

Canadian Society of Chemistry Undergraduate Program Accreditation Appendix

Guidance on Implementing Green Chemistry and Sustainability into Curricula

Revised: September 2026

Purpose

This appendix is intended to support chemistry departments in meeting the Canadian Society for Chemistry (CSC) accreditation requirement that:

“As a discipline, Chemistry plays an integral role in progress towards societal sustainability and wellbeing, and in addressing global targets such as the UN’s Sustainable Development Goals. To that end, an accredited program must provide students with a working knowledge of the Twelve Principles of Green Chemistry, as well as sustainability in the context of chemistry.”

1. Overarching Principles

Departments should strive to ensure that graduates of accredited programs are able to:

1. Understand and apply the Twelve Principles of Green Chemistry in terms of their contribution to sustainability.
2. Develop practical laboratory habits aligned with the Twelve Principles that include reducing waste, energy consumption, and exposure to hazardous substances.
3. Evaluate chemical products, processes, and technologies through various lens of best green chemistry practices, including the Twelve Principles, life-cycle assessment, and systems-thinking.
4. Appreciate the relationship between chemistry and sustainability-related global challenges such as climate change, pollution prevention, circular economy principles, and human health.

2. Learning Outcomes to be Met on Accredited Program Graduation

Knowledge

Students will be able to:

- Describe and apply the Twelve Principles of Green Chemistry
- Describe how chemistry as a discipline can be used to understand global sustainability challenges and provide potential solutions, as related to the UN Sustainable Development Goals)
- Explain key sustainability concepts, including circular economy, life-cycle thinking, resource efficiency, and environmental stewardship

Skills

Students will be able to:

- Assess synthetic routes using appropriate green chemistry metrics and utilization of the Twelve Principles
- Compare alternative reagents, solvents, and reaction conditions
- Evaluate environmental, health, safety, and economic trade-offs
- Apply sustainability principles to experimental design
- Communicate sustainability considerations to both scientific and non-scientific audiences

Professional Attitudes

Students will be able to:

- Recognize the societal responsibilities of chemists
- Consider long-term environmental impacts of chemical decisions
- Value continuous improvement toward safer and more sustainable practices

3. Curriculum Integration Model

Principles of green chemistry and sustainability are very effectively incorporated across the undergraduate curriculum in a progressive manner, with several instructors involved. The goal is not simply to add a single dedicated course on green chemistry, but rather to integrate concepts throughout a program (in appropriate class and laboratory components) so that graduates can understand and demonstrate how chemistry contributes to both societal challenges and their solutions.

(a) First Year Courses: Awareness and Foundations

Intended Student Outcomes

Students recognize the importance of sustainability within chemistry, identify examples of green chemistry in practice, and appreciate the role that fundamental chemical principles can play in solving global sustainability challenges.

Sample Suggested Topics

- Introduction to sustainability and sustainable development in the context of chemistry
- Overview of the Twelve Principles of Green Chemistry
- Chemistry and its relationship as a discipline to the United Nations Sustainable Development Goals: discussion of global sustainability challenges
- Case studies involving ocean acidification, climate change, water quality, or ammonia production
- Chemical hazards and risk reduction
- Waste minimization in teaching laboratories: basic laboratory waste audits

(b) Second Year Courses: Application Within Core Chemistry Sub-Disciplines

Intended Student Outcomes

Students can identify how sustainability principles apply within individual chemistry sub-disciplines, and can quantitatively evaluate the sustainability performance of chemical processes.

Organic Chemistry: Sample Suggested Topics

- Green chemistry metrics: introduction to mass metrics such as atom economy, reaction mass efficiency and process mass intensity, including their relative strengths and weaknesses
- Catalysis as a green chemistry principle in designing more efficient multistep syntheses to minimize the number of steps, use of protecting groups, and waste production while improving chemoselectivity, regioselectivity and stereoselectivity
- Concepts regarding preferred solvent and reagent selection, solvent-free syntheses
- Energy efficiency considerations in reaction design

Analytical Chemistry: Sample Suggested Topics

- Microscale analytical approaches: direct analysis with no sample preparation, small-scale extractions
- Solvent reduction and replacement in chromatographic techniques
- Use of field-portable instrumentation and energy-efficient methodologies
- Environmental applications (e.g., water treatment and pollution monitoring, emerging contaminants, ozone depletion and refrigerants)

Physical Chemistry: Sample Suggested Topics

- Use of boiling points, heat capacities, vapor pressure and explosivity limits in evaluating the environmental, health and safety outcomes of chemicals and chemical processes
- Use of thermodynamics and kinetics in understanding environmentally important reactions and improving the efficiency of chemical and/or biochemical reactions
- Renewable energy technologies
- Application of computational and spectroscopic techniques to green chemistry-related concepts: designing environmentally friendly reaction conditions, polymerization kinetics, toxicity evaluation, and the study of gas phase molecules and solids present in the environment

