemistry's Contribution to Our Global Future**, Wiley-VCH, Weinheim, 2011, Chapter 1, 1-70.
- G. Mehta, A. Krief, H. Hopf, S.A. Matlin. [Living messages from chemistry icons: Legacies with contemporary relevance](#). *The Chemical Record* 2019, **19**, 675-686..
- A. Krief, H. Hopf, G. Mehta, S.A. Matlin. [Repositionnement des sciences chimiques en vue de créer un avenir durable](#). *Chimie Nouvelle* 2018, **127**, 21-31.
- S.A. Matlin, H. Hopf, G. Mehta, A. Krief. [Repositioning the chemical sciences for a sustainable future](#). *Chimie Nouvelle* 2018, **128**, 17-27.
- S. A. Matlin, A. Krief. [Glenn Seaborg, The Periodic Table and a Belgian NGO](#). *Chimie Nouvelle* 2018, **129**, 1-10..
- S. A. Matlin, H. Hopf, A. Krief, G. Mehta. [The simple matter of sustainability](#). *Current Science* 2019, **116**, 7-8.
- S. A. Matlin, G. Mehta, H. Hopf, A. Krief. [The periodic table of the chemical elements and sustainable development](#). *European Journal of Inorganic Chemistry* 2019, **39-40**, 4170–4173.
- S. A. Matlin. [Thomas Eisner, chemical ecology and the sustainable development of natural products](#). [Perspective](#). **International Organization for Chemical Sciences in Development, Namur**, published online June 2019, 2p.

The chemical sciences and equality, diversity and inclusion

In collaboration with **Vivian Yam** (Hong Kong University, China), the **C4S** group discusses the **challenge of dealing with conscious or unconscious forms of bias and discrimination in the sciences** and argues that the chemical sciences can play a leading role in addressing biases, through (1) becoming a **model of good systemic practice** in policies, processes and actions; (2) developing **practical skills through training in cultural competence**; and (3) promoting a **stronger evidence base**, to uncover both the extent of problems and the degree to which approaches to improve equality, diversity and inclusion are working.

- S. A. Matlin, V.W.W. Yam, H. Hopf, A. Krief, G. Mehta. [Tackling Science's Gender-Parity Problem](#). Posted online by **Project Syndicate**, 9 February 2018: this article was syndicated in newspapers around the world.
- G. Mehta, V.W.W. Yam, A. Krief, H. Hopf, S.A. Matlin. [The chemical sciences and equality, diversity and inclusion](#). *Angew. Chem. Internat. Edn.* 2018, **57**, 14690-14698.
- S.A. Matlin, V.W.W. Yam, G. Mehta, A. Krief, H. Hopf. [The need for cultural competence in science: A practical approach to enhancing equality, diversity and inclusion](#). *Angew. Chem. Internat. Edn.* 2019, **58**, 2912-2913.

- S. A. Matlin. [It's time to fix the inequality problem in science](#). **International Organization for Chemical Sciences in Development**, Namur, posted online 28 January 2019.
- V.W.W. Yam. [Encouraging woman and girls in science](#). **International Organization for Chemical Sciences in Development**, Namur, posted online February 2019.
- V.W.W. Yam. [Experiences making a career in chemistry](#). YouTube Video Q&A, IUPAC Global Breakfast "Empowering Women in Chemistry", 12 February 2019.
- S.A. Matlin. [International Women's Day 2020: An equal world is an enabled world – in science, too](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, published online 7 March 2020, 2p.

Science, society and policy

The **C4S** group highlights the critical importance of a well-functioning relationship between science, society and policy as the best protection against threats posed by oncoming global challenges.

- G. Mehta, H. Hopf, A. Krief, S.A. Matlin. [Realigning science, society and politics in uncertain times](#). **Royal Society Open Science** 2020, 7: 200554, doi: 10.1098/rsos.200554.
- S.A. Matlin, G. Mehta, H. Hopf, A. Krief. [Science, society and politics – an uneasy but essential ménage à trois](#). **Royal Society Open Science**, published online 22 May 2020.
- S.A. Matlin. [Science, society and policy: A trivalent vaccine for uncertain times](#). Perspective. **International Organization for Chemical Sciences in Development**, Namur, published online May 2020, 2p.

Prof Henning Hopf Germany h.hopf@tu-braunschweig.de	Prof Alain Krief Tunisia, Belgium alain.krief@unamur.be	Prof Stephen Matlin UK stephen@matlin.org.uk	Prof Goverdhan Mehta India gmehta43@gmail.com
--	--	---	--

Chemists for Sustainability (C4S) is an action group supported by the **International Organization for Chemical Sciences in Development** (www.iocd.org).

C4S is grateful for contributions from the German Chemical Society, Royal Society of Chemistry and Syngenta R&T Centre, Goa.