Inorganic Chemistry: Sample Suggested Topics

- The classification of some metals/metalloids as critical or endangered due to geological abundance, geopolitical, and/or economic factors
- Centrality of inorganic materials to renewable energy technologies such as batteries, photovoltaics, thermoelectrics, and materials for artificial photosynthesis
- Design of catalysts that are recyclable or recoverable and/or use earth abundant metals
- Green inorganic materials design principles

(c) Third & Fourth-Year Courses: Integration, Evaluation and Experimental Design

Intended Student Outcomes

Students can propose and justify more sustainable chemical solutions using evidence-based reasoning, and engage with authentic problems requiring integration of scientific and sustainability considerations.

Sample Suggested Topics

- Process chemistry: analysis and evaluation of industrial syntheses & pharmaceutical manufacturing routes
- Synthetic route design and process redesign exercises
- Sustainable materials and recycling technologies
- Toxicology and exposure reduction, including environmental chemistry metrics
- Understanding of risks/hazards, environmental fate, persistence, biodegradation, reaction mechanisms in biological systems
- Circular economy frameworks
- Life-cycle assessments
- Alternative energy production and storage systems
- Research projects with sustainability components
- Community-engaged sustainability projects

4. The Twelve Principles of Green Chemistry across the Curriculum

Departments should ensure students encounter each principle more than once and in varying contexts (e.g., different sub-disciplines, laboratories, classes, tutorials):

Green Chemistry Principle	Example Educational Context
Prevention	Laboratory waste reduction approaches
Atom Economy	Synthetic route analysis and design
Less Hazardous Synthesis	Appropriate reagent appraisal and selection
Designing Safer Chemicals	Product design considerations
Safer Solvents and Auxiliaries	Solvent replacement exercises
Energy Efficiency	Reaction optimization
Renewable Feedstocks	Biomass and bio-based materials
Reduce Derivatives	Synthetic planning
Catalysis	Organic and inorganic synthesis, industrial case studies
Design for Degradation	Environmental chemistry & toxicology
Real-Time Analysis	Process monitoring techniques
Inherently Safer Chemistry	Risk assessment and process safety approaches

5. Laboratory Implementation

Undergraduate laboratories are particularly important for demonstrating aspects of green chemistry and sustainability. As well as demonstrating the Twelve Principles through hands-on experiences, laboratory work lends itself to comparative exercises, critical analyses, guided-inquiry and research-driven activities, and student-led decision making.

Recommended Approaches

(a) Microscale and Small-Scale Experiments

Benefits include:

- Reduced chemical consumption
- Lower waste generation
- Improved safety
- Reduced cost of chemicals and waste disposal

(b) Solvent Substitution

Encourage use of safer alternatives where possible (including removal/replacement of dichloromethane in teaching laboratories, and discussion of solvent selection guides).

(c) Waste Tracking

Students can:

- Measure waste generation
- Classify waste streams
- Reflect on opportunities for reduction of waste or possible recycling opportunities

(d) Energy Awareness

Students can assess the following:

- Heating requirements
- Cooling requirements
- Instrument energy use

6. Suggested Assessment Strategies (Laboratory & Classroom)

As with all content-based CSC accreditation requirements, it is essential that student learning outcomes are monitored via appropriate assessments, in order to provide evidence of learning. Green chemistry and sustainability topics should not be viewed as “add-on” material that is taught yet not assessed in a meaningful manner. Assessments should evaluate both conceptual understanding and practical applications, and should move beyond the writing of laboratory reports (e.g., assignments, projects, term test/examination questions).

Examples

- Pre- and post-laboratory assessments on green chemistry principles and how they relate to an experiment students have undertaken, or are about to perform
- Term test/final examination short-answer questions regarding the Twelve Principles
- Green chemistry metric calculations and comparisons
- Solvent selection exercises that promote reflection on performed experimental work. Students evaluate alternative solvents using recognized solvent selection guides and justify their chosen solvent based on safety, environmental impact, performance and cost
- Synthetic route comparisons to determine the “greener” approach. Students compare two published or performed synthetic routes and evaluate them through the number of steps, solvent selection, hazard profiles, energy requirements and waste generation. Students recommend the more sustainable route and justify their decision.
- Life-cycle assessment projects
- Sustainability case studies
- Laboratory improvement proposals: students redesign a traditional laboratory experiment to improve sustainability by reducing scale, modifying reagents, improving metrics, reducing energy use, and minimizing hazardous waste
- Sustainability reflections: students complete a comprehensive evaluation of a chemical product, process, or technology, considering the application of green chemistry principles, life-cycle considerations, environmental impacts, economic considerations, social implications, and recommendations for improvement
- Construction of systems-thinking concept maps
- Ethical analyses and professional responsibility discussions

7. Evidence to Meet Accreditation Requirements

Departments should be prepared to demonstrate how green chemistry and sustainability learning outcomes are achieved and assessed. Potential evidence includes:

- Course syllabi and associated learning outcomes
- Laboratory manual content and report requirements
- Assignment and term test/final examination examples
- Assessment rubrics
- Student work samples (e.g., laboratory reports, assignments)
- Curriculum maps showing coverage across the program curriculum
- Capstone project descriptions and examples
- Faculty professional development activities

8. Suggested Minimum Expectations for an Accredited Program

A department should be able to demonstrate that:

1. All graduates are introduced to and are able to appropriately apply the Twelve Principles of Green Chemistry through intentional curriculum design and delivery.
2. Green chemistry and sustainability concepts are integrated into multiple required courses across different sub-disciplines.
3. Students apply green chemistry considerations in solving problems both in laboratory and non-laboratory environments.
4. Students encounter examples linking chemistry to societal and global sustainability challenges.
5. Green chemistry and sustainability learning outcomes are assessed in multiple courses.

9. Faculty Development and Departmental Support

Successful implementation requires institutional support. Departments should:

- Provide faculty development opportunities in green chemistry and sustainability, including ensuring that new instructors teaching laboratory courses receive orientation on sustainable laboratory practices
- Encourage departmental interdisciplinary collaborations, and share curricular resources/laboratory activities
- Engage industrial and community partners where possible
- Organize periodic curriculum mapping exercises related to green chemistry learning outcomes, and maintain a shared repository of green chemistry teaching resources and laboratory activities
- Consider sustainability and green chemistry during regular curriculum review processes
- Recognize sustainability-related teaching innovations

Suggested Faculty Training Resources

To support implementation of CSC accreditation requirements, departments should encourage faculty participation in professional development activities focused on green chemistry, sustainability, systems thinking, and sustainable laboratory practices.

(a) Beyond Benign/Green Chemistry Commitment

Beyond Benign (beyondbenign.org) is widely recognized as a leading organization supporting green chemistry education. It provides faculty-focused professional development, curricular resources, webinars, communities of practice, and the Green Chemistry Commitment (GCC: beyondbenign.org/he-green-chemistry-commitment) framework for higher education institutions. Universities and colleges that sign the GCC (23 within Canada as of September 2026) have access to funding that can be used for curriculum development and other activities.

(b) Green Chemistry Teaching and Learning Community (GCTLC)

The GCTLC (gctlc.org) is an international community of practice where educators share teaching materials, laboratory activities, assessment strategies, and implementation experiences.

Departments can encourage faculty to:

- Participate in discussion forums
- Attend webinars
- Share instructional resources
- Access peer-reviewed curricular materials (one example is the “Toxicology for Chemists Curriculum” (gctlc.org/toxicology-chemists-curriculum))
- Collaborate with other institutions implementing green chemistry curricula

(c) American Chemical Society Green Chemistry Institute (ACS GCI)

The ACS Green Chemistry Institute (acs.org/green-chemistry-sustainability/acs-green-chemistry-institute) provides a comprehensive collection of teaching materials and professional development opportunities focused on integrating green chemistry and sustainability into undergraduate education.

Recommended resources:

- Green chemistry teaching modules
- Sustainability and systems-thinking workshops
- Green chemistry case studies
- ACS webinars and recorded presentations
- ACS annual Green Chemistry and Engineering Conference
- Faculty mentoring networks

Particularly useful are the undergraduate teaching modules, which connect traditional chemistry topics to sustainability, systems thinking, and the UN Sustainable Development Goals.

10. Conclusion

CSC-accredited undergraduate programs should assess student achievement of green chemistry and sustainability learning outcomes using a combination of knowledge-, laboratory-, project-

based, and integrative assessments. By graduation, students should be able to apply the Twelve Principles of Green Chemistry, evaluate the sustainability of chemical products and processes using qualitative and quantitative methods, and communicate sustainability considerations within professional chemical contexts. Evidence may include assignments, laboratory reports, examinations, capstone projects, portfolios, presentations, and associated rubrics. Green chemistry and sustainability should be viewed as foundational elements of contemporary chemistry education rather than standalone topics. By embedding these concepts throughout classes, laboratories, assignments, and capstone experiences, chemistry departments will prepare graduates to contribute effectively to scientific innovation, environmental stewardship, economic prosperity, and societal well-being. Such an approach aligns with CSC accreditation expectations and reflects the increasingly important role of chemistry in addressing local and global sustainability challenges.

11. Useful References & Resources

